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XVth ISEK Congress

June 18-21, 2004

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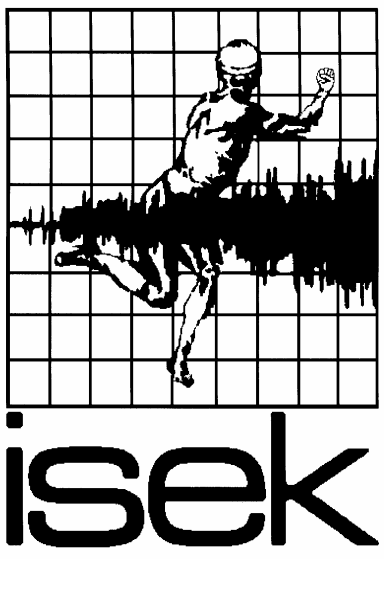

"An Invitation to Innovation"

Editors

Serge H. Roy, ScD, PT
Secretary General
Paolo Bonato, PhD
Chair, Scientific Committee
Jens Meyer, Dipl.-Ing.
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Foreword

The fourth International Society of Electrophysiology and kinesiology (ISEK) Congress was held exactly one quarter century ago here in Boston. Here we are again, at the shores of the Charles River 25 years later! Much has changed in technology, innovation, and knowledge of our interdisciplinary areas of study. The theme of this Congress, "An Invitation to Innovation" celebrates this change in a city known for innovation in science, medicine, and technology. It is a fitting place and an appropriate time to organize a meeting in which we can reflect and learn about how far we have come in the field of electrophysiology and kinesiology. Innovation has inherent value, but its true worth can be appreciated more completely by its impact in the applied sciences, such as physical rehabilitation, sports, ergonomics, and countermeasures to aging and spaceflight. You will hopefully find these areas of advancement to be inseparable from the technological and methodological innovations that are present among this compendium of scientific papers.

We are pleased you could join us in Boston.

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Keynote Addresses

487 - Electrophysiology and Kinesiology for Health and Disease

Toshio Moritani
Laboratory of Applied Physiology, Graduate School of Human and Environmental Studies, Kyoto University, Kyoto, Japan

Introduction: In this honoured Basmajian keynote address, I would like to dedicate my presentation to Dr. Herbet A. deVries, the mentor of my research career. The following topics will be covered from the standpoint of electrophysiology and kinesiology for health and disease: 1) Muscle fatigue and soreness, 2) Cardiac depolarization-repolarization characteristics of normal individuals and patients, 3) Etiology of obesity (diabetes mellitus) and the autonomic nervous system, and 4) Functional electrical stimulation for health and disease, respectively.

Muscle Fatigue and Soreness: Delayed onset of muscle soreness (DOMS). We investigated the physiological effects of static muscle stretching upon delayed onset of muscle soreness (DOMS) in conjunction with the spinal alpha motoneuron pool excitability and peripheral muscle blood flow in seven healthy male subjects. Electrophysiological measurement included the H-reflex as a measure of spinal alpha motoneuron pool excitability. Results demonstrated that the static stretching brought about a statistically significant reduction in the H/M ratio (23.5%, $p < 0.01$) of the experimental leg. These changes were accompanied by nearly a 78.5% increase ($p < 0.01$) in blood flow after stretching of the leg with experimentally induced soreness. The result of reduction in alpha motoneuron excitability was entirely consistent with earlier studies, suggesting that the inverse myotatic reflex (Ib inhibition) may be the basis for the relief of muscle soreness by static stretching. The increase in blood flow after stretching found in the present study suggested that static stretching could bring about a relief of spasm, which could have caused local muscle ischemia and pain.

Mechanomyogram changes during muscle fatigue. Previous studies suggested that mechanomyogram (MMG) analyses might offer not only MU recruitment and rate coding characteristics, but also their mechanical properties, including the fusion properties of activated MUs that could not be obtained by conventional EMG analyses. To further shed some light on this matter, we studied 14 isolated MUs in the medial gastrocnemius (MG) muscle of 7 healthy male subjects. Different stimulation frequency trials indicated that there were highly significant and progressive reductions in the force fluctuations from 5 Hz to 50 Hz that were almost mirrored by the similar and significant reductions in the MMG amplitudes. Mixed stimulations to different MUs clearly demonstrated that both MMG and force recordings showed two distinguished peak frequencies that were delivered to the underlying MUs. Lastly, our MU fatigue study with prolonged stimulation at 12 Hz demonstrated that MMG amplitude decreased progressively as contractile slowing occurred as a function of time. Our recent human low back muscle fatigue study also indicated that there were significant initial increases in MMG amplitude that were followed by progressive decreases at the end of fatiguing contractions. Simultaneous recordings of EMG, MMG, and NIRS demonstrated that restriction of blood flow due to the high intramuscular mechanical pressure was one of the most important factors to evoke the muscle fatigue, particularly in low back muscle.

Cardiac Depolarization: Repolarization Characteristics of Normal Individuals and Patients with Ischemic Heart Disease and Diabetes. Cardiac autonomic dysfunction is prevalent in diabetic patients and associated with a prolongation of the myocardial repolarization period. Ten patients with ischemic heart disease (IHD), 30 patients with diabetes mellitus, and ten control subjects (CON) volunteered for this study. The patients with diabetes mellitus were further divided into three subgroups according to the severity of neuropathy: patients without any neuropathy (N0), with peripheral neuropathy (N1) and with autonomic neuropathy (N2). Computer-aided cardiac depolarization-repolarization analyses were performed to assess ECG activation time (AT),

106 - Decision-Making Based On Surface EMG-Signals: Different Approaches to Information Extraction

Catherine Disselhorst-Klug
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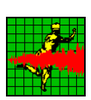
Introduction: The rapid technical advances in the recording and processing of biophysical signals have made the detection of Surface Electromyographic Signals (SEMG) easier. Thus SEMG has opened a commonly used and powerful tool for the assessment of muscular function. Similarly, very advanced 3D movement analysis systems and procedures have been developed to measure movement parameters and reaction forces. Information about muscular co-ordination and the resulting movement patterns are now available for anyone interested in. As a rule, however, large volumes of data are generated, which are still yet too extensive for effective implementation, especially in the clinical routine. Additionally, there is a serious risk for mis- and over-interpretation of the data. The reduction and extraction of relevant information is therefore an essential step towards a reliable interpretation and decision-making. The following examples highlight three different approaches to information extraction especially developed to support clinical decision-making.

Analysing Single Motor Unit Properties: During the last 20 years it has been shown, that the combination of electrode arrays and spatial filters allows the non-invasive detection of single motor unit activity. Two-dimensional electrode arrays with an inter-electrode distance in the mm-range combined with a two-dimensional Laplacian filter (NDD-Filter) have turned out to be a powerful tool for the non-invasive detection of pathological changes in the properties of single motor units [1]. Considering, that the extraction of the single motor unit activity from the superimposed SEMG signal itself can be seen as an information extraction approach, parameters are needed to quantify the nature and the degree of the pathological changes. In the case of neuromuscular disorders 7 parameters have been identified allowing a distinction between healthy volunteers, patients with muscular disorders and patients with neuronal disorders with an accuracy of more than 97% [1]. During the European project NEW the non-invasive detection of single motor unit activity has been used to asses work-related muscular disorders in the elderly. Parameters, such as conduction velocity, number of active motor units or number of firings per second have been investigated in order to distinguish between cases with pain in the shoulder-neck region and healthy volunteers.

Interpretation of Conventional Surface-EMG: Information concerning the muscular co-ordination pattern is of great relevance not only in the treatment of movement disorders but also in other fields e. g. rehabilitation medicine or sport sciences. However, the interpretation of the surface-EMG signals is often difficult even for experienced users. One reason for this is the high risk of misinterpretation. During the European project SENIAM standards for SEMG detection have been established in order to minimise errors due to electrode arrangement and location [2]. However, cross-talk is one example of the possible disturbances, which can be minimised by an accurate electrode configuration, but which unfortunately can not be avoided. Recently, new methodologies have been developed based on fuzzy-logic, that allow a prediction of the risk for cross-talk [3]. In patients suffering from a plexus brachialis lesion

Surface-EMG signals simultaneously recorded from different muscles provide information about the muscular co-ordination pattern. To date, this information is not commonly used in the clinical routine, even though it is important for the treatment of patients with muscular dysfunction, e. g. spasticity. For this reason an expert system based on the fuzzy-inference-method has been developed, which supports the assessment of the muscular co-ordination pattern detected by SEMG [4]. The muscular co-ordination pattern associated with ankle joint movement has been chosen as an example to show the method's feasibility. Based on the SEMG data, the expert-system reliably predicts the effectiveness of the ankle joint movement during gait. In this way, it supports the interpretation



of the muscular co-ordination pattern detected by surface-EMG and thus makes this information accessible for clinical routine.

Quantitative Description of Movement: Since the musculo-skeletal system is highly redundant, interpretation of SEMG data must always be in the context of the contraction being performed. This becomes more important when dynamic contractions are considered. Movement analyses, especially of the lower limbs, have been established for a long time. Recently, movement analyses of upper extremity movements have become more reliable [5]. Highly developed movement analysis systems are available, providing the kinematic and kinetic data needed for the interpretation of the muscular co-ordination pattern. However, the interpretation of the kinematic and kinetic movement data itself is often problematic and time consuming. For interpretation of upper extremity movements a set of parameters has been introduced, which regards the duration, the smoothness, the acceleration and the reproducibility of the movements. In first clinical investigations of patients with shoulder impairment it has been shown, that these parameters are correlated with the individual's movement capacity during the performance of a variety of tasks and are suitable for an objective assessment of the patient's functional impairment.

Conclusion: Data reduction and information extraction are indispensable prerequisites for reliable decision-making based on SEMG and movement analysis data. This becomes crucial in clinical applications since the time constraints of the clinical routine have to be taken into account. Some approaches for information extraction with clinical impact have been shown, which improving the interpretation of the data and which, in principle, can be utilized in various fields. However, decision-making based on information extraction in the movement sciences is still in an early stage.

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057 - Issues in the Motor Control of the Trapezius Muscle: Possible Relevance for the Development of Shoulder

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Introduction: Motor control is a mature research field with major contributions made throughout the last century. A lecture on the motor control of a muscle may thus seem superfluous at this time. However, shoulder pain as a world-wide epidemic is a fairly recent phenomenon that provokes a fresh look at some motor control issues that have not been much researched. The following facts have served as a background for our study of trapezius motor control:

- Trapezius is an apparent source (or at least location) of shoulder pain
- The physiological response to stress includes trapezius motor activity
- The biomechanical action of trapezius is complex, pointing to functional compartments
- Trapezius is a postural muscle that contributes to the control of head and arm movement, possibly also to respiration; the motor control literature has focused on the control of extremity muscles

This lecture describes features of the trapezius activity pattern as viewed by surface EMG (SEMG) recording at work, in leisure time and during sleep, motor unit (MU) firing and MU contribution to SEMG, trapezius response to stress and finally, summarize the evidence regarding a link between trapezius motor activity and shoulder pain.

Methods: Several hundred subjects (>90% female) have participated in the different studies. They are subdivided by occupation and work tasks, medical diagnoses and subjective health variables. Regular EMG recording systems with SEMG and single MU recording capabilities have been used. A SEMG system was designed to achieve 24 hr recording capabilities. Options to record postural movement, respiration and heart rate were provided. MU firing patterns were determined from intramuscular EMG recordings by use of an analysis system described by De Luca and Adam (1999). Physiological recordings were in several of the studies supplemented with subjectively reported variables including pain, fatigue and perceived tension. In most studies the SEMG response is calibrated in percent of the SEMG response in maximal voluntary contraction (% EMGmax).

Results: SEMG activity patterns. The distribution of median SEMG amplitude among subjects who perform sedentary work tasks, resemble a gamma distribution. Median SEMG amplitude over the workday ranged from ~0.5% to >10% EMGmax; median 2.7% and mode ~1% EMGmax (285 recordings). Recordings in leisure time show a closely similar distribution. The marked inter-individual variation in activity pattern is also clear with respect to burst duration (SEMG>2% EMGmax for 15-95% of recording time) and rest time (SEMG<0.5% EMGmax for 0-65% of recording time). Contrasting the large inter-individual variation, repeated recordings of the same subject show very consistent results. Twenty-three subjects were successfully re-recorded with a separation of >2 yrs, with very high correlation between recordings: r=0.70-0.86 for the three above variables. Correlations between work and leisure recordings are likewise high, r=0.6-0.7. Thus, the general usage of the trapezius represents an example of "motor habit", with consistent intra-subject and divergent inter-subject activity pattern. Despite the considerable inter-subject differences in trapezius motor pattern, which should help detect associations between muscle activity and pain, there is no substantial indication of more SEMG activity or different SEMG activity pattern for those subjects reporting shoulder pain.

Control of MUs. First, trapezius MUs have very consistent firing pattern in sustained contractions, with firing rates typically of 10 pulses per s (pps). Very low-threshold MUs increase their firing rate by 2-3 pps when SEMG in sustained contractions increase from <2 to >4% EMGmax. Trapezius MUs are very responsive to changes in contraction force, showing rapid increase in firing rate to >30 pps in ramp contractions of moderate amplitude and

rate of rise. Second, MU substitution, i.e., the temporary silencing of a MU to be replaced by another MU of higher threshold, is an interesting phenomenon with potential relevance for motor fatigue and pain development. It appears that MUs with thresholds far from the contraction level in constant-force contractions participate in the substitution only to a limited extent (Westad et al. 2003). Force variation promotes MU substitution. Third, evidence will be presented to show that the respiratory modulation of firing rates for MUs firing near recruitment threshold is most likely due to peripheral afferent input.

Stress-induced MU activation. Many studies show activation of trapezius MUs in situations with stress. Several theories exist regarding the physiological pathways that cause a coupling between the autonomic nervous system and motor activation, including sympathetic innervation of muscle spindles, sympathetic activation of end plates, as well as connections at the spinal cord level. Evidence in favour or opposing the different theories will be discussed. Phenomena of interest include stress-induced, local EMG activity in trigger points and low-frequency modulation of the firing pattern of trapezius MUs.

Trapezius motor activity and shoulder pain. The putative causal association between motor activity and pain is attempted demonstrated in field and laboratory studies, recording physiological responses and using epidemiological methods. Traditional ergonomic risk factors that entail a high level of trapezius activity, such as working with elevated arms, represent a clear risk of shoulder pain. The current challenge is to determine mechanisms in stress-induced shoulder pain, occurring at low muscle activity levels and with motor activation being part of a response that also includes the autonomic system. A favoured hypothesis to explain pain development at low muscle activity levels is low-threshold MU overexertion, a hypothesis that is difficult to falsify due to the very low activity levels of potential relevance and differences in MU activity patterns (differences in substitution) that cannot be observed by SEMG recording. The overall pattern in these studies is one of inconsistent results, including those of the present presentation that find some borderline significant results. A possible conclusion is that the trapezius motor response to stress is part of a more complex physiological activation response that over time promotes pain, but trapezius motor activity is not necessarily causally implicated in all forms of stress-associated shoulder pain.

Conclusion: Trapezius shows motor control features that are distinguished from classic descriptions of motor control, based on studies of extremity muscles. As such, a thorough understanding of the motor control of trapezius supplements the established motor control literature. A crucial motivation for this research is a possible association between motor activity and muscle pain. At this point in time we cannot conclude for or against the hypothesis proposing stress-induced shoulder pain due to low-level motor activity; however, new insight is generated and some key issues are hopefully soon resolved.

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147 - Cervicomedullary Stimulation in Human Subjects

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A high-voltage electrical pulse passed between the mastoid processes can evoke short-latency responses in muscles in the upper limb in human subjects

(1). These responses are most likely due to activation of the axons of the corticospinal tract at the level of the cervicomedullary junction. Bending of the axons at the pyramidal decussation probably makes this a preferential site of stimulation. Collision studies, in which descending corticospinal volleys evoked by electrical or magnetic stimulation of the motor cortex are occluded by cervicomedullary stimulation, have shown that for hand muscles and for biceps brachii many of the same axons are activated by the cortical and subcortical stimulation

(2). In response to cervicomedullary stimulation, post-stimulus time histograms of the firing of single motor units show single narrow peaks. The width of these peaks is comparable to those seen in response to activation of Ia afferents and suggests that there is a strong monosynaptic component to the responses

(3). Thus, cervicomedullary motor evoked potentials (CMEPs) can provide a test of motoneurone excitability via the major pathway controlling voluntary movement in humans.

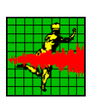
The major pitfall encountered with cervicomedullary stimulation is spread of the stimulus to activate the axons of spinal motoneurones. If the motoneurones are stimulated distal to their cell bodies, rather than synaptically, then the size of the evoked responses will be independent of the excitability of the motoneurones. The change of stimulation site from the cervicomedullary junction to the ventral root can be seen as a 1-2 ms jump in the onset latency of the potential with an increase in stimulus intensity (1,3). Spread of stimulation occurs to proximal muscles at lower intensities than to distal muscles because they are supplied through higher cervical roots.

As a test of motoneurone excitability, CMEPs have significant advantages over responses to transcranial electrical stimulation (TES) and over H-reflexes. CMEPs can be large, so that a large fraction of the motoneurone pool can be examined. Even in resting muscle, responses of >50% of the maximal compound muscle action potential can usually be evoked. In contrast, when TES is used with intensities slightly higher than threshold, responses start to be influenced by cortical excitability because of transsynaptic activation of corticospinal neurones. CMEPs can be evoked in most muscles in the upper limb in most subjects whereas H-reflexes can be evoked in few muscles in a limited number of subjects. Furthermore, unlike Ia afferents, corticospinal axons are not subject to classical pre-synaptic inhibition so that the test volley is much less likely to be affected by other descending or afferent activity

(4). However, CMEPs also have disadvantages. The stimulation is painful and subjects can have difficulty keeping muscles relaxed. In addition, cervicomedullary stimulation activates proximal muscles before distal ones. Thus, if responses are evoked in the hand muscles, there are also twitches of many other muscles in the arms as well as direct stimulation of neck muscles. By comparison, TES is also painful but small responses in the hands can be elicited with less proximal disturbance. During voluntary contraction, the increased excitability of specific motoneurone pools means that CMEPs can be evoked with lower intensity stimuli and are targeted to the contracting muscles.

Comparison of CMEPs, H-reflexes and motor evoked potentials (MEPs) elicited by transcranial magnetic stimulation (TMS) can clarify changes in the motor pathway. When

subjects make a strong isometric flexion of one wrist and hold the contralateral arm relaxed, MEPs in the relaxed wrist flexors are facilitated while H-reflexes are markedly inhibited



(5). However, CMEPs are not changed in size. Together these findings suggests that motor cortical excitability is increased and motoneurone excitability is unchanged but that there is strong presynaptic inhibition of the Ia afferent volley associated with a strong contralateral voluntary contraction.

Cervicomedullary stimulation has revealed interesting changes in the corticospinal-motoneuronal pathway during and after voluntary contractions. During fatiguing 2-min maximal voluntary contractions of the elbow flexors, CMEPs are unchanged for the first minute and then become reduced in size. This suggests that the motoneurones are inhibited and is consistent with previous findings of decreased motor unit firing rates and depression of reflexes. However, recovery of the CMEPs is not altered if the muscle is held ischaemic at the end of the sustained contraction to maintain firing of fatigue-sensitive small-diameter muscle afferents

(6). This contrasts with maintained depression of motor unit firing rates and H-reflexes and refutes the view that these muscle afferents are responsible for the inhibition of motoneurones in fatigue. The afferents may act presynaptically on Ia afferents and/or 'upstream' of the motor cortex. At the same time as CMEPs are depressed, MEPs are increased. Thus, TMS must evoke greater output from the cortex than in control unfatigued maximal efforts. This might occur because of extra excitability of the motor cortex but might also occur if lower voluntary output reduced the number of cortical cells that were effectively refractory at the moment of stimulation.

After strong voluntary contractions of as short as 5 s duration, CMEPs in the resting biceps brachii are depressed by ~50%. Recovery takes about 1.5 minutes

(7). A post-synaptic inhibition of the motoneurones is unlikely as the CMEP depression does not occur with antidromic and reflex activation of the motoneurones by 30 Hz stimulation of the peripheral nerve. An activity-dependent decrease in the excitability of the corticospinal axons is also unlikely. We suggest that the depression reflects a decrease in efficacy of transmission at the corticospinal-motoneuronal synapse. The effect is abolished transiently during brief maximal efforts but is seen during weak contractions. Psychophysical experiments suggest that transmission of voluntary activity is also reduced

(8). Thus, this decrease in efficacy of the corticospinal pathway may influence control of many voluntary movements.

After fatiguing voluntary contractions, MEPs in resting muscles become dramatically depressed and can remain so for >20 mins. In contrast, after their initial depression, CMEPs become facilitated (7). Although the mechanism of this facilitation is unknown, comparison of the MEPs and CMEPs emphasises the change that must occur in the motor cortex.

Cervicomedullary stimulation activates motoneurones via many of the same axons as TMS and can be used under conditions that range from rest to maximal voluntary contractions. It does not require averaging and can detect brief as well as longer term changes in motoneurone excitability. It is probably the most appropriate comparison to reveal whether changes in MEPs result from cortical or spinal events

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507 - The EXtremity Constraint Induced Therapy Evaluation (EXCITE) Trial for Upper Extremity Stroke Rehabilitation: Potential Linkages to ISEK

Steven L. Wolf[1], Ph.D., PT, FAPTA, Andrew J. Butler[1], Ph.D., PT and Jay L. Alberts2, Ph.D.

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The EXCITE Trial represents the National Institutes of Health first funded national randomized clinical trial for a physical intervention to improve upper extremity function following sub-acute (3-9 months post-injury) stroke. The study, now in its fifth and final year involves several institutional sites (Emory University, University of Southern California, University of Alabama at Birmingham, University of Florida, University of North Carolina, Wake Forest University, and the Ohio State University). Washington University serves as the Data Management Center. There is also a mandatory Data Safety and Monitoring Board. The involvement of several institutions in the Southeastern United States is attributable, in part, to the greater incidence of stroke in that geographical sector. The overall purpose of this blinded cross-over study is to determine if two weeks of intense upper extremity treatment, called constraint-induced (CI) movement therapy improves function more than usual and customary care and whether such improvements: (a) show persistence for at least one year; and (b) differ in magnitude of improvement based upon the severity of the stroke among patients categorized as having "higher" or "lower" function. Furthermore, because patients are randomized into immediate or delayed (one year post enrollment) CI therapy treatment, this trial affords the opportunity of comparing differences in the magnitude of functional changes in sub-acute and chronic patients. The later group has been studied extensively (see Wolf et al, 2002 for a review). A detailed methodological discussion of the EXCITE Trial has been published (Winstein et al, 2003).

Briefly, CI therapy involves intense treatment of the more impaired upper extremity lasting two weeks for the EXCITE Trial and building in treatment time from 1.5 to 5 hours per day over two consecutive weeks, based upon the endurance of the patient. During this time participants receive behavioral (shaping or adaptive) task practice and repetitive task practice in the absence of formal shaping. The time committed to each type of training is based upon the functional level of the patient. The primary outcome measures involve a laboratory setting measure of functional ability (Wolf Motor Function Test, {WMFT}) and real world capabilities measured through an ordinal scale that asks how often and how well patients perceive the use of their more impaired limb in 30 everyday activities (Motor Activity Log).

While of considerable value as a clinical enterprise, the EXCITE study provides a unique opportunity to exploit physiological indices of improvement measured through biomechanical assessments, transcranial magnetic stimulation, and functional MRI, all of which represent approaches or modalities totally compatible with the mission of ISEK. Some examples are provided in this lecture. For example, we have explored how hand dexterity might improve through instrumenting the base of a key with a force transducer that permits on-line recording of force and torque generation as participants either hold the key or attempt to turn a key in a lock, which is one task in the WMFT (Alberts et al, 2004). Four of five patients randomized to CI therapy and evaluated in blind fashion showed increased maximum precision grip force, improved grip force and torque regulation and reduced variability of in rate of grip force production compared to 5 patients in the control group. These preliminary data suggest that CI therapy may bestow some potential for manual force generation and control among patients receiving such training.

Preliminary TMS studies monitoring the extensor digitorum communis muscle and finger/wrist extension in able-bodied participants (Wolf et al, 2004) and in stroke patients who met inclusion criteria for EXCITE (Butler et al, 2004). These studies share the unique attribute of multiple repeated measures of TMS-derived measures to ascertain

inherent variability over time. Such measurements have not been repeated as frequently in at least one study purported to demonstrate cortical reorganization derived from mapping the abductor pollicis brevis muscle following CI therapy in chronic stroke patients (Liepert et al 2000). The large variability seen in shifting of center of gravity calculations over repeated sessions without provision of the intervention are in excess of those reported by Liepert after CI therapy with chronic stroke patients, thus opening for discussion the extent to which this approach induces functionally relevant cortical reorganization.

The EXCITE Trial is funded by NIH Grants HD37606 and 40984.

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509 - Ligament Function

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To understand ligament function in the joints of the skeleton, we find it best to consider the interactions between ligaments, articular surfaces and muscles rather than to consider ligaments in isolation. To understand ligament function in activity, we find it best to consider separately how ligaments contribute to the control of joint mobility and to the control of joint stability. When studying mobility, we consider the joint to be unloaded, and movement takes place without tissue deformation. When studying stability, we consider the joint to be stationary and examine the tissue deformation which occurs as the structures of the joint develop the forces necessary to resist movement. It is then easier to put the concepts of mobility and stability together in the study of activity, to determine patterns of tissue deformation during movement under load. In this lecture, the roles of the ligaments at the elbow, knee and rear-foot complex (ankle and subtalar joints) will be discussed.

Starting with the elbow, the articular surfaces of both humerus and ulna are circularly cylindrical and the axis of passive flexion passes along the axis of the cylinder. The medial and lateral collateral ligaments are both fan-shaped. They arise on the epicondyles of the humerus near the centre of curvature of the cylindrical articular surfaces. The fibres insert around the edges of the trochlear notch of the ulna. Hypothetical fibres arising at the centre of curvature of the epicondyles *allow* passive flexion and extension without stretching or slackening; i.e. they remain isometric. Fibres passing anterior to the axis of flexion are slack in flexion and tighten during extension. Fibres passing posterior to the axis of flexion are tight in flexion and slacken during extension. Simple experiments with unloaded specimens confirm that the elbow is a simple hinge, a pure revolute, with an axis of passive flexion which remains stationary relative to both bones. The articular surfaces simply slide upon each other during passive flexion/extension movements. Under load and in the presence of muscle forces, the articular surfaces compress and ligament fibres stretch to develop the forces necessary to balance the external loads and the intrinsic muscle forces.

The knee and the ankle, although both hinge-like joints, differ fundamentally from the elbow. The axis of passive flexion/extension movements in these two joints is not fixed but rotates and translates relative to the bones.

Experiments with the knee moving under very light loads show that axial rotation, abduction/adduction and the three components of translation of any arbitrary point in one bone relative to the other are uniquely coupled to flexion angle. Neither the origins of the four principal ligaments (ACL, PCL, MCL, LCL) on the femur nor their insertions on the tibia lie along the axis of motion. These experiments quantify the so-called screw-home mechanism or terminal rotation when passive flexion/extension is accompanied by an obligatory axial rotation about the axis of the tibia, the bones following a unique path relative to each other. When forces are applied to perturb the motion, the path is modified but the path of passive motion is recovered when the loads are removed. The knee joint during passive motion therefore exhibits only one degree of unresisted freedom which is dynamically stable.

Analysis of the movement of the articular surfaces upon each other reveals that the femur rolls as well as sliding on the tibial plateau during passive flexion/extension. The areas of contact on the tibial plateau move backwards in each compartment during flexion and forwards during extension. Some fibres within the ACL, PCL and MCL remain sensibly isometric while all fibres within the LCL slacken during flexion and tighten again during extension.

These experimental observations on the knee are reproduced in a mathematical model which treats the joint as a parallel spatial mechanism, with five constraints to motion limiting the relative motion of the bones to a single degree of freedom. Continuity of contact in the medial and the lateral compartments provide two constraints, isometric fibres in the ACL, PCL and MCL provide the other three. Mathematical analysis of this model predicts coupling of axial rotation to flexion very similar to that observed experimentally. Most other fibres of these ligaments slacken and tighten during passive flexion and do not stretch to develop tension forces which could resist

passive motion. The patterns of fibre slackening and tightening predicted by the model largely agree with patterns observed experimentally in many laboratories.

The parallel spatial mechanism is a 3-D generalisation of the sagittal plane four-bar linkage (4BL) model which was first described by Zuppinger in 1904 and has since been developed extensively. Both models show how ligament fibres rotate about their origins and insertions during passive motion. When the 4BL model was used to study simple muscle strengthening exercises, it was found that ligament forces increase non-linearly with increasing load and muscle force so that very large loads can be transmitted through the joint while the ligament forces remain at modest levels. This phenomenon is related both to the progressive stretching and recruitment of ligament fibres and to the associated deformation of the cartilage layers covering the articular surfaces.

Similar studies of the rear-foot complex revealed similar results. During passive flexion/extension movements of the calcaneus relative to the tibia, the complex was found to exhibit a single degree of freedom and a unique path of movement. Furthermore, the surfaces of the tibia and talus were observed to roll as well as slide upon each other. Fibres within the fibulo-calcaneal ligament on the lateral side and within the deltoid ligament on the medial side were found to remain essentially isometric during passive motion. During passive motion, very little movement was observed at the subtalar level. However, when forces were applied to perturb the path of passive motion, significant movements were detected at subtalar level which were reversed when the perturbing loads were removed. It was concluded that the ankle joint is a single degree of freedom system whereas movements at subtalar level can be elicited only by the application of load with consequent tissue deformation. The subtalar level behaves like a flexible structure,

Many of the observations on the rear foot are explained by a four-bar linkage model which predicts well the rotation of ligament insertions about their origins and the rolling movements of the surface of the talus on the tibia. A 3-D parallel spatial mechanism model is under development.

This abstract summarises a body of work carried out by the author's students at the Oxford Orthopaedic Engineering Centre. The work is described in more detail in the book *Daniel's Knee Injuries*, Lippincott Williams and Wilkins, 2003, ISBN 0-7817-1817-1.

Whitaker Symposium

502 - The Potential of Dermal Fibroblasts as a Cell Source for the Repair of Ligamentous Tissues
504 - Dynamic Stability and the ACL Injured Knee: Differential Neuromuscular Responses Reflect Functional Compensation (Implications for Bioengineering)
506 - Strategies for Anterior Cruciate Ligament Tissue Engineering
508 - Smart Scaffolds for Stimulation Of Anterior Cruciate Ligament Healing

502 - The Potential of Dermal Fibroblasts as a Cell Source for the Repair of Ligamentous Tissues

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Introduction: The anterior cruciate ligament (ACL) is an intraarticular ligament comprised of fibroblasts in a dense collagenous matrix designed to transmit tensile loads and stabilize the knee joint. Approximately 150,000 ACL replacements are performed annually in the United States as a result of the poor healing capacity of the tissue. The lack of a viable healing response in the ACL may be due to multiple factors including the limited proliferative and biosynthetic activity of ACL fibroblasts in comparison to those of other fibrous tissues. In this study, we investigate the potential of dermal fibroblasts to serve as an alternate cell source for the repair of ligamentous tissues. Specifically, human dermal fibroblasts were evaluated for their ability to express genes for extracellular matrix (ECM) components characteristic of ligaments. In addition, the cells were assessed for their tendency to adopt a unidirectional alignment, analogous to the cellular organization of native ligament tissue, when seeded on three-dimensional scaffolds.

Materials and Methods: Human dermal fibroblasts (Cascade Biologics, Portland, OR) were maintained in minimum essential medium with Earle's BSS supplemented with 10% fetal bovine serum and antibiotics. Fibroblasts were seeded on bioerodible polymer scaffolds composed of a poly(glycolic acid) (PGA) fiber mesh (Biomedical Structures, Slatersville, RI) reinforced in poly(L-lactic acid) (PLLA) (2.0 x 106 cells/polymer) for 21 days. Cellular organization was characterized using histological methods and electron microscopy, and the gene expression profile of ligament ECM components was determined by RT-PCR. In an additional study, dermal fibroblasts were seeded on expanded PTFE (ePTFE) membranes surface-modified with a bioactive peptide, P15, that mimics the putative cell binding domain of human type I collagen. Cell proliferation was assessed over a 7-day period by metabolic labeling with [3-H]-thymidine, and the specimens were analyzed using standard histological methods, electron microscopy and confocal laser scanning microscopy.

Results and Discussion: After 3 days in culture on the PGA/PLLA scaffolds, human dermal fibroblasts were organized into dense, parallel arrays. The mRNA expression of types I and III collagen, biglycan, decorin and versican by cells cultured on the bioerodible polymers was confirmed by RT-PCR analysis. A marked increase in the expression of these genes was detected over the 21-day culture period. Surface-modified ePTFE membranes exhibited a greater number of adherent fibroblasts after 24 hours, whereas few cells attached to control ePTFE specimens, forming cell clumps with little spreading. By 3 days, dermal fibroblasts grown on P15-modified ePTFE membranes displayed a unidirectional alignment of actin cytoskeletal filaments and cell nuclei together with the deposition of type I collagen in a similar pattern. Cells seeded on control membranes were randomly oriented and secreted a disorganized collagenous matrix. After 7 days, dermal fibroblasts cultured on the P15-ePTFE substrates showed enhanced proliferation and formed three-dimensional colonies consisting of multiple cell layers. Taken together, these findings suggest that the natural growth characteristics and expression pattern of human dermal fibroblasts cultured on bioerodible polymer fiber scaffolds makes them well-suited for ligament repair. Moreover, surface modification with the collagen-mimetic peptide, P15, may be of clinical use in promoting guided tissue regeneration, particularly for tissues requiring specific orientations such as ligaments and tendons.

504 - Dynamic Stability and the ACL Injured Knee: Differential Neuromuscular Responses Reflect Functional Compensation (Implications for Bioengineering)

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The ACL is not a passive structure, but rather a complex ligament with a rich sensory innervation that has a profound affect on muscle action that can, in some cases, compensate for loss of passive knee stability. Our collective work provides indirect evidence for two concepts, that the reflex activity from the ACL is of intermediate loop duration and can be affected by training and that restoring passive knee stability does not reliably restore normal knee function. This presentation will detail the evolution of our concepts of the interplay between muscle (specifically the quadriceps) and the anterior cruciate ligament, how ligamentous disruption affects the complex neuromuscular coordination required to stabilize the knee over a large range of activities and also what implications this has for the development of 21st century graft constructs.

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506 - Strategies for Anterior Cruciate Ligament Tissue Engineering

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Introduction: Clinical problems associated with ligament and tendon healing have prompted investigations of tissue engineering strategies to facilitate regeneration of the tissues. These strategies involve the use of porous, absorbable scaffolds, exogenous cells, and cytokines or their genes alone or in combination. For some tissues the reparative strategy needs to address the negative effects of surrounding tissues and fluids: a) the collapse of surrounding tissues into the defect site or b) dilution or dissolution of the reparative elements by fluid bathing the defect site, as occurs intraarticularly with synovial fluid. One approach that can be implemented to address this problem is to contain the defect site temporarily under a protective cover or in a tube. In the present study a novel rabbit tendon rupture model was developed that allowed for the isolation of the defect from the surrounding tissues and fluid by entubulation in a silicone tube. This approach was first applied to the Achilles tendon of the rabbit because of the accessibility of the tissue in contrast to the intraarticular ligaments of the knee joint. A silicone tube was used in the initial investigation for its ease of handling; the ultimate plan is for use of an absorbable collagen tube. Associated with this approach was the investigation of the reparative response induced by a porous absorbable collagen-glycosaminoglycan (CG) scaffold inside the tube.

Methods: The right Achilles tendon of 25 skeletally mature male New Zealand white rabbits was transected transversely at the midsection. The tendon stumps were inserted into a silicone tube (I.D.= 3.8 mm). The stumps were sutured to the silicone tube, producing a gap length of 10 to 12 mm. In one group the tube was empty and in the other, the tube contained a CG sponge-like scaffold with an average pore size of 60 µm. The knee was immobilized with an external fixation device for 10 days postoperatively to reduce loading at the defect site in the early stages of healing. Animals were sacrificed after 1.5, 3, 6 and 12 weeks (n= 3-5). Histologic sections were evaluated for the areal percentage of selected tissue classes.

Results: Gross observation revealed that a thin cable of tissue spanned the gap in both the empty and the CG-filled tubes at all time periods. The volume of tissue in the scaffold-filled tube was greater than in the empty control tubes at all time periods. As early as 3 weeks, most of the tissue in the empty tubes was dense fibrous tissue. The tissue had highly aligned matrix fibers without crimp, and spindle-shaped cells. At 3 and 6 weeks, the fraction of tissue which was classified as granulation was much higher in the collagen-GAG filled tubes. By 12 weeks, most of the tissue in the empty tube was dense fibrous tissue that also had a crimp pattern seen under a polarized light microscope that was consistent with scar. The volume of healing tissue was greater in the scaffold-filled tubes.

Discussion: Use of the novel animal model allowed observation of healing events in a 10-mm gap in Achilles tendon. The results showed that the tendon stumps induced synthesis of a tissue cable inside the silicone tube in both the presence and absence of CG matrix. In empty tubes, the new tissues consisted of dense aggregate of crimped scar-like fibers. Tubes filled with CG scaffold contained a significantly greater volume of tissue at all time periods. This study demonstrates the potential for entubulation of tendon and ligament ruptures to facilitate a reparative response; the use of a bridging CG scaffold inside the tube warrants additional investigation.

508 - Smart Scaffolds for Stimulation Of Anterior Cruciate Ligament Healing

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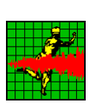
The Clinical Problem: Rupture of the anterior cruciate ligament (ACL) is increasingly common among young, athletic patients. The ACL, unlike other ligaments in the body, does not heal spontaneously or even with suture repair. Thus, treatment for this injury currently consists of removing the torn ligament and replacing it with a graft of tendon, an operation called ACL reconstruction. This operation results in good restoration of knee stability at the time of surgery and the ability to return to sport; however, the reconstruction commonly stretches out over time and a significant percentage of patients go on to have premature osteoarthritis of the knee. Therefore, new solutions for ACL rupture are needed.

Smart Scaffolds: The approach we have been pursuing is using a "smart scaffold" to stimulate guided tissue regeneration and healing of the ligament after rupture. This approach has significant potential advantages over ACL reconstruction, including preserving the original ACL tissue, bony insertion sites, proprioceptive nerve fibers and biomechanical properties of the ligament. Preserving the proprioceptive nerve function protects the static restraint of the knee (the ACL) by recruiting the dynamic stabilizers of the knee (the hamstrings) when the ligament is stressed. The multiple bundle anatomy of the ACL could be preserved using guided tissue regeneration to heal the tissue between the insertion sites (at the site of rupture), rather than replacing the insertion sites and ligament with a single bundle of tendon graft.

Summary of work to date: In developing this approach, our work has first focused on defining the cellular and vascular density in the human ACL, both in the intact ligament and in the ligament after rupture. Next, we used a collagen sponge to test the migration potential of cells in the human ACL. Once the basic functions of cell proliferation, collagen production and migration had been established for human ACL cells, we began focusing on the development of a "smart scaffold" which would maximize the ingrowth of cells and "ligamentogenesis" in a ligament rupture site both in vitro and in vivo. Key elements of our in vivo and in vitro work will be presented today.

Conclusions: In summary, the long-term problems of knee laxity and osteoarthritis associated with loss of ACL function and reconstruction failure require the development of new treatment methods. Techniques that preserve as much as possible of the structure and functions of the ligament are likely to be advantageous in treatment. Our preliminary work on the cell biology of the ACL provides a starting point for investigating guided tissue regeneration as a novel treatment method for ACL rupture. Future directions of research include additional in vitro optimization and in vivo testing of the "smart scaffold".



Mini-Symposia

007 - Use-Dependent Plasticity of the Human Motor Cortex in Health and Disease
022 - Standing Platform for Chronic Low-Back Pain Patients
036 - Contralateral Organization of the Human Central Nervous System
068 - Role of Afferent Input in Motor Organisation in Health And Disease
083 - Changes in Spinal Excitability Induced By Subthreshold High or Low Frequency Repetitive Transcranial Magnetic Stimulation of the Motor Cortex in Humans.
170 - Fatigue Development in the Upper Trapezius and Biceps Brachii In Subjects With Neck-Shoulder Pain
174 - MUAP Rate: A New Measure to Assess Motor Control
182 - The Effect of Postural Correction on Muscle Activation Amplitudes Recorded From the Cervicobrachial Region
206 - Three Advanced Approaches to Surface EMG Decomposition at Low Contraction Forces
216 - Are Abdominal Muscle Temporal Activation Patterns Related To Lumbar-Pelvic Motion Control?
283 - Effects of Spatial Filtering On Multi-Channel Surface EMG MUAP Shapes
288 - The NEW-Study. Neuromuscular Assessment in Elderly Workers from 4 EU Countries with and Without Work Related Musculoskeletal Disorders.
300 - Analysis of Fatigue in the Erector Spinae Muscle During Sustained Isometric Back Extension By Means Of Surface EMG
318 - Single Motor Unit Contribution to Surface Mechanomyogram Investigated In Two Hand Muscles
325 - Development Of A New Functional Test To Assess The Capacity of Back Muscles : Assessment of Face Validity.
350 - The Influence of Three Intermittent Myofeedback Relaxation Training Schedules on Trapezius Muscle Activity While Performing a Gross-Motor Task
351 - How to Improve Working Conditions for Spinal Cord Injured? An Intervention Study Including Myofeedback Training
368 - Assessment of Fatigue in Low Back Muscles of Elderly Nurses
479 - Field Calibration of an EMG Assisted Model to Predict Spinal Forces, Without Use of MVC

007 - Use-Dependent Plasticity of the Human Motor Cortex in Health and Disease

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Transcranial magnetic stimulation (TMS) of the motor cortex can evoke isolated and directionally consistent thumb movements. In most subjects, 30 minutes of continuous voluntary thumb motor training changes the direction of the movement evoked by TMS. Therefore, motor training rapidly and transiently establishes a change in the cortical network representing the thumb, which encodes kinematic details of the practiced movement. This capacity has been termed use-dependent plasticity and is likely to underlie learning and memory processes and functional recovery after brain injury. In these studies, we hypothesized that it is possible to modulate plastic changes measured my TMS using different interventions in humans. Here, we tested the ability of peripheral nerve stimulation delivered to the training body part and pre-medication with noradrenergic drugs to enhance brain plasticity associated with motor training. Pre-medication with noradrenergic drugs resulted in faster induction, increased magnitude and prolonged duration of use-dependent plasticity elicited by motor training in comparison to a control intervention with motor training alone. Similarly, somatosensory input in the form of peripheral nerve stimulation delivered to the training body part resulted in enhancement of use-dependent plasticity in the human motor cortex. These results suggest that modulation of brain plasticity measured by TMS may be a useful tool to develop new strategies in neurorehabilitation.

022 - Standing Platform for Chronic Low-Back Pain Patients

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Introduction: The Delta Balance Standing Platform was presented with anecdotal evidence of providing relief to patients of low back pain. Thus an experiment was designed to study comparatively the effect of Delta Balance Platform (platform) use while standing on downward slope, horizontal surface, and upward slope. The study received ethics approval and 5 male and 5 female subjects volunteered. These subjects were required to stand on three surfaces for 5 minutes each.

Methods: EMG was recorded from the bellies of tibialis anterior, gastromenemii (medial and lateral), vastus lateralis, vastus medialis, hamstrings, lumbar erector spinae and thoracic lumbar spinae all on the right side of the body. For reference activities the subjects were required to stand on heels, toes, and undergo full trunk flexion and subsequent extension. The EMG values for heel stand was used to normalized tibialis anterior (TA) and hamstrings (HM) toe stand for lateral gastrocnemius (LG) medial gastrocnemius (MG), vastus lateralis (VL) and vastus medialis (VM). Extension from flexed trunk posture was used to normalize lumbar erector spinae (l3) and thoracis erector spinae (T12). The subjects were then asked to assume the three positions in a random order for five minutes in each position without moving their heads, torsos, arms or bending in any direction. A camera was placed in coronal plane at two meters to take profile picture at the start and at one minute intervals thereafter. The EMG data was sampled at 1248 Hz for a period of five minutes after preamplifying the signals at source by a factor of 10. The raw signals were passed through a band pass filter with lower end cut off 20 Hz and the upper end cut off at 450 Hz. The signals were further amplified by a factor of 1,000 before recording on the computer hard disk. The amplifier was fully isolated and had a frequency response from DC to 5 kHz, and a common mode rejection ratio of 92 dB. Upon return to the laboratory the EMG signals were full wave rectified and linear envelope detected. The peak and average magnitudes were extracted in microvolts (uv) and normalized against the reference activity for the muscle in question. The raw data was used to carry out special analysis through Fast Fourier Transform to obtain Median frequency (MF), mean power frequency (MPF), total power (TP) and peak power (PP) fall muscles for each of the three activities were calculated. Using the photographs of all subjects at every minute time interval the wrist, elbow, shoulder, hip, knee and elbow angles were measured. These angles along with the height, weight and gender of the subject was input into the University of Michigan biomechanical model. The analysis yielded lumbosacral compression and shear, L4/L5 compression and shear, and forces generated by the left and right erectors spinae at L3, T12, rectus abdominis (RA), internal oblique (IO), external oblique and latissimus dorsi (LD). These data were analyzed statistically to provide descriptive statistics of means and standard deviations. Subsequently each of these variables was subjected to analysis of variance (ANOVA) to discern significant differences, if any. Analysis revealed that the data throughout the five minute period of recording were not significantly different from each other. Hence all data for the five minute period were collapsed within the variable and mean values extracted. These represented the individual channel values for individuals. A global analysis of variance was carried out for all EMG variables and the two genders. The analysis revealed that there was no significant difference between males and females with respect to EMG variables expect the median and mean power frequencies. The data of two genders were pooled and subjected to ANOVA and multiple comparisons.

Results: The peak and average EMG for both raw and normalized EMG did not show significant difference between the three standing surfaces. However, when the EMG values were normalized against the down slope values and plotted the EMG magnitude (peak and average) the EMG output of all channels combined were lowest for the down slope standing. In frequency domain, the peak power and total power also did not show significant difference between the three standing surfaces. However, the median frequency and the mean power frequency showed significant differences between the three standing surfaces ($p<0.05$). The down slope had values lower than horizontal as well as upslope values. Also, the mean total power and mean peak power for the downward slope

were lower than the upslope as well as the horizontal values. A lack of significant difference in EMG magnitude data (peak and average EMG; and peak and total power) are thought likely due to overall very small magnitude of muscle activity

The biomechanical analysis yielded more decisive results. The lumbosacral compressions were found to be significantly different between males and females ($p<0.001$) as well as between the three experimental conditions tested ($p<0.01$). The downward slope had significantly lower lumbosacral compression than horizontal ($p<0.009$) and lower than the upslope as well. Standing on down slope generated significantly different forces in the erector spinae ($p<0.01$) from horizontal with a lower mean value. The rectus abdominis, internal and external obliques also generated significantly different forces while standing on down slope as compared to both horizontal and upslope ($p<0.05$). In most cases the down slope standing generated lower forces.

Discussion: Therefore, it clearly demonstrates while standing down-slope one reduces the EMG demands and lumbosacral compression. The lumbosacral compression is the most important biomechanical variable related to causation of low back pain. A significant reduction in compressive load relieves the spine providing a scientific rationale for sustained use of this device to relieve chronic low back pain.

036 - Contralateral Organization of the Human Central Nervous System

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Chronic unilateral motor activity affects performance of the contralateral homologous muscle. The first evidence for force transfer appeared in the psychomotor literature over a century ago. A flurry of subsequent studies confirmed the phenomenon of force transfer using chronic voluntary, imagined, stimulated contractions of large antigravity and small intrinsic hand muscles, resulting in force transfer up to 80%. The hallmarks of these adaptations are that the amount of force or skill transfer is proportional to the gains in the trained muscle, it is highly specific to the involved muscle pair, independent of limb dominance, age, and gender, and it occurs while the "untrained" muscle is electrically silent.

The contralateral changes can be clinically meaningful. Nerve damage on one side causes the death of motoneurons innervating the homologous muscle on the contralateral side. On the other hand, clinically meaningful changes in force or skill transfer or deficit occur from one side of the body to the other in patients with spinal cord injury, selected neuromuscular disorders, spastic hemiparesis, knee arthroplasty, and in patients with orthopedic deficits.

The neural mechanisms of these effects from one side to the other side of the body are unknown. The presentation will examine the possibility that there are direct changes in the excitability of transcallosal paths and indirect but linked effects on excitability of contralateral corticospinal projections. Thus, unilateral practice would affect interhemispheric inhibition and in addition these changes it would provoke changes in excitability of the contralateral corticospinal projections. Finally, the possibility will be also examined that there is a spinal component in force transfer. Unilateral voluntary and stimulated contractions both modulate spinal reflexes but in many cases in the opposite direction. In summary, this presentation will overview the organization of the human CNS with special emphasis on the mechanism involved in chronic practice-induced force transfer from one side of the body to the other.

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068 - Role of Afferent Input in Motor Organisation in Health And Disease

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Introduction: In the healthy brain there is a highly organised relationship between sensory input from one part of the body and the motor cortical output to muscles acting on the same part. We recently introduced a technique using small amplitude vibratory inputs and TMS to study the pattern of this organisation in the muscles controlling the human hand. Given pervious work in monkeys that has shown that receptive fields in the primary sensory cortex change after periods of sensory training we ask whether such changes in somatosensory organisation reflect also on the pattern of sensory interaction with motor cortex. If so then this may be a way of retraining sensory motor organisation in patients whose motor (but not sensory) functions are compromised.

Methods: Vibration (80Hz, <0.5mm amplitude) was applied to the belly of the APB (abductor pollicis brevis), FDI (first dorsal interosseous) or ADM (adductor digiti minimi) muscle for 1.5s periods (followed by 3.5s rest) while single or paired TMS pulses were used to probe the excitability of the corticospinal system during the time vibration was applied. We examined the effects of this short term vibration on MEPs, and on short and long interval intracortical inhibition (SICI, LICI). The former is thought to probe excitability of GABAa and the latter GABAb circuits in the motor cortex. Sensory training consisted of applying vibration continuously in alternating periods of 2s on and 2s off to the APB and FDI muscles for 15 minutes with or without demanding attention from the subjects. Eight healthy normal subjects were studied.

Results: Before training, short term vibration of one muscle increased MEPs and LICI and decreased SICI in the vibrated muscle while having the opposite effects on the other two muscles. After a 15 min period of synchronous vibration with attention, short term vibration of either FDI or APB now produced the same effect in both muscles (increased MEP and LICI, decreased SICI), although the effect on the ADM was unchanged. These changes lasted for at least 30 min after the end of the 15 min training. If the 15 min vibration was applied without the subjects paying attention, subsequent short term vibration applied to either APB or FDI no longer had any effect on either muscle, although the effect on ADM was unchanged.

Discussion: After training with attention, a short period of vibration applied to either APB or FDI appeared to be interpreted as having been given to both muscles simultaneously. This may be analogous to the fusion of sensory cortex receptive fields reported after simultaneous vibration of muscle groups in experiments on monkeys. The same 15 min vibration applied without subjects attending appeared to cause the CNS to ignore further inputs in the vibrated input channels. Interestingly, these effects were specific to the motor output directed to the vibrated muscles, and did not affect the way short periods of vibration affected the excitability of projections to other muscles. We conclude that this form of training might be a useful way or reorganising the disrupted sensory-motor organisation that is know to occur in patients with focal dystonias or in patients after stroke.

083 - Changes in Spinal Excitability Induced By Subthreshold High or Low Frequency Repetitive Transcranial Magnetic Stimulation of the Motor Cortex in Humans.

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Introduction: Repetitive Transcranial Magnetic Stimulation (rTMS) at high or low frequencies is able to modulate cortico-spinal and intracortical motor cortex excitability, depending on the stimulation parameters. However, rTMS effects on spinal reflex excitability remain unclear. In the present study we explored the effects of high and low frequency rTMS on H-reflexes as a marker of segmental spinal excitability.

Methods: Two groups of 10 right handed healthy male subjects, 20 Hz or 1Hz rTMS was applied to the optimal motor cortex position for activation of the flexor carpi radialis (FCR) muscle at an intensity 10% below motor threshold through a focal, 8-shaped coil. Before and after rTMS a complete recruitment curve of the compound motor action potential M (direct response) and H (monosynaptic reflex) responses were determined by stimulating electrically the median nerve at the elbow, with increasing intensities. In a control experiment, the same subjects were studied receiving sham 20 Hz or 1 Hz rTMS through a special coil.

Results: After 1 Hz rTMS, H wave minimal and optimal threshold were decreased around 13-20% of their pre rTMS values. Maximal H wave and H/M amplitude ratio were both significantly increased to 39% of its baseline, whereas M responses remained unchanged. Similarly, the area under the H response recruitment curve was significantly increased by 77%, whereas the M wave area remained unchanged. After 20 Hz rTMS, H wave minimal and optimal threshold were both increased around 15% of their pre rTMS values. Maximal H wave and H/M amplitude ratio were both significantly decreased to 43% of its baseline, whereas M responses remained again unchanged. The area under the H response recruitment curve was significantly decreased by 42% whereas the M wave area showed once more no significant change. Neither 20 Hz nor 1 Hz Sham rTMS induced any noticeable change in M or H responses or their recruitment curves in any of the groups.

Conclusions: 1 Hz rTMS applied to primary motor areas increases the monosynaptic spinal cord H reflex, whereas 20 Hz induces the opposite effect, presumably by modulating inhibitory descending cortico-spinal projections onto spinal motoneurons.

111 - Myoelectric Signal Characteristics of Lumbar Muscle in LBP Patients

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Introduction: The use of surface electromyographic (sEMG) techniques has played a major role in our understanding of the functional activity of trunk muscles in both healthy and low back pain (LBP) subjects. However, sEMG signal consists of many motor unit action potential (MUAP) discharges and has some chaos and non-stationary characteristics. Therefore, the traditional linear signal spectrum analysis could not reflect all and natural sEMG signal features. In this study, we use non-linear signal complexity and Recurrence quantification analysis(RQA) methods together with the traditional linear spectrum analysis to study the signal features of non-specific LBP patients and the efficacy of active rehabilitation on lumbar muscle function.

Methods: 17 middle-aged NLBP patients and 17 normal subjects participated in the study ,they were divided into three groups, that is before active rehabilitation, after rehabilitation and normal control group. The active rehabilitation included 24 exercise sessions during 12 weeks in an out-patient clinic. An isoinertial back extensor endurance test were performed by each subject with first performed upper trunk isometric extension for about 10 seconds, then performed repetitive extension against a movement bar at the rate of 30 repetitions per minute(the movement amplitude was adjusted between 25□flexion and 5□ Extension, The test was continued up to 90 seconds.).,and at last performed another 10 seconds isometric extension. Both L3-L4 and L5-S1 sEMG signal were collected continuously during test. Spectral mean power frequency(MPF), signal complexity(C(n)) and determinism% were calculated by FFT, Kaspar-Schusyer and RQA methods for the initial and last 5seconds isometric contractions.

Results: All the sEMG parameters calculated in this study were not influenced by signal sampling position and AEMG was not influenced by subjects groups as indicated by MANOVA report, while sampling time and subjects groups had a significant effects on the changes of MPF,C(n) and Determ% ,these results indicate that both subjects groups and sampling time are the independent factors ,while sampling position is not. Multiple comparisons also indicated that the significant differences of MPF,C(n) and Determ% between normal subjects and NLBP patients even appeared in the non-fatigued and initial phase of exercise test. Binary logistic regression showed that AEMG collected in every sampling position and sampling time had a relative low discrimination(35.3%~58.8%) on the CLBP and active rehabilitation effects, while that of MPF□C(n) and Determ% was relative high(58.8%~91.4%).

Discussion: The above results indicated that sEMG signal amplitude which collected in the initial and last isometric phase of exercise testing in both normal and NLBP patients groups were statistically same, while other linear parameter for example MPF and non-linear parameters C(n) and Determ% showed a significant difference. The phenomenon that MPF,C(n) and Dterm% differences between normal and CLBP patients appeared in the initial , non-fatigued low intensity isometric contractions indicated that these sEMG parameters could be used for the diagnosis and rehabilitation effect evaluation more conveniently than that of traditional time consuming and exhaustive endurance test.

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170 - Fatigue Development in the Upper Trapezius and Biceps Brachii In Subjects With Neck-Shoulder Pain

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Introduction: Work-related disorders affecting the trapezius muscle are common in many occupations. Aim of the present study was to investigate to which extent these disorders affect the activity in other non-painful muscles, in particular in the biceps brachii.

Methods: Two groups of female subjects (age > 43 years) participated in the study: 7 subjects with self reported disorders in the shoulder-neck region (cases) and 9 healthy subjects (control group). Multi-channel electromyography (EMG) and force were recorded during maximum voluntary contractions (MVC) and during 6 minutes sustained contractions (at 30% MVC) of the upper trapezius and biceps brachii of the dominant side. From the EMG signals, root mean square (RMS), median frequency (MDF) and single motor unit (MU) conduction velocity (CV) were estimated, from the force signal the coefficient of variance was calculated.

Results: Differences between cases and controls were found in the MVC force of the upper trapezius, which was lower in cases (253 ± 70 N) than in controls (357 ± 75 N), while the coefficient of variance of force during the sustained contraction was increased (cases: 5.5 ± 2.2; controls: 4.1 ± 1.9). RMS (percentage of RMS at MVC) during the sustained contractions was significantly lower in cases than in controls in both upper trapezius (initial 10 seconds, cases: 38 ± 6%, controls: 44 ± 15%) and biceps brachii (cases: 22 ± 13%, controls: 25 ± 9%). A tendency towards a smaller increase of RMS with fatigue was found in the trapezius muscle only (RMS slope; cases: 6.5 ± 14.1%/min, controls: 10.2 ± 12.9%/min). No differences between the two subject groups were found with respect to MDF and single MU CV in both muscles.

Discussion/Conclusion: The present findings on the trapezius muscle can be interpreted as an inhibitory effect of pain on the electrical activity of the painful muscle. The finding of reduced RMS in the biceps brachii of cases indicates a generalized pain related effect also of the non-painful upper extremity muscles. However, the fatigue development in the non-painful muscle was not affected.

174 - MUAP Rate: A New Measure to Assess Motor Control

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Introduction: Motor control is commonly investigated using bipolar surface Electromyography (EMG), resulting in a rather global view of muscle activation patterns. To study motor control in more detail, it would be desirable to assess both the number of active motor units (MUs) and their firing frequency, since these are the main parameters used by the Central Nervous System for motor control. As such, we propose to assess the number of MU action potentials (MUAPs) per second (MUAP Rate, MR) as a measure for motor control. MR can be assessed by using multi-channel electrode arrays in combination with advanced signal processing techniques (1,2). The objective of the present study was to explore the behaviour of MR in relation to force.

Methods: EMG of the dominant upper trapezius of nine healthy subjects was recorded during a step-wise ramp contraction using a two-dimensional 16-channel array with 10 mm inter-electrode distance (3). The ramp consisted of five force levels of 20 to 100N in steps of 20N. Force feedback to the subjects was provided. The duration of each level was 10 seconds. MR was calculated for each second from single differential signals showing propagating MUAPs.

Results: In Figure 1, the relation between MR and force is shown. It can clearly be seen that MR increases with force. A linear regression analysis revealed a significant relation between MR and force, with 58% explained variance. The slope of the regression line was 0.44 (significantly different from zero, $p<0.000$).

Conclusion: It can be concluded that MR increases almost linearly up to forces of 80N. The flattening for higher values is likely due to the occurrence of superpositions. The relatively high force value for the starting point of the flattening is probably related to the limited number of MUs that contribute to the EMG signal, due to the electrode configuration. MR seems to be a valuable tool for assessing motor control.

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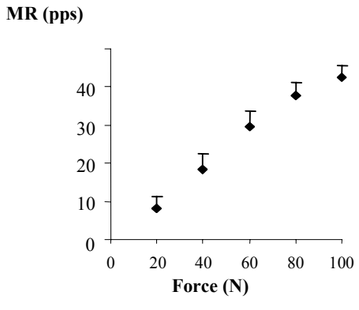

Figure 1 Relation between MR and force. Black diamonds show the average MR values for each force level, bars show standard errors of the mean.

182 - The Effect of Postural Correction on Muscle Activation Amplitudes Recorded From the Cervicobrachial Region

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Introduction: Forward head posture (Chiu, 2002) and sustained static muscle activation (Sluiter et al., 2001) have been associated with chronic neck and shoulder pain. In addition, computer workers demonstrate a progressive deterioration of posture and an increase in trapezius muscle activity while performing work tasks (Kleine, 1999), which leads to chronic changes in sitting posture (Haughie, 1995) Education and exercises aimed at postural correction is a common treatment approach employed by rehabilitation professionals. Little is known, however, about the effect of postural correction on muscle activation in the cervicobrachial region. Increasing the required activity of certain muscles to maintain posture may result in muscle fatigue and may exacerbate symptoms of repetitive strain injury.

Hypothesis: It was suspected that postural correction in sitting and standing would result in changes in muscle use in the cervicobrachial region.

Methods: Eighteen healthy male and female volunteers participated in this study. Surface electrodes were located over the levator scapulae, upper trapezius, supraspinatus, posterior deltoid, masseter, rhomboid major, cervical erector spinae, and sternocleidomastoid muscles of each subject's dominant side. All EMG data were sampled at 2000 Hz using Bortec Octopus AMT-8 amplifiers (CMRR 100dB at 60Hz, Input impedance 1 Gohm) and acquired and processed using a 16-bit A/D converter (National Instruments) and Labview v.6.1 software. All postural data were normalized to the maximum voluntary electrical activation (MVE) of each muscle. Subjects performed five repetitions of each of four seated typing tasks (in their habitual posture, in a standardized corrected posture, in forward head posture, and in slouched posture) and three standing tasks while performing a mental subtraction task (in their habitual posture, in a standardized corrected posture, and in a forward head posture). A repeated-measures analysis of variance (alpha = 0.05) was used for each muscle to determine the effect of posture on muscle activation amplitude.

Results: Other than masseter, which demonstrated muscle activity between 16.1 and 19.7 % MVE, the overall range in muscle activation was 3.0-5.9 %MVE in standing, and from 3.2-6.2 %MVE in sitting. During the seated typing tasks, all muscles studied demonstrated significantly lower activation in the corrected posture than in forward head posture ($p<0.01$). In all muscles except for supraspinatus and posterior deltoid, muscle activity was also significantly lower in a slouched posture than in a forward head posture without slouching ($p<0.01$). In these muscles, the slouched posture required the same amount of muscle activity as corrected posture. During the standing task, the corrected posture required higher activation in all muscles than during habitual posture ($p<0.01$).

Conclusions: Postural correction had a statistically significant effect on muscle activation amplitude, whereby correction decreased the level of muscle activation required in all muscles studied during seated computer work. Conversely, postural correction in standing significantly increased the level of muscle activation required to sustain posture. The clinical relevance of these amplitude changes may be negligible due to the small differences in level of activation observed (Postural changes resulted in changes in muscle activation between 0.59 and 4.4%MVE and 0.45 and 1.8% MVE in sitting and standing respectively.) Over a long-duration task, these differences may become relevant in terms of muscle irritation and/or fatigue.

206 - Three Advanced Approaches to Surface EMG Decomposition at Low Contraction Forces

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Introduction: Surface electromyography (SEMG) has become a rather developed measuring technique, providing all the required reliability, robustness, and repeatability. One of the most challenging issues still lacking confidence and general robustness remains the SEMG decomposition to its constituent motor-unit (MU) action potential (MUAP) trains. Recently, three novel techniques capable of resolving the high-level MUAP superimpositions were introduced [1, 2, and 3]. They are all suitable for the decomposition of SEMG recorded during isometric low-force muscle contraction. In this study their performance was compared.

Methods: To evaluate the influence of the number of active MUs (5 and 20) and the signal-to-noise ratio (SNR, from 20 dB to 0 dB) all three methods were first applied to 10 s long synthetic signals. In each of the 20 simulation runs (10 runs per each number of MUs) the depth of MUs (uniformly distributed over [3,10] mm), their firing rate (normally distr. with mean and st. dev. of 15±4Hz), the number of fibres (uniformly distr. over [50,300]), and conduction velocity (normally distr., 4±1m/s) were randomly selected. The detection system with 1×1 mm electrodes arranged in 10 lines and 5 columns was centred over innervation zone (columns aligned with the direction of fibres). Single differential recordings were sampled at 1024 Hz. The experimental tests were conducted on the 30s long SEMG recorded with a matrix of 61 electrodes (5 columns and 13 lines, columns aligned with muscle fibres) from the dominant biceps brachii muscle of 3 healthy male subjects (age 28.3±3.0 years, height 176±6 cm, weight of 66.0±3.6 kg). Isometric contractions were performed at 5% and 10% of the maximum voluntary contraction (MVC) force. Single differential recordings were amplified, band-pass filtered (3 dB bandwidth, 10 Hz-500 Hz) and sampled at 2500 Hz.

Results: On average 4.6±0.6 (SNR=20 dB) and 3.6±0.9 (SNR=10 dB) out of 5 simulated MUs, and 8.5±1.4 (SNR=20 dB) and 6.4±1.9 (SNR=10 dB) out of 20 MUs were completely identified by the method [1]. The method [3] detected 4.1±0.8 (SNR=20 dB) and 3.1±1.3 (SNR=10 dB) out of 5 MUs, and 7.3±1.1 (SNR=20 dB) and 5.7±2.1 (SNR=10 dB) out of 20 MUs. Due to computational complexity the method [2] was applied only to the signals with 5 active MUs. On average 2.2±0.9 MUs (SNR=20 dB) and 2.0±1.1 MUs (SNR=10 dB) were completely identified. Reconstructed MUs exhibit almost a perfect match with their reference trains. On average 98±0.8% of pulses (method [1]) and 91±2.9% of pulses (method [3]) were accurately recognised at SNR of 10 dB (method [2] enables only MUAP reconstruction). In the case of experimental signals 5.3±0.6 MUs (5% MVC) and 8.0±1.0 MUs (10% MVC) were detected by the method [1], and 2.7±0.6 MUs (5% MVC) and 3.2±1.3 MUs (10% MVC) by the method [3]. While innervation trains identified by the method [1] exhibited highly regular firing patterns, only 85.0±7.5% of pulses detected by the method [1] was identified by the method [3]. Finally, the method [2] (applied only to the signals at 5% MVC) identified 2.3±1.0 MUs.

Conclusions: Whereas all the methods proved significantly noise-resistant, the best results were obtained by the method [1]. Although successfully decomposing the synthetic signals, the methods [2] and [3] proved less reliable on the experimental signals.

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216 - Are Abdominal Muscle Temporal Activation Patterns Related To Lumbar-Pelvic Motion Control?

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Introduction: Achieving spinal stability requires continual changes in the three-dimensional moments of force produced by muscles in response to loads (McGill et. al., 2003) with the central nervous system continually interpreting data on stability and movement, and planning mechanisms to respond (Hodges & Moseley, 2003). The link between lumbar-spine instability, dysfunction of the neuromuscular system and low back pain has been made in the literature. Co-activation is an important neuromuscular control strategy for spinal stability, but few studies have evaluated temporal co-activation patterns during dynamic tasks. Differences were reported in temporal co-activation patterns among abdominal muscles between low back pain and healthy control subjects performing a low-demand dynamic stability task (Hubley-Kozey & Vezina, 2002). The purpose of the present study was to compare temporal co-activation patterns among abdominal muscles during tasks with different dynamic stability demands on the lumbar spine between those able to minimize lumbar pelvic motion and those who were unable to minimize motion. The aim of this work is to gain insight into how the muscles respond between the two groups and potentially identify specific neuromuscular control impairments that will help focus training for low back pain.

Methods: Thirty-five healthy volunteers were placed into a stable (S) or an unstable (US) group based on their ability to maintain lordosis and pelvic angle while performing five levels of a supine-lying leg-extension exercise progression in random order. After standard skin preparation surface electromyograms (EMG) were recorded from the upper and lower rectus abdominus and the anterior, lateral and posterior fibres of the external oblique muscles. The signals were amplified (Bortec, Ltd, Calgary, Canada) then sampled at 1000 Hz using Labview TM software and a National Instruments TM card. The raw EMG were full-wave rectified, low pass-filtered at 6 Hz, amplitude normalized to average and time normalized to 100% for the entire exercise. The normalized EMG waveforms for each subject, muscle, level and trial formed a matrix (101 X 1980) to which a Karhunen Loeve transform was applied. ANOVA models tested for group, muscle, and level main effects and interactions for the weighting coefficients derived from the principal patterns ($\alpha = 0.05$).

Results: Nineteen subjects (age 24+/-3.4years) made up the (S) group and 14 (age 24 +/-2.4 years) made up the (US) group. There were no significant differences between groups for age, mass, height and activity level ($p>0.05$). Ninety one percent of the variance in the normalized waveforms was explained by 5 principal patterns. All two-way interactions were significant ($p<0.05$) for principal patterns 1, 2 and 5. The muscle by level interaction for principal pattern 3 and muscle by group interaction for principal pattern 4 were also statistically significant ($p<0.05$). The post hoc findings illustrated differences in temporal patterns between groups for specific muscles as well as differences among muscle sites.

Conclusion: The temporal waveforms for the (US) group had more variability in their patterns among muscles compared to the (S) group in particular for the less challenging tasks. These quantitative differences illustrate temporal co-activity within muscles for the (S) group, a lack of temporal synchrony among muscle sites for the (US) group, differential roles for different muscle sites and differences in how the abdominal muscles of the (S) subjects responded to the dynamic stability challenges compared to the (US) subjects.

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283 - Effects of Spatial Filtering On Multi-Channel Surface EMG MUAP Shapes

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Introduction: Effects of different multi-channel (MC) surface electromyogram (SEMG) spatial filtering techniques on motor unit action potential (MUAP) properties, have previously been studied by e.g. Farina et al. (2003). For decomposition purposes, it is desirable to increase MUAP shape differences between different MUs. The aim of this study was to investigate (1) how the inter-MU differences between MC SEMG MUAP shapes depend on spatial filtering, and (2) how these differences are related to the muscle force level.

Methods: Four subjects volunteered to participate. A 3-channel bipolar intramuscular wire electrode was inserted into the right upper trapezius muscle, and a 16-channel monopolar 2D surface electrode (Disselhorst-Klug et al., 2000) was centred on the insertion point. Each subject performed 30 seconds of static contraction at five levels: 1, 2, 5, 10 and 20% of maximal voluntary contraction (MVC), respectively.

The intramuscular EMG (iEMG) data was decomposed and used for spike-triggered averaging of the SEMG data. Two different spatial filters were applied on the SEMG data: longitudinal single differential (SID, 12 channels), and normal double differential (NDD, 6 channels). Within each subject, the shape similarity between each spatially filtered MC SEMG MUAP segment and one MU template (its own and other) was computed using a MC goodness of fit (GOF) measure. For each MU, the percentage of segments, where the GOF with its own template was higher than for all other templates, was calculated in order to estimate the possibility of correct segment classification to its own MU.

Results: At the 5 %MVC contraction level, 21 MUs with on average 129 (SD: 73) segments were identified for 3 subjects. Data from subject 4 was disregarded due to signal disturbances. For these MUs, the average percentage of correct classification was 21.0 (SD: 11.9, range: 3.3-39.3) and 23.2 (SD: 14.3, range: 3.6-64.7) % for SID and NDD filtered signals respectively. No significant difference between SID and NDD (t-test; $P>0.44$) was found, while they were weakly correlated (Pearson test; $r=0.53$, $P<0.05$). Similar statistical results were found for the 22 identified MUs at 20 %MVC contraction level, but with overall lower percentages of correct classification; average 18.1 (SD: 12.9, range: 1.7-53.1) and 19.3 (SD: 11.2, range: 3.3-40.6) % for SID and NDD filtered signals respectively.

Discussion: Both the SID and NDD filtered signals showed a low estimated percentage of correct classification, illustrating the difficulties encountered with decomposing the surface EMG signal. The low percentage might have been caused by the relatively deep location of the MUs picked up by iEMG, resulting in MUAP shapes that are superimposed with signals from more superficially located MUs.

The results indicate that for low and intermediate contraction levels of the upper trapezius muscle, a 6-channel NDD signal delivers at the least as much information as a 12-channel SID signal with respect to MC MUAP shape differences. Thus, NDD may be preferred to use since it is more spatially specific and uses fewer channels which facilitates a shorter computation time for MU decomposition.

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288 - The NEW-Study. Neuromuscular Assessment in Elderly Workers from 4 EU Countries with and Without Work Related Musculoskeletal Disorders.

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Introduction: Musculoskeletal disorders in the neck and shoulder area are a major occupational concern in the European countries. Among secretaries and computer workers these disorders are particularly frequent and their incidence increases with age.

Methods: Four European countries: Switzerland (CH), the Netherlands (NL), Sweden (SE), and Denmark (DK) agreed on common questionnaires, functional (e.g. muscle strength) and clinical tests, as well as physiological recordings to be applied in workplace related field studies. The recordings included multi-channel EMG measurements using small portable data-loggers developed for this purpose. The field studies were conducted during the time period April 2002 – July 2003. Workplaces of interest encompassed exposure contrast groups of monotonous work represented by computer users and physically heavy work represented by nurses. Screening questionnaires were distributed within these exposure groups to identify contrast groups regarding age and self reported musculoskeletal disorders. The present data are on the elderly female workers (above 45 years) having worked at least 5 years with the present job and working at least 20 hrs a week. Two groups were identified: 1) Neck/shoulder (NS) cases: reported trouble (ache, pain, discomfort) in the neck and/or shoulder region for more than 30 days during the last year, and 2) Neck/shoulder (NS) controls: reported trouble in the neck and/or shoulder region for no more than 7 days during the last year.

Results: The total population in the NEW-Field-Database is 358 female workers from the four countries. Among these 335 were elderly workers, i.e. 45 – 68 years: 113 from CH, 93 from NL, 65 from SE, and 64 from DK. Only in CH both nurses (60) and computer users (53) were included, resulting in a total of 275 elderly computer users from the four countries. Among the elderly computer users 88 were NS-cases and 164 were NS-controls The mean (±SE) were for age 53 ± 0.3 years, height 1.66 ± 0.003 m, weight 70 ± 0.9 kg and body mass index (BMI) 25 ± 0.3 with no difference between cases and controls. There were no major differences in smoking habits and sickness leave but NS-cases reported more eye problems than the controls. Also the NS-cases had lower muscle strength during shoulder elevation: 310 ± 15 N compared to the controls: 363 ± 14 N, while no differences were found regarding endurance time at 30% MVC. On 61 NS-cases and 80 controls successful EMG recordings were obtained during the 6 min 30 %MVC endurance test, showing significant difference between NS-cases and control on EMGrms: 111 ±15 μV vs. 179 ± 20 μV. However, EMGmpf did not show differences between groups and also not the slopes for the two variables computed for the 6 min contraction period. For three of the countries also global conduction velocity was calculated. No differences were found between 27 NS-cases and 61controls for neither the initial value nor the slope. The overall mean initial value was10 (range 4-25) m/s of which approx. 1/3 were below 6 m/s. Regression analysis showed BMI to account for less than 10 % of the variation in global conduction velocity.

Discussion: The major finding on the large-scale epidemiological study is the significant difference in muscle strength. This finding was supported to be of muscular origin by the lower EMGrms value in the NS-cases compared with the controls. In the presented large multi-center field study the inclusion of global conduction velocity into the evaluation of the EMG analyses produced some methodological difficulties and did not reveal

conclusive results. This may call for more subtle analysis of the EMG for objective identification of muscular disorders in the neck/shoulder region in computer users.

300 - Analysis of Fatigue in the Erector Spinae Muscle During Sustained Isometric Back Extension By Means Of Surface EMG

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Introduction: During fatiguing static contraction the muscle activity pattern in the lumbar part of erector spinae (ES) appears to deviate from the characteristic fatigue related electromyographic (EMG) changes seen on in other muscles. In contrast to the simultaneous increase in EMG amplitude and decrease in mean spectral frequency (MSF) normally seen during fatigue, the lumbar part of ES shows constant or even decreased EMG amplitude during sustained static back extension (Essendrop et al. 2002). The decrease in MSF has been related to a fall in conduction velocity (CV). The aim of this study was to establish a detailed picture of surface EMG fatigue parameters in the entire lumbar part of the ES. A linear array electrode allowed the detection of possible regional differences in EMG response to fatigue and, if detectable, to correlate changes in CV to spectral variables.

Methods: Eight healthy men performed sustained static back extension until exhaustion at 40% of their maximal voluntary contraction (MVC). Visual feedback of the load was given to the subject throughout the test. Surface EMG on the right ES were recorded with a linear array electrode (LISiN-SPES Medica) consisting of 16 electrodes with an inter-electrode distance (IED) of 10 mm. The array was placed parallel to the spinal cord, 3 cm laterally and reference electrode was placed around the right wrist. The most caudal electrode was placed at the level of L4/L5, placing the most cranial electrode at the level of T11/T12 depending on the size of the participant. In the data analysis an IED of 20 mm was used giving a total of 14 single differential EMG channels sampled at 2048 Hz. Averaged rectified amplitude values (ARV) were calculated along with mean power frequency values (MNF) on epochs of 1 s. Manual visual detection of periodic traveling components was performed and CV was computed with a multi-channel CV estimation algorithm (Farina et al. 2003). For this calculation the algorithm was applied to the double differential signals with 10 mm IED.

Results: For the eight most cranial channels the ARV slopes (μV/s) were significantly higher than zero (one-sample t-test). However, the two-way ANOVA within subjects with EMG channels as independent factor showed no statistically significant dependency of the ARV slope on the position along the array. A significant decrease in the MNF slope (Hz/s) was seen for the nine most caudal channels, and a tendency ($p<0.08$) existed for the five most cranial channels. The decrease in MNF was highest caudally at the L4/L5 level and diminished continuously to the level of T11/T12. The global CV estimation values were comprised between 5 m/s and 20 m/s, with a mean value of the initial values for the computed regression lines of 9.8±3.9 m/s.

Conclusion: The analysis of the EMG signals acquired with the linear electrode array showed an increase of the muscle fatigue, detected as an increased slope of EMG variables, towards the caudal portion of the ES, during the contraction.With the linear array electrode a gradual upward movement of the surface EMG activity was shown as the muscle fatigued. It is unknown whether the muscle load is shifted upwardsconcentrated in the lower part of ES or whether deeper parts of the ES muscle or other muscle structures may have unloaded the caudal part of the ES. In line with results from Farina et al. (2003) the estimated CV values were not physiological and could not be interpreted. This inability to estimate CV may be caused by non-propagating signal components due to end-of-fiber effects, or misalignment of the array with respect to the fibers and/or segmental muscle innervation.

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318 - Single Motor Unit Contribution to Surface Mechanomyogram Investigated In Two Hand Muscles

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Introduction: In the European Shared Cost Project "Neuromuscular assessment in the Elderly Workers" the investigation of the hand muscles have been considered crucial for computer workers. As a consequence a method for non-invasive assessment of single motor unit (MU) electro-mechanical properties was developed. This addresses the extraction of information about single MUs activity by the joint analysis of surface electromyogram (EMG), surface mechanomyogram (MMG), and force signals. The approach is based on the identification of MU action potentials with EMG decomposition and on the spike triggered averaging of the MMG and force single MU contributions [1].

Methods: Surface EMG signals were detected with an adhesive linear array of 8 electrodes (5 mm inter-electrode distance). The EMG signals were amplified, band pass filtered (3 dB bandwidth, 10 Hz-500 Hz), sampled at 2048 Hz, and converted to digital form by a 12 bit A/D converter. The muscles studied were the abductor digiti minimi (ADM) and first dorsal interosseous (FDI) of the dominant hand. MMG was detected by an accelerometer (ADXL202JE, Analog Devices, 5 mm edge, 2 g weight) fixed by double adhesive tape to the muscle bellies. Force was measured by a load cell fixed at the level of the second phalanx of the second (for the FDI muscle) and fifth (for the ADM muscle) finger, respectively. Ten healthy male volunteers (age, mean ± SD, 27.1 ± 2.8 years; height, 179.4 ± 6.9 cm; weight, 73.4 ± 8.5 kg) participated to the study. The subjects performed two voluntary isometric contractions lasting 60 s at 2% and 5% of the maximal voluntary contraction (MVC) force. A third contraction was performed by selectively activating a single MU with surface MU action potential visual feedback provided to the subject.

Results: Table 1 reports the characteristics of the MUs identified from the two muscles during the three contractions. The peak-to-peak value of single MU MMG was significantly different for the same MU in different contractions, indicating a non-linear summation of the single MU contributions.

Table 1 Features of individual MUs extracted from surface EMG, MMG, and force signals obtained by spike triggered averaging using the firings of the MUs identified from the two muscles in the three contractions. Values are reported as means ± SE over the number N of MUs identified from all the subjects. PkPk stands for peak-to-peak value, MNF for mean power spectral frequency, RTime for rising time.

	Table 1	EMG Pk	EMG MNF	MMG Pk	MMG MNF	FRP Pk	FRP RTime
		μV	Hz	mm/s^2	Hz	mN	ms
FDI	2% MVC - N=18	54.8± 5.7	128.4± 3.5	9.6± 2.0	33.7± 1.7	6.48 ± 1.18	63.6± 3.9
	5% MVC - N=17	90.2±10.1	132.6± 3.5	11.0± 1.8	30.3± 2.0	7.42 ± 1.34	58.1± 5.0
	Sng.UM - N=18	50.8± 5.6	127.3± 3.7	15.0± 4.1	29.9± 1.1	5.60 ± 1.31	54.4± 2.9
ADM	2% MVC - N=12	65.1±13.3	115.1± 5.5	36.3± 7.3	23.4± 2.1	16.53 ± 4.3	59.5± 1.8
	5% MVC - N=20	116.3±20.2	131.9± 4.4	32.3± 6.5	21.3± 1.2	14.4 ± 2.9	57.2± 1.7
	Sng.UM - N=18	64.1± 5.7	118.3± 3.1	33.8± 6.7	24.1± 2.1	11.1± 3.05	64.4± 3.1

Conclusions: The method applied is promising for the non-invasive assessment of single MU contractile and membrane properties. Moreover, it can provide important information for modelling the MMG signal generation process.

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325 - Development Of A New Functional Test To Assess The Capacity of Back Muscles : Assessment of Face Validity.

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Introduction: Poor back muscle endurance has been identified as a predictor of a first episode of low-back pain [1]. To better assess this back muscle characteristic, surface EMG has been promoted as a motivation-free measure to assess back muscle fatigability. However, the tasks generally used (high-intensity short-duration sustained contraction) clearly involve muscle fatigue mechanisms that do not correspond to an actual work task, which makes difficult inference about muscle endurance in relation to work. A new functional fatigue test is proposed to assess back muscle capacity. The test is more closely related to common occupational tasks as it involves static intermittent contractions (8 s work-rest cycles) using a fixed load (90 Nm) for all subjects. Being an absolute endurance task (endurance test using the same load across subjects), it was hypothesized that the performance on this new test would be influenced by both strength and relative endurance (endurance test using a load equal to the same percentage of maximal voluntary contraction [MVC]), thus demonstrating its face validity.

Methods: Thirty-two healthy subjects (15 males and 17 females) were tested on three different days in a static trunk dynamometer [2]. The first session (session 1) was used for familiarization. During each assessment session, three MVCs, separated by a minimum of 2 min. rest, were followed by the functional fatigue test that lasted 10 min. in session 1 and to exhaustion in session 2. The functional test consisted in repetitions of an 8-s cycle subdivided into 1.5 s of progressive increase to reach an absolute load (L5/S1 extension moment of 90-Nm), 5 s to sustain this level of force (plateau), and 1.5 s of rest. Relative endurance (session 3), used the same protocol except that the load was equal to 41% of the MVC recorded in session 2. Both types of endurance (absolute and relative) were defined as the time to reach exhaustion (Tendabs and Tendrel respectively; they were logarithmically transformed to obtain LogTendabs and LogTendrel) whereas Strength was defined as the peak MVC performed at session 2. The relative 41% MVC load matched (on average across the subjects) the absolute load used in the functional fatigue test (90 Nm) and was estimated from a database of male and female subjects.

Results: Strength was significantly correlated to LogTendabs (r = 0.61) and LogTendrel (r = - 0.60). Using stepwise regression analyses, it was observed that Strength and LogTendrel (no other predictors such as gender, age, height or body mass were retained in the model) each explained almost equivalent portions (34.7 and 26.8% respectively) of Tendabs (variance explained : 61.5%), thus confirming our hypothesis.

Conclusion: These results support the face validity of the new functional fatigue test. In other words, this test has the potential to better infer the strength and endurance capacities of chronic LBP patients relative to more realistic occupational tasks.

References

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Acknowledgements: This project was co-funded by the Occupational Health and Safety Research Institute Robert-Sauvé (IRSST) of Quebec and the Canadian Institutes for Health Research (CIHR).

350 - The Influence of Three Intermittent Myofeedback Relaxation Training Schedules on Trapezius Muscle Activity While Performing a Gross-Motor Task

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Introduction: This study aimed at investigating the influence of three intermittent feedback training schedules, as provided by a Cinderella-based myofeedback system, on relaxation training and resistance-to-extinction of the trapezius muscle in subjects performing a unilateral gross-motor task.

Methods: Eighteen healthy subjects (mean age 30.3±9.7) were randomly assigned into 3 groups. Three schedules were defined, based on a myofeedback evaluation interval length of 5, 10, or 20 seconds. Measurements were performed on three consecutive days in each subject and the subjects were exposed to the three schedules in different order according to the group they had been assigned to. Bipolar surface EMG recordings were performed at the dominant upper trapezius muscle. Each day, subjects performed a gross-motor task without (Baseline; B), with (Task 1-4; T1-4), and subsequently without feedback (Extinction 1-2; E1-2). Auditory feedback was provided when the pre-set level of muscular rest during 80% of the interval was not reached. Training effect was defined as increased time spent in muscular rest (Relative Rest Time, RRT) and decreased muscular activity (RMS).

Results: RRT was significantly increased during the tasks for the 5 (T1-4; $p \leq .049$), 10 (T1-2; $p \leq .011$) and 20 seconds schedules (T1; $p \leq .024$) compared to baseline. RMS was only decreased under the 10 (T1; $p \leq .043$) and 20 seconds schedules (T1-2; $p \leq 0.036$). None of the schedules showed resistance-to-extinction.

Discussion: In this study the 10 seconds schedule was preferred over the 5 and 20 seconds schedules in relaxation training of the trapezius muscle in subjects performing a gross-motor task. However, further studies are required and should aim at the lasting effect of myofeedback training.

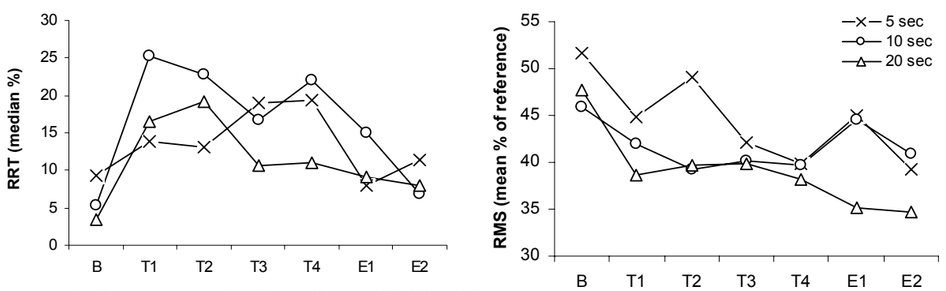

FIG. 1: RRT (left) and RMS (right) values for the three intervals during gross-

351 - How to Improve Working Conditions for Spinal Cord Injured? An Intervention Study Including Myofeedback Training

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Introduction: The working conditions among meningomyelocele (MMC) and traumatic spinal cord injured are poorly known. About 80% of those having traumatic spinal cord injury are employed or studying two years after the injury according to a Swedish study. It has also been reported that neck- and shoulder problems are twice as frequent in this group compared with the regular workforce, one obvious explanation being the use of crutches or wheel chair, but even mild movement problems lead to extra load of the upper limbs when taking support etc. Today many workplaces tend to promote "active" working conditions, which can bring additional load to a physically challenged employee. The overall purpose of this on-going pilot study is to plan, perform and evaluate improvements of the workplace, working conditions and techniques in a group of spinal cord injured. A specific part of the study is to see if a myofeedback device can be applicable and of use to promote less unfavourable activation of the neck- and shoulder muscles.

Methods: The current study includes seven participants representing MMC and spinal cord injuries at the cervical, thoracic and lumbar level. A physiotherapist visits the participants at their workplace to make a "baseline" video recording and evaluation of the situation at work with special focus on how to reduce load on the shoulder and upper limbs. At this first visit also basic ergonomic information is given and changes of the workplace are discussed and carried out if practicable. The participants are also offered to use a myofeedback device which should be carried during regular work and which gives alarm if the shoulder muscles haven't reached a preset level of muscular rest time (relative rest time, RRT, i.e. the amount of time the muscle has been in rest). The participants using the myofeedback device also keep a diary and fill in ratings of pain on an interval VAS-scale. The physiotherapist visits them every week up to four weeks to record the latest week's experiences. The short version of the QPS Nordic questionnaire and interval VAS-scales about current problems of the neck/shoulder are completed at the first and last visit. All changes at the workplace are carried out in close co-operation with the participants and their respective employers.

Results: The study is running and will be completed during the first half of 2004. Up to now, six participants have been enrolled and in all but one case have these visits led to ergonomic changes being carried out. Four of the participants have opted to use the myofeedback device.

Discussion: It is the authors' belief that experiences from this study will be valuable in future ergonomic assessment and intervention planning at workplaces of spinal cord injured and MMC. The intention is to present the results in such a way that they can be directly applied by ergonomists and practitioners in the field.

368 - Assessment of Fatigue in Low Back Muscles of Elderly Nurses

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Introduction: Surface EMG techniques have been extensively applied to the analysis of low back muscles, both in healthy subjects and low back pain patients [1]. Surface EMG analysis is promising for objective fatigue assessment and has been applied in many rehabilitation fields. Moreover, myoelectric manifestations of muscle fatigue were shown to be predictor of the trunk extensor endurance time, thus reflecting mechanical fatigue. However, despite the numerous works which showed potential usefulness of the surface EMG approach in clinical routine, this technique still presents limitations related to repeatability, sensitivity to electrode location, and type of contraction performed. The aim of this study, done within the framework of the EU Project "Neuromuscular assessment in the Elderly Worker (NEW)" was to compare EMG variables, in a group of elderly female nurses suffering from low back pain and in a control group, during sustained contractions of the low back muscles.

Methods: Cases (11 subjects, age, mean±std.dev., 50.1±5.5 years, height, 157.1±7.8 cm, weight, 64.2±17.6 kg) were nurses, who, at the time of the study, had worked at least 20 hours/week on the same job for at least 5 years and reported trouble (ache, pain, discomfort) in low-back for more than 30 days during the last year. Nine control subjects were selected to match the cases for age and body mass index (age, mean±std.dev., 50.1±3.8 years, height, 160.3±6.7 cm, weight, 64.7±11.7 kg). Multichannel surface EMG signals were detected bilaterally from Longissimus Dorsi (LD) and Multifidus (MF) muscles using four 4-electrode, 10 mm interelectrode distance (i.e.d.) adhesive arrays aligned with muscle fiber direction. Single differential (SD) detection method was used. The subject was held in horizontal position, with trunk and arm leaning off a bed, and asked to perform a sustained contraction of the low back (Sörensen test [2]) while keeping the trunk horizontal until exhaustion (endurance time reached). At the end of the test, the subject was asked to provide an indication of fatigue according to the Borg scale, and of low back pain on a VAS scale. The test was repeated on three non-consecutive days to assess repeatability. For each array, the three SD signals were summed to obtain a 30 mm i.e.d. equivalent signal. Averaged rectified value (ARV) and mean power spectral frequency (MNF) were calculated on 1 s epochs. Linear regression analysis was performed to compute ARV and MNF initial value and slope.

Results: Endurance time was significantly shorter (mean±SE 152±10 vs.142±9 s) and the pain score higher for cases with respect to controls (mean± SE 3.4±0.4 vs. 5.1 ± 0.3), while no differences were found in Borg scale values. ARV initial value and slope were significantly different in the two groups, with lower amplitude (mean±SE 63±2 vs. 48±2 μV) for cases. No difference was observed in the EMG variables between subsequent trials, indicating good repeatability of the estimates. No difference was observed between MNF decrease rates.

Discussion: EMG measures were repeatable as indicated by the absence of differences between measures obtained in different trials. The two subject groups showed similar MNF slope values, despite a shorter endurance time for the cases. This can be explained by the subjective pain scores, which suggest that cases stopped the contraction because of low back pain. The amplitude patterns suggest different activation strategies in the two groups, probably due to the discomfort caused by muscle ache.

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479 - Field Calibration of an EMG Assisted Model to Predict Spinal Forces, Without Use of MVC

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Introduction: As part of the dutch ExoZorg project methods are under development for coaching and training of subjects with back pain. So far, ambulatory methods for estimation of 3D kinematics and net moments are developed for practical use in the field (Baten, 2002). This paper validates a proposal for a practical method for estimation of spinal forces given the net moments, EMG signals and trunk kinematics. Current EMG driven methods need a large series of Maximum Voluntary Contractions (MVC) for calibration, which is not feasible in the field and with patients. An alternative method (van Dieën, 2003) uses optimisation based on kinematics, EMG and known net moments, without use of MVC.

Methods: The force distribution model comprises 164 muscle slips, activated in 10 groups, each represented by one EMG channel: $Fmusci = gainj*(SREj * pcsai * \omega i * \delta i) + Q*Fpeci$

(Here: Fmusci = force of muscle slip; SREj = smooth rectified emg; pcsai=physiological cross sectional area; ωi = velocity correction; δi = muscle length correction; Fpeci = parallel elastic component)

For each subject 10 gain values and Q are optimised using a set of calibration movements.

Validation was performed for 10 subjects in static and 6 subjects in dynamic calibration trials. In a sensitivity study effects of different sets of calibration movements and optimisation constraints were examined. Net moments calculated from the found muscle slip forces were compared to the net moments estimated from inverse dynamics for a variety of tasks and weights.

Results and **Discussion:** For symmetric conditions correlations higher then 0.93, and mean absolute errors (MAE) of less then 15 Nm were found, for asymmetric conditions correlations varied around 0.74, MAE around 22 Nm. Relative errors over all conditions varied from 8 to 11 % between subjects. Possible causes for differences between performance in symmetric and asymmetric conditions are sub-optimal representation of EMG signals of the oblique abdominal muscles, and unbalanced coverage of the range of motion and acceleration.

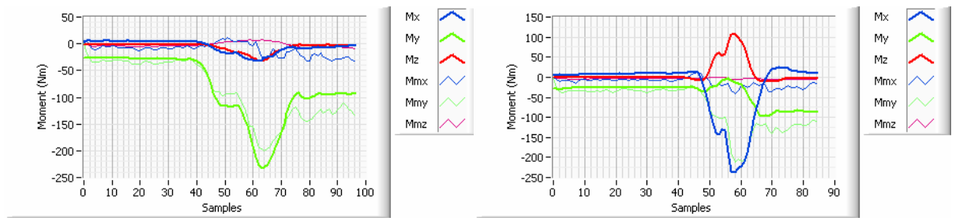

Figure: estimated net moments (Mm) against reference values (M) for one subject in three components (x,y,z); left for symmetric, right for asymmetric lifting).

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Ambulatory Recordings

015 - A Tool to Quantify the Temporal and Spatial Properties of EMG Patterns during Gait
056 - Muscle Activity In Trapezius And Lower Back Muscles During Standing/Ambulating And Seated Work Postures
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015 - A Tool to Quantify the Temporal and Spatial Properties of EMG Patterns during Gait

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Introduction: An innovative technique for analyzing the temporal and spatial properties of EMG patterns collected during gait is presented.

Methods: A gait metric is computed, consisting of both magnitude and phase components. For the magnitude component, the processed EMG pattern is compared to normative EMG gait-related data across the gait cycle, where the metric is incremented if the muscle is firing during expected active regions or is silent during expected inactive regions. The magnitude metric is penalized when the EMG is silent during phases of expected activity or when the EMG is active in regions of expected inactivity. The phase component of the metric computes the percentage of the gait cycle when the muscle is firing appropriately, that is, active in expected active regions and silent in expected inactive regions. The magnitude and phases components of the metric are normalized and combined to yield the EMG pattern that demonstrates the closest spatial and temporal characteristics compared to normative gait data collected under similar walking conditions.

Results: The proposed gait metric was tested using both simulated and experimental data and has been shown to be accurate in quantifying both the magnitude and phase of EMG activity relative to a normative condition during gait. **Discussion:** The strengths of the method include: 1) its ease of use and understanding; 2) it quantifies the EMG activity of the entire gait cycle using a single value that facilitates interpretation of the quality of the walking condition; and 3) the metric values for each muscle can be examined to determine if it is activated appropriately relative to the normative condition.

Conclusions: This gait metric is extremely useful for comparing the EMG patterns demonstrated in subjects trained under various conditions, e.g. with changes in body-weight support or walking speeds. This is clinically important in patients with neurological injuries who often demonstrate poor coordination among muscle groups; particularly if the walking conditions are too difficult Clinical uses for the gait metric include determining optimal gait training conditions in individuals following stroke and spinal cord injury.

056 - Muscle Activity In Trapezius And Lower Back Muscles During Standing/Ambulating And Seated Work Postures

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Introduction: Prolonged seated work is associated with physical impairments in upper extremities, shoulders and neck (Blatter & Bongers, 2002), as well as swelling of the lower extremities. Prolonged sitting is also suggested to be a risk factor for the development of low back pain (Pynt et al., 2002). Ergonomic guidelines for sedentary work recommend frequent breaks involving walking or alternating between seated and standing work. Thus, the guidelines assume differences in physiological responses during sitting and short periods of standing/ambulating that is of significance for the promotion of musculoskeletal health. We would like to know if there are characteristics in muscle activity patterns during standing/ambulating that is different for the seated work posture.

Material and Methods: Twelve female subjects employed at a call-centre participated in the study (mean age 42.9 SD 9.8). Thigh angle and surface EMG signals were recorded (Physiometer PHY-400, Premed A/S, Norway) over the full workday. Bilateral EMG recordings included upper trapezius, iliocostalis lumborum, longissimus thoracis and lumbar multifidus. Thigh angle was measured by electrolytic liquid level sensors allowing the detection of standing/ambulating and seated work.

Results: The time (% of workday) spent sitting was considerable larger than the time spent standing or ambulating (mean 87.5% SD 3.2% vs. 12.5% SD 3.2%). There was no difference in EMG responses between right and left side. The data was therefore pooled by averaging the right and left responses (Table 1). Standing/ambulating resulted in an elevated and more variable muscle activity as indicated by group median values (Table 1, $p<0.01$ for all comparisons, Wilcoxon signed ranks test).

Discussion: The present findings, together with the existing ergonomic guidelines, suggest that relatively short intermittent periods with increased and more variable muscle activity promote musculoskeletal health in sedentary occupations.

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Table 1. Median EMG (%EMGmax) level and SD of the EMG signal during standing/ambulating and seated work postures (95% Cl in brackets).

	Median EMG (%EMGmax)		Median SD of EMG signal	
Muscle	Seated work	Standing/ambul.	Seated work	Standing/ambul.
Trap.	1.4 (0.9 – 2.1)	3.3 (2.6 – 5.1)	3.1 (2.7 – 5.2)	6.0 (3.8 – 9.2)
Ilicost.	1.5 (0.8 – 2.9)	4.1 (1.9 – 5.7)	3.0 (2.3 – 4.9)	7.2 (6.0 - 12)
Multif.	1.9 (1.1 – 3.6)	6.2 (2.8 – 12)	3.6 (2.2 – 6.8)	10.6 (7.4 – 15)
Longis.	1.5 (0.9 – 5.1)	7.0 (3.3 – 8.0)	4.2 (2.3 – 4.9)	8.8 (5.5 – 12)

195 - Comparison of Energy Expenditures while Going Up and Down the Staircase: Measured by 2-D Accelerometer and Respiratory Gas Analyzer

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Introduction: The purpose of this study is to compare energy expenditure during staircase ascending and descending measured by 2-dimensional (2-D) accelerometer and respiratory gas analyzer. Quantification of physical activity is important in various aspects of physical therapy and all healthcare, especially when patients need exercise prescription. Increasing and decreasing of physical activities are important to conditioning of health and fitness. Going up and down the stairs is high intensity during the daily life activities, and contributed significantly to the daily energy consumption. Stairs climbed or total amount of daily physical activity is known to oppose risk of ischemic heart disease. However, because the impact on feet during stair climbing is smaller as compared to walking, energy expenditure measurement during stair climbing with 2-D or 3-D accelerometer commonly used to measure daily energy expenditure, may underestimate actual energy expenditure. It is important for us to know the limitation of commonly used device of convenience.

Methods: Ten male subjects (mean age 20 yr., height 175 cm, and body weight 65 kg) who gave full written informed consent participated in this study. A standard 2-D accelerometer(Lifecorder: Suzuken co. Japan) with a sampling rate of 4 seconds was fixed to the subject's belt on his iliac spine. He also wore a portable respiratory gas analyzer(K4b2: Cosmed Ltd. Italy) for oxygen uptake measurement in a breath-by-breath mode. The subject was then told to climb up and down a stairs (120 stairs) at their maximum effort. The intensity of activity measured by the accelerometer was assigned to 10 ranks, and energy expenditure was calculated accordingly. Oxygen consumption of 1L was considered as 5kcal of energy expenditure. Statistical analysis was performed by Student's paired t-test, and a significant level was set at 5%.

Results: The mean values of energy consumption calculated from accelerometry during stair ascending and descending were 0.017 and 0.013 kcal/ kg/ min, respectively, while that from respiratory gas analysis was 0.075 and 0.051 kcal/ kg/ min, respectively. Energy expenditure calculated from respiratory gas analysis was significantly higher than that from accelerometry ($p<0.05$).

Discussion: Standard 2-D accelerometer has been validated for estimating energy expenditure during walking or running on flat surfaces. However, it was shown in this study that it largely underestimates energy consumption during stairs ascending and descending. Large underestimation may be due to smaller impact on feet and pelvis during stair ascending and descending as compared to flat surface walking. It is suggested that scoring stairs ascended and descended should separately be performed to calculate daily energy expenditure using accelerometer.

A part of this work was doctoral dissertation in Tohoku University Graduate School of Medicine, and was supported by the Ministry of Education, Culture, Sports, Science and Technology. KAKENHI (15700442)

299 - The Effects of the Height of Parallel Bars on Walking and Physical Movements

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Introduction: Handrails and parallel bars are used at home and public institutions to relieve and to support body weight and movement in walking. Thus in practice, the height of the handrail or parallel bar when in used in this way must be important. Our investigation has indicated that the parallel bar suitable at the level of greater trochanter, but now we intend to evaluate the height of greater trochanter against various height of parallel bar.

Methods: Subjects: Six healthy male students in Niigata University of Health and Welfare, with a mean (SD) age, height and weight of 18.8±0.41 years, 172±6.7cm and 60±5.6 kg respectively were selected. The average height of the greater trochanter from the floor was 87.5±4.5cm.

Experimental Procedures: Subjects walked with two-point gait between parallel bars. A reciprocal gait pattern was used, so that as one foot moved ahead, the hand of the opposite side grasped the parallel bar. This was alternated with each step. Each subject walked under three experimental conditions, once with the height of the parallel bars set the same as their greater trochanter and once each with the bars set 5cm higher and 5cm below this height.

Muscles Observed:

(a) Rectus femoris

(b) Lateral gastrocnemius

(c) Anterior tibial muscle

The pressure of plantar surface of the foot on the floor was also measured (vertical force).

EMG Recording and data analysis: Surface EMG signals of the muscles were recorded while subjects walked between parallel bars. Prior to the start of recording, the skin area was cleaned with alcohol and the electrodes were attached.

Blue sensor disposable bipolar electrodes were attached to the skin over each muscle using adhesive gel. Each pair of electrodes were positioned on the midline of muscle belly with the detection surface oriented in parallel to the longitudinal direction of muscle fibers.

EMG signals were fed into an NEC multi channel differential amplifier, with a filtering range of 10 Hz and 500 Hz for low cut-off and high cut-off frequencies respectively. The amplified signal was passed to a personal computer with 1KHz sampling frequency. Root-mean-square (RMS) amplitudes were calculated for each walking condition.

Results: Vertical force during walking was lower with the bar height set to that of the greater trochanter when compared to bars set 5cm higher ($P<0.05$).

RMS of gastrocnemius during walking was greater with the bar height set to that of the greater trochanter when compared to bars set 5cm lower ($P<0.05$).

Discussion: Walking between parallel bars set to the height of the greater trochanter can provide more benefit than when set 5cm higher or 5 cm lower. An increase in the RMS of lateral gastrocnemius may provide greater push off from the floor when walking. For the rehabilitation of walking, setting the height of the parallel bars to that of the greater trochanter is recommended.

315 - Use of a New Brace for CVA Clients with Sensory Disturbance During Walking.

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Introduction: There is currently no standard treatment approach for CVA clients. Every therapist will use the approach they believe to be most effective. We should aim to standardise treatment supported by scientific evidence to achieve best treatment results. Often motor dysfunctions are the main treatment target of rehabilitation. However, many clients are also troubled by sensory disturbances. We have developed a new brace for CVA patients with both sensory and gait disturbance.

SUBJECTS and Methods: Twenty five CVA clients were studied (mean age 60.2±10.3). There were 10 female patients (4 left and 6 right hemiparesis) and 15 male patients (9 left and 6 right hemiparesis). In terms of the sensory involvement, there were two anesthesia cases, three with mild sensory disturbance, twelve moderate and six severe cases. In ADL eleven cases needed close supervision to walk and five required distal supervision. Nine were independent when walking with canes.

A new gait analyzer called "Super Rainbow" has been developed by Engineering Research Laboratory, Hitachi Kiden Kogyo, LTD in conjunction with Professor Takagi. It consists of parallel bars which collect data from the upward, downward, forward and rearward forces applied through them (Newtons or kg weight). It also has two CCD cameras to obtain data of step lengths, step widths, gait speed, and strides. It can also show instantaneous foot prints to illustrate differences between the paralized side step length and the non-affected side.

The main aim of this study was to improve gait by using a new type of brace. We used flat elastic braces for the trunk, pelvic band, thigh, and lower leg. These were similar to elastic bandage but enabled different therapists to apply similar pressure, whereas using conventional elastic bandage can lead to differences in tightness being applied between therapists.

RESULTS: We gathered data on step length, step widths, gait speed, stride and differences between the paralyzed step length and the unaffected leg. Changes were observed in some of the variables after using the new brace. After applying the braces to the trunk and pelvic band, some left hemiparetic CVA clients were able to stand straighter and walk faster and/or use the paralyzed leg with longer step length and faster movement. However, a few cases did not show such good responses.

DISCUSSION and CONCLUSION: We have "seen" the invisible man in bandages written about in some novels. We believe that the new braces will show good evidence of improvements during waking brought about by stimulating the paralyzed side of the trunk, pelvic band, thigh, lower leg, etc, and through increased sensory stimulation after applying the braces. It is hoped that these improvements will be maintained during standing and walking thereafter. Another explanation is that this kind of stimulation facilitates the unconscious awareness of poorly integrated brains.

At this time we are not able to decide whether electrophysiology or neuro-psychology is more effective. More research using pet-scan or other assessment tools are needed.

410 - Introduction to a Portable, Wireless Gait Evaluation and Biofeedback Tool

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Introduction: We developed a novel wireless, portable gait evaluation tool with biofeedback capability, including a multi-sensor foot position system. It is difficult to evaluate gait thoroughly among persons with movement disorders during a one-time visit in a gait analysis laboratory. The ability to recognize patterns of fluctuating mobility with the option of biofeedback in the home environment will improve evaluation and offer new treatment options.

Methods: We introduce a "smart shoe", portable gait evaluator (PGE) that simultaneously collects foot/ankle kinematics, time and pressure parameters. The PGE records information from bilateral insoles and other on-board sensors, which transmit the information wirelessly to a laptop computer. We collected simultaneous gait data from the PGE and a well-established Gait Laboratory on ten healthy persons and six persons with Parkinson's Disease. A small digital synthesizer connected to the laptop computer, allow data from the PGE's sensors to be organized into a biofeedback signal delivered to the patient as a sound. Currently, the device provides "smart" biofeedback in the form of music and auditory rhythmic cues, to an individualized targeted stride time based on heel strike.

Results: Data from both gait systems show similar step length, stride times, foot to floor clearance height and ankle dorsi / plantar flexion kinematic patterns, as well as foot ground reaction forces. Initial data from auditory rhythmic cue times with the timing of heel strike, demonstrate the merits of biofeedback for gait cadence on healthy persons.

Discussion and Conclusion: PGE measurements were accurate and precise, lending credence to its diagnostic and feedback potential. At approximately 300g the system is clearly ready for field trials outside the lab. The PGE introduces a system that will allow foot motion and gait to be measured in a variety of environments (stairs, ramps, etc.). The ultimate clinical goal for patients is to restore health and promote independent living in the home environment. The PGE may provide clinicians a new avenue to improve treatment plans and offer persons a novel treatment approach allowing self-correction of gait patterns in the home environment.

475 - A Wearable Functional Activity Monitor for Stroke Patients

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Introduction: The ability to monitor a patient's functional capacity, unobtrusively and automatically in their home, is a challenging task. Such a capability could be worthwhile for determining a patient's need for support services or long-term care. Quantitative objective measures of physical activity could also be useful to the research community to validate self-report functional instruments, which are the current standard in rehabilitation. Of the different activity monitors commercially available, all use mechanical sensors such as accelerometers (ACCs), and most are limited to non-specific motor activities. In the research literature, monitoring capability has not evolved much beyond distinguishing between different postures or various forms of ambulation. This limited capability led us to develop an electromyographic (EMG) -based monitor, which was capable of identifying a variety of specific functional activities in a healthy population [1]. The current study describes the results for a system that incorporates EMG and ACC sensors which was used to evaluate a broad range of functional activities in patients with hemiparesis from stroke.

MATERIALS AND Methods: The classification algorithms for the monitor combines feature extraction, a multilayer feed forward neural network, and an adaptive neuro-fuzzy inference network. We tested the algorithms on a set of 11 functional motor activities (FMAs) derived from the Functional Independence Measure scale [2] that included feeding, dressing, grooming, ambulating, and toilet activities. The classification ability of these algorithms was "challenged" using a set of 11 Non-Identification FMAs that are similar kinematically to the Identification FMAs, but different functionally. The initial set of experiments utilized EMG signals acquired from 8 upper and lower limb muscles in 14 stroke subjects (55±9 yrs). A second set of similar experiments was conducted in 10 stroke subjects (52±10 yrs) where 8 accelerometers (ACC) were placed in close proximity to the EMG sensors. All stroke subjects had moderately severe motor impairment (Brunstrom Grade III-V), and provided written informed consent. Various combinations of algorithms, neural network topologies, and iterations were compared.

RESULTS AND DISCUSSION : For the first set of experiments, a multilayer feed forward neural network comprised of 2 hidden layers with 44 and 22 neurons, respectively, was found to be the best configuration for classification of FMAs based on the EMG signals. Performance was substantially enhanced by the addition of an adaptive neuro-fuzzy inference system. When all eight EMG channels of data were used to define the FMAs, a sensitivity of 80% and a specificity of 98 % were obtainable, with a misclassification rate of 40%. Further analysis indicated that it is possible to achieve comparable classification results for a 4-EMG sensor configuration. These classification results were not as impressive as those reported for healthy control subjects using similar algorithms [1]. For the second set of experiments, however, the preliminary results using similar feature sets and algorithms indicate that classification rates in stroke subjects can be significantly improved by the use of data from both EMG and ACC sensors.

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478 - Automated Activity Profiling For Use in Continuous Dynamic Human Motion

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Introduction In many rehabilitation and ergonomic applications the activities performed by a subject are classified by e.g. direct observation or by observation via video. Several methods proposed in the past using accelerometers succeeded in recognizing postures but performed poorly in motion. A new automated method for assessing activity sequences is proposed, which recognizes dynamic and static activities equally well. This method for automated activity profiling (AAP) uses Hidden Markov Models (HMM) fed by inertial sensing data This paper shows a proof of concept and examines the possibilities of this technique in a sensitivity analysis around a test case in which the method is learned in supervised mode to recoginze 3 activities, being fed with a random sequence of the kinematic data of the activities plus a list of activity names. The AAP method gave also activity start and end times.

Methods 20 sets of 12 activities performed in random order were used in the test case in a Jack Knife style training and validation with varying training set sizes and compositions. In training the AAP method developed a HMM for each activity (Figure 1). In application the AAP method estimated 3 likelihoods, a start and an end time for each acivity; the largest likelihood determined the classification outcome. Input data were combinations of acceleration components and/or angular velocity of the trunk in the sagittal plane. A full sensitivity analysis was performed for all HMM model and training parameters and training set composition.

Results From the results of the sensitivity analysis critical and less critical model and training parameters were identified and optimal parameter value (ranges) were determined. In this test case a recognition accuracy of 98.6 ± 1.2 % was achieved with a 5-state HMM-set trained in 3 iterations with 6 files containing acceleration and angular velocity data.

Discussion The AAP method was developed from a desire to aid interpretation of detailed ambulatory biomechanical assessments of hours duration, where typically inertial sensing technology delivers in 3D: global body segment orientation, angular velocity and angular and linear acceleration. In this papers test case only a fraction of this information appeared to yield a very low error for 3 tasks. This suggests that the using all information available would enable classification of enough tasks to form a useful tool for ergonomics and rehabilitation. HMM technology rather deals with data changes than with data states like do all previously proposed methods of activity monitoring. This could explain why it appears to be more suitable for use in continuous dynamic activity. The method uses the kinematic data directly and does not require feature extraction first as is required for state detecting methods. This offers the method the opportunity to make its own optimal choices to use the information present in the signal. Feature extraction always discards part of the information. The fact that inertial sensing delivers body segment kinematics rather than sensor kinematics suggests the future possibility of generalizing over subjects without training each subject individually.

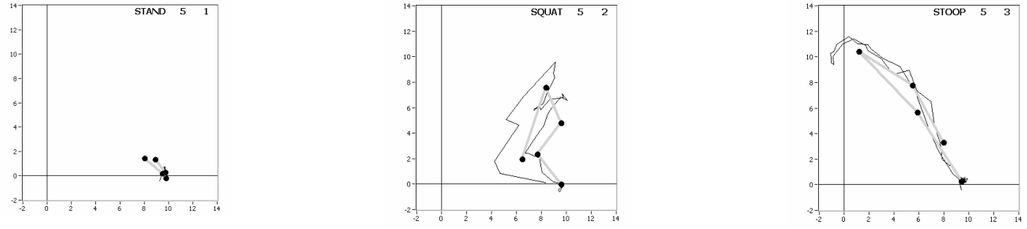

Figure 1: 5-state representations (dots) + signal (line) in 2 variables vertical and horizontal acceleration in sagittal plane of HMMs for 'stand', 'squat lift' and 'stoop lift'.

488 - Monitoring Motor Fluctuations in Parkinson's Disease: a Data Mining Approach

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The goal of this ongoing pilot study is to identify the characteristics and severity of motor fluctuations in patients with Parkinson's disease (PD) on the basis of data recorded from wearable sensors. New and improved methods of assessing longitudinal changes in patients with PD are needed to better optimize treatment and help patients function at their maximal capacity. The study is focused on testing the hypothesis that movement disorders accompanying late-stage PD will present with identifiable and predictable features of surface electromyographic (EMG) and accelerometer (ACC) signals recorded during the execution of standardized motor assessment tasks.

In the adopted protocol, we utilize EMG and ACC sensors to gather bioelectrical signals during standardized clinical tests including sitting, finger-to-nose, tapping, sit-to-stand, walking, stand-to-sit, and writing. EMG sensors are placed on the following muscles: right and left anterior deltoid, right and left flexor digitorum superficialis, right biceps brachii, right erector spinae, right vastus lateralis, and right tibialis anterior. ACCs are placed on the right and left upper arm, right and left forearm, right and left thigh, right shin, and sternum. The EMG and ACC sensors are connected to an ambulatory system (Vitaport 3, Temec BV, the Netherlands) equipped with data acquisition hardware and software to collect and store the bioelectrical signals. Subjects are asked to delay their first medication intake in the morning and are tested in a practically defined OFF state (the period of most severe parkinsonian symptoms). Subsequently, patients take their medications and are tested twice in the best ON state (the period of maximal therapeutic benefit from medication) and once during the "wearing off" period when dyskinesia is most apparent.

The first stage of analysis is to calculate features from short intervals of data extracted from each of the three motor states (ON, OFF, and Dyskinetic). The features represent signal characteristics during each interval such as energy, amplitude modulation, dominant frequency, and coactivation. The next level of analysis is to explore the features using data mining visualization techniques. Scatterplot matrices of values corresponding to features from different sensors are examined in search for distinct clusters corresponding to the motor states described above. Preliminary results suggest that clusters are especially apparent for right/left and proximal/distal pairs of features. This observation indicates that symmetry and patterns of coordination change during motor fluctuation cycles in a predictable manner. Current work is focused on using scatterplot matrix representations to select subsets of EMG and ACC features for further analysis using clustering techniques such as self-organizing maps. The objective is to identify subsets of data in the feature space and remap them in the time domain. Each cluster is expected to be associated with a different motor state.The proposed method has tremendous potential. Data mining techniques provide tools to successfully identify motor patterns of primary and secondary movement disorders in PD, such as tremor, rigidity, dyskinesia, akinesia, and dystonia in a manner that is both objective and automatic. In addition to successfully classifying these disorders for the purpose of assessment, data mining has the potential of increasing our understanding of these disorders. Surprisingly little information is available today in the research literature on the study and comparison of specific motor patterns from the full complement of movement disorders in advanced PD, and on factors that contribute to variability among patients and within the same patient over time.

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489 - Objective Field Assessment of Exercise Capacity in Chronic Obstructive Pulmonary Disease

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Accurate assessment of exercise capacity is important for individuals with chronic obstructive pulmonary disease (COPD) to aid in diagnosis of symptoms, enable assessment of the functional impact of disease progression over time, and identify responses to treatment interventions such as pulmonary rehabilitation or medication. Currently available measures are, however, constrained by their assessment of the patient at a single point in time in a controlled laboratory environment, a significant limitation due to the large daily variability in their clinical status that these patients experience. Our work seeks to address this issue through development of a wearable sensor system that continuously monitors exercise and mobility-related activities in the field, i.e. the home and community. Here we show that such activities can be reliably distinguished from one another based on data from accelerometer (ACC) sensors attached to the upper and lower limbs.

We studied 5 males and 3 females with severe obstructive lung disease, mean age 68 + 11 years. Single-axis ACCs were mounted bilaterally on the lateral aspect of the right and left forearm and thigh, oriented in the anterior-posterior direction. Subjects were outfitted with an ambulatory recorder worn about the waist to digitize and store sensor data continuously throughout the experiment. Each subject performed at least 3 minutes each of exercises comprising the aerobic portion of the pulmonary rehabilitation exercise program: walking on a treadmill, cycling on a stationary bike, and operating an arm ergometer. Identification of the exercises was based on the output of an artificial neural network (ANN) trained with examples of ACC data corresponding to each of the exercise conditions. ANN performance was evaluated by calculating sensitivity (percentage of correct classifications), specificity (percentage of errors where one exercise classified as another), and misclassification (percentage of errors where a non-exercise activity was classified as exercise). For a set misclassification acceptance level of 5%, sensitivity of the classifier was high, ranging from 93 to 98%, and specificity was exceptionally high in all cases, with a minimum specificity over all subjects and tasks of 97.5%.

In addition, 3 COPD patients followed an expanded protocol that included activities representing mobility in daily life in addition to the original aerobic exercise set, such as stair climbing, level walking, and various household chores. Due to the physical limitations of these individuals, it was not feasible to gather more than a minute of data for certain tasks, an insufficient sample size for ANN training and testing. Instead, the multidimensional feature sets representing movement characteristics captured by the ACC signals such as limb orientation, movement amplitude, movement frequency, and coordination were reduced to two dimensions via principal components analysis. Scatter plots of the projections revealed well-defined clusters for most activities, indicating that the ACC signals contain sufficient information to reliably discriminate among the various activities.

Future work will focus on gathering data from many more individuals to better understand the relationship between inter-subject variability and inter-task variability. Also, it will be essential to construct a more rigorous test of robustness to non-identification tasks by increasing the number and variety of these tasks to mimic real-life condition

Augmented & Virtual Reality

038 - Reaching In Reality and In Virtual Reality: A Comparison of Movement Kinematics

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Virtual reality (VR) is an innovative tool for sensorimotor rehabilitation. Despite growing interest in VR, there has been no study suggesting that movements made in VR are similar to those made with real objects. The purpose of this study was to compare the kinematics of an identical functional arm movement made by healthy subjects and adults with left hemispheric stroke in real and virtual conditions. In both tasks, seated subjects grasped a real or virtual ball of 7 cm diameter with their right hand, beginning from the edge of a table, reached forward by leaning the trunk and then placed the ball within a 2 cm x 2 cm yellow square on a real or virtual target (6 trials per condition). The VR environment was displayed in 2 dimensions (2D) on a computer screen placed 75 cm in front of subject's manubrium. A virtual representation of the hand was obtained using a 22 sensor fibre optic glove on which was applied a prehension force feedback device (CyberGlove, CyberGrasp, Immersion). An electromagnetic tracker (Fastrak, Polhemus) was used to orient the glove in the virtual environment. Kinematic data from the arm and trunk were recorded with 6 active markers at 120 Hz using Optotrak. We analysed temporal and spatial parameters of movement in each environment (movement time, relative time to peak wrist velocity, timing of maximal grip aperture, trajectory curvature or interjoint coordination between the elbow and shoulder, joint angles). In healthy subjects, movements made in VR were only different from those made with a real object in terms of the amount of wrist and elbow extension used at the end of the reach and timing of maximal grip aperture during the reach while no difference in performance was found in participants with hemiparesis. Differences may be explained by the use of a 2D instead of a 3D display for the virtual environment and the absence of haptic feedback from the VR target. Results suggest that VR is similar enough to reality to provide an effective training environment for rehabilitation.

053 - Innovative Virtual Reality Training for Hand Rehabilitation Post-Stroke

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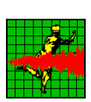
Introduction: Multiple studies have shown that repeated practice that entails new motor skill acquisition may be necessary to induce significant improvement in the manual function of individuals who have had a stroke. A critical variable needed to induce this plasticity is sensorimotor stimulation that is intensive, highly repetitive and rewarded. However, for millions of people with stroke-related disabilities, current therapy service delivery models cannot provide the time needed for intensive practice. Computerized robot-assisted therapy systems have been shown to be an effective augmentation to existing therapies suitable for training of the required intensity. Systems currently under development are focusing on the rehabilitation of elbow-shoulder and wrist function. Another equally important, but technically challenging aspect, is the recovery of hand function. Recovery of the manipulative abilities of the hand are important to improvement of the quality of life post-stroke. We have recently developed a unique fully computerized system for the rehabilitation of hand function.

Methods: In a pilot study we have recently demonstrated that technology-assisted intensive therapies that utilize virtual reality (VR) interfaces can improve hand function. Eight subjects (6 male, 2 female; age range 50-81) participated in this study. Seven of the subjects sustained a right hemisphere lesion and one had a left hemisphere lesion all occurring at least one year prior to the training. None of the subjects were receiving therapy at the time of the study. The computerized VR system uses two hand input devices, an 18-sensor CyberGlove (Immersion Co.) and a Rutgers Master II Haptic Glove (RMII). Each has advantages for certain types of exercise. The CyberGlove, was used for exercising range of motion, speed and fractionation of movement and the RMII force feedback glove was used for finger strengthening. The RMII glove is a light (less than 100g) compact haptic interface. The custom pneumatic actuators attached to the fingertips are pressurized to apply force to the user's fingertips and uses noncontact position sensors to measure the fingertip position in relation to the palm. Four hand exercise VR simulation programs have been developed using the commercially available WorldTool Kit graphics library. The exercises in the form of simple games are designed to exercise one parameter of hand movement; either range of motion, speed of movement, fractionation of individual finger motion or strengthening of the fingers. In each game the patients get visual, numerical and auditory feedback about their performance and about their target goal. All patients participated in an intensive program consisting of 13 days of training and two weekend breaks for a total of nearly 3 weeks of training. The subjects trained for 2 to 2 and one-half hours each day.

Results: We utilized both clinical tests (Jebsen Test of Hand Function) and kinematic analyses of five-finger prehension movements to evaluate the degree of transfer of the gains acquired by the subjects in the VR exercises to real life hand movements. Overall, 6 out of 8 subjects significantly increased their finger and thumb range of motion ($p<.05$, unpaired t-test, averaged across all fingers, the first two days versus the last two days of the therapy). Similarly, 4 subjects significantly improved in finger speed, 2 in thumb speed, 7 in fractionation and 3 in the strength exercise. Patients showed good retention when measured one-week post intervention.

Conclusion: Importantly, these improvements transferred to gains on clinical tests, as well as to significant reductions in task completion times for the prehension of real objects. These results are indicative of the feasibility of this exercise system for rehabilitation in patients with hand dysfunction resulting from neurological impairment.



054 - Impact of Visual Information on Posture is Influenced By Other Sensory Inputs

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Introduction: Previous studies have demonstrated that visual information assists in postural stabilization of the head and trunk. To examine the relative weighting of visual and physical information on the postural response, we have presented congruent (sled and scene at same amplitude), augmented (different amplitudes, same frequency), and incongruent (different amplitudes and frequencies) visual and physical motion during a postural task.

Methods: Seven healthy (22-37 yrs) adults stood on a platform (sled) that translated sinusoidally in the a-p direction at 12 cm/s for 165 sec within a virtual environment (VE) consisting of a room with texture and contrast. The VE could was moved in the fore-aft direction at 6 m/s. Frequencies of the sled and visual scene were 0.1 Hz or 0.25 Hz. Trials were randomly presented as platform motion only (congruent visual feedback), scene motion only (augmented visual feedback), and both platform and scene motion (augmented and incongruent visual feedback). Head movement was fed into the graphics program by an Ascension sensor so that the VE could accurately reflect motion of the head during congruent motion of the sled and scene. 3-D movements of anatomical landmarks were captured at 120 Hz by an Optotrak system. Triaxial forces and moments were recorded at 1000 Hz from an AMTI OR6-7 force platform. Fast fourier transforms (FFT) were performed on kinematic data from the head, trunk, and lower limb to derive power of the segmental responses with respect to the scene and the platform. Root-mean-square (RMS) of head, trunk, and shank segmental displacements was calculated. Principal component analysis (PCA) was performed on the relative displacement of head re trunk, trunk re shank, and shank re sled to reveal multi-segmental control strategies and relative weighting of sled and scene signals.

Results: Power at each segment was greater with combined inputs than to either alone when the sled was 0.25 Hz for both augmented and incongruent conditions. The head and trunk exhibited greater power at the frequency of the scene, the shank at the frequency of the sled. This effect was not seen at 0.1 Hz. Phase responses indicated an organizing effect of visual information on the segmental organization so that phase responses with respect to the visual scene were more consistent across segments when the scene moved. PCA revealed that the relative weighting of each input fluctuated across a trial and that the combined inputs did not demonstrate superposition. Responses to the various sensory conditions were subject specific. Some subjects exhibited behaviors suggestive of proprioceptive dominance while others exhibited behaviors indicating visual dominance. With single inputs, subjects consistently selected a single segmental strategy. With multiple inputs, most produced fluctuating segmental strategies. ANOVA and post-hoc comparisons ($p < 0.05$) performed on the RMS data demonstrated a significant increase in response magnitude, primarily in the trunk with combined inputs. The head tended to be held stable with respect to the trunk.

Discussion: These data suggest that when there is a confluence of meaningful inputs, none of the inputs are suppressed. Rather the postural response is modulated by all existing sensory signals. Both frequency and direction of the visual motion modified the postural response. A non-additive effect occurred in the energy of the response with combined inputs. Individual perception of the sensory structure suggests a significant component of postural responses in these protocols.

135 - Visual Search for a Target in a Virtual Environment: Effects on Stabilization of Posture in Young and Elderly

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Introduction: The presence of a stable focal image modifies the effect of motion of the peripheral visual field on the stabilization of standing posture (Strupp et al., 2003). We explored age-related differences in the impact of a focal image on posture when subjects searched for focal images within the moving visual environment.

Methods: Three young and 3 elderly adult subjects were exposed to a 3-D complex texture mapped visual scene during stance. For trials where a target was presented within the scene, subjects searched to locate the target and touched a button to indicate the target's orientation before the next one appeared. Sinusoidal, fore-aft translations of the scene and support surface occurred in- and out-of-phase (0.25 Hz), at different frequencies (0.1 Hz and 0.25 Hz), and while one input remained stationary relative to the other (0.25 Hz). Response latencies and root mean square (RMS) values were calculated, and FFTs were performed on the segmental center of mass (COM) of the head, trunk, and shank to derive response magnitude over time and power at each frequency.

Results: Button press latencies in elderly subjects were significantly longer than in young adults ($p < 0.006$). RMS values of head and trunk COM revealed an interactive effect of age, target presence, and perturbation type. When searching for the target during in-phase scene and surface motion, both young and elderly adults exhibited reduced RMS values; in the absence of the target, RMS values were reduced for young adults only. In both groups, translation of the sled and scene at the same frequency (0.25 Hz), increased power of head and trunk COM responses when the target was deployed regardless of the phase relationship. Translation of scene and surface at different frequencies produced an increase in power of the response only at the frequency of the scene translation (0.1 Hz) when searching for the target.

Discussion: These data suggest that the elderly depend more upon a focal image for stabilization of posture in the presence of peripheral visual field motion. A visual searching task appears to enhance the postural response to peripheral visual information in both age groups.

259 - Virtual Reality Delivery Modalities Affect Displacement and Velocity of the Center of Pressure during Voluntary Reaching in Young and Old Adults

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Background: Voluntary movements result in internal perturbations of balance and equilibrium. One variable regulated during movement is the position of the center of pressure (COP). Sensory information from the visual, vestibular and somatosensory systems is used in establishing relevant frames of reference for postural control. In this study, we were interested in determining whether aging resulted in differential regulation of the COP when different approaches to delivering virtual environments were used and when visual information incoherent with vestibular and somatosensory information was provided.

Methods: Healthy young (n = 18) and old (n = 18) adults completed five, one-minute trials of voluntary lateral reaches to the limits of their individual reach distances under three conditions: continuous lateral reach (CLR), flatscreen virtual reality (FS), and head-mounted display virtual reality (HMD). The presentation order of the reaching tasks was counterbalanced. For all reaching tasks, participants stood with their feet comfortably spaced on a force platform that recorded ground reaction forces. The foot traces from the lateral reach were taped on the force platform and used to maintain consistent foot positions between trials and conditions. Participants were allowed to bend their knees and hips, but were instructed to reach their arms out directly to the side at shoulder level, to return to a neutral standing position after each reach, and to keep both feet completely on the force platform at all times. The extent of voluntary leaning for maximal reaching was indexed by force plate measures of maximum anterior-posterior and lateral displacement and velocity of the COP. The CLR involved reaching left to center followed by right to center to a 0.67 Hz metronome beat while trying to touch the hands of research assistants positioned at increasing distances on either side of the force platform. The VR leaning exercises used a juggling scenario developed by IREX (www.irexonline.com) that required participants to reach laterally to contact as many virtual balls as possible. In the HMD condition, the virtual environment was projected through a pair of Sony Glasstron VR glasses that displayed the two-dimensional image.

Results: In both groups, lateral COP displacement and velocity decreased in the HMD relative to the FS condition. In contrast, maximum displacement and velocity of A/P COP increased as a function of reaching task with HMD realizing the greatest amount. There was significantly less displacement and velocity recorded in the old compared to the young adults but the differences were not condition-specific.

Conclusion: The lack of an exocentric frame of reference in HMD coherent with information from other sensory systems results in limiting COP movement within the base of support (BOS) in order to decrease the challenge to the postural control system but this difference does not appear to change with aging.

260 - A Virtual Reality Exercise Program Improves Balance and Mobility in Community-Living Adults with Traumatic Brain Injury

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Background and Purpose. There is limited data to support the effectiveness of exercises for balance problems even though exercise is understood to be a basic part of the management of balance problems after traumatic brain injury (TBI). The purpose of this study was to determine whether virtual reality (VR) is a better approach to exercise for balance retraining than an activity-based exercise program for TBI survivors with residual balance deficits.

Subjects. A convenience sample of 33 adults (age 18-66) who had sustained a moderate or severe TBI (initial Glasgow Coma Scale # 12) at least six months prior to the start of the study participated in the study. Individuals were excluded if they had vestibular deficits, benign postural vertigo, or orthopaedic problems limiting mobility.

Methods. Subjects were quasi-randomly assigned to an exercise group, activity-based exercise (ABE) or VR exercise (VRE), or to a Control (C) group. Groups were balanced as closely as possible based on initial Berg Balance Scale scores (BBS), age and years post-TBI. Exercise programs consisted of between 15 and 18 fifty-minute one-on-one exercise sessions three times per week. Both programs were designed to normalise stance symmetry, increase standing stability, increase ability to shift away from the midline and increase difficulty of the balance activities through changing task, foot placement and support surface conditions. The ABE program used conventional apparatus such as balls, wobble board, and obstacle courses. The VRE program included five applications delivered by a VR interface (IREX, www.irexonline.com). Participants viewed themselves in a virtual environment on a flatscreen monitor and were asked to interact with virtual objects appearing in the field. The placement, speed and number of objects viewed was preset by the exercise leader. Laboratory measures of quiet stance as well as clinical measures of functional mobility of all participants were measured at the beginning of the study, after 6 weeks and 3 months later.

Results. Following intervention, both VRE and ABE groups improved significantly relative to the C group on the Community Balance and Mobility scale (CB&M) scores (ABE: $p = .002$; VRE: $p = .014$). Although not statistically significant, the VRE group generally scored higher than the ABE group. In addition, clinically significant improvements of greater than five points between the baseline and post-intervention evaluations were recorded for four and ten subjects in the ABE and VRE groups, respectively. There were no statistically significant improvements in stability during quiet stance.

Discussion and Conclusion. Both exercise groups demonstrated improvement in functional balance after weeks of exercise, a trend that was still present after three months. The VRE group overall showed higher scores of functional balance and mobility. A comparison of mean changes revealed trends to support the VR delivery of exercise as a potentially valid method of receiving exercise that may be more beneficial than a traditional approach. The VR approach to balance exercise offers a new perspective on balance retraining.

279 - Postural Stability And Adjustments In An Immersive Virtual Environment

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Introduction: The maintenance of upright stance is a sensorimotor integration task that depends on the correct weighting of visual, proprioceptive, and vestibular information. The present study was undertaken to examine how upright stance was regulated under changing surface and visual conditions.

Methods: Four healthy subjects stood on a sled looking straight ahead at a visual scene displaying a virtual environment (VE) of a hallway with texture and contrast. After 30 s of quiet stance, a pseudorandom ternary sequence (PRTS) translated the sled in the anteroposterior (AP) direction for 60.5 s. The PRTS consisted of random velocities of -0.12, 0, and 0.12 m/s, with a ramp amplitude of 3 cm and duration of 0.25 s. The same PRTS sequence translated the VE in fore-aft (synchronous or opposite to sled motion), yaw, or roll. Each trial concluded with another 30 s of quiet stance without scene or sled motion. Trials of scene without sled motion were interspersed randomly with trials of both scene and sled motion. Two trials of stationary-PRTS-stationary sled motions alone with either the eyes open (EO) or closed (EC) were also included. 3-D movements of anatomical landmarks were captured at 100 Hz by an Optotrak system. Triaxial forces and moments were recorded at 1000 Hz from an AMTI OR6-7 force platform. Displacement and root-mean-square (RMS) of the head, trunk, thigh, and shank segments, as well as the center of pressure (CoP) in the AP and mediolateral (ML) directions were computed offline.

Results: Postural sway increased significantly but with minimal head movement during scene or sled motion alone or combined. In the AP direction, head stability was maintained across all subjects and conditions, including the EC condition, with a mean RMS of 1 mm or less. However, in the ML direction, head movements were significantly increased during EC and in all conditions with scene motion with or without sled motion. Head motion was much smaller than trunk or thigh motion. Head ML motions were larger with yaw scene motion than roll motion, and the support surface translations did not result in any significant differences. Sled motion alone induced a distal to proximal AP displacement pattern of shank, thigh and trunk segments, whereas scene motion alone induced a proximal to distal pattern. The AP RMS errors of the trunk, thigh, and shank segments were significantly larger when the sled was in motion, with the trunk and thigh moving more than the shank. Trunk and thigh AP RMS were maximal under the EC condition and when the scene was translating opposite to the sled. In the ML direction, RMS errors of the trunk, thigh, and shank were not significantly different across conditions, except when the scene moved in roll and sled translated with a PRTS during which the trunk ML RMS was significantly increased. CoP displacements in the AP or ML directions were not significantly correlated with scene or sled motion, indicating that more complex postural strategies other than simply loading or unloading the fore-rear or left-right foot are required for stability.

Discussion: These findings suggest that head stabilization in space is an important goal in the maintenance of balance when varying visual and proprioceptive conditions, as experienced in an immersive VE system. Postural coordination can propagate in a top-down or bottom-up manner, depending on how the stimuli are manipulated. Further analyses with systems identification will determine the inherent CNS mechanisms and strategies.

332 - Virtual Reality Applications for Assessment and Rehabilitation of Cognitive and Motor Processes

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Virtual Reality (VR) has now emerged as a promising tool in many domains of therapy and rehabilitation. Continuing advances in VR technology along with concomitant system cost reductions have supported the development of more usable, useful, and accessible VR systems that can uniquely target a wide range of physical, psychological, and cognitive rehabilitation concerns and research questions. What makes VR application development in the rehabilitation sciences so distinctively important is that it represents more than a simple linear extension of existing computer technology for human use. VR offers the potential to create systematic human testing, training and treatment environments that allow for the precise control of complex dynamic 3D stimulus presentations, within which sophisticated interaction, behavioral tracking and performance recording and analysis is possible. Much like an aircraft simulator serves to test and train piloting ability, virtual environments (VE) can be developed to present simulations that assess and rehabilitate human functional performance under a range of immersive stimulus conditions that are not easily deliverable and controllable in the real world. When combining these assets within the context of functionally relevant, ecologically valid VEs, a fundamental advancement emerges in how human functioning can be addressed in many rehabilitation disciplines. This presentation will focus on reviewing three VR applications that have been developed at the USC Integrated Media System Center. Data will be presented from VR testing and/or training of Attention and “hands-on” measures of Visuospatial Skills and discussion will follow on our development of a series of game-like interaction environments designed to address motor performance. These will include:

Visuospatial Processes - We have completed a series of research trials using a three-dimensional (3D) projection display VR system to deliver component-based scenarios that target hands-on assessment and training of spatial rotation, depth perception, 3D field dependency (virtual rod and frame test), static and dynamic manual target tracking in 3D space, and visual field-specific reaction time. This research has produced results demonstrating training improvements in both young and elderly subjects and one study on training produced enhanced performance levels in initial poor performers and in females relative to males as measured on a standard paper and pencil visuospatial test of mental rotation. A PC version of these applications has now been created (and is undergoing evaluation) that can deliver such 3D stereoscopic stimuli on a standard computer monitor.

Attention Processes – We have developed a HMD VR system that has demonstrated added value as a cognitive assessment tool for measuring attention performance in normal children and children with Attention Deficit Hyperactivity Disorder (ADHD) using a virtual classroom. The virtual environment consists of a virtual classroom scenario that allows for ecologically enhanced diagnostic assessment of attention and motor reactivity while in the presence of systematically delivered distractions. Other assessment tasks have been developed within this VR Classroom environment (i.e. Stroop, Boston Naming, etc.) and an attention process rehabilitation module is currently being developed.

Motor Performance – We have developed a series of immersive motor rehabilitation scenarios that can be delivered in both a stereoscopic Head Mounted Display (HMD) and off of PC-based projection displays. These applications are currently being tuned to foster motor interaction in a series of game-like scenarios to assess and rehabilitate eye-hand coordination, range of motion and other relevant motor activities. Significant effort is being put into the interface design that will allow a therapist the capacity to easily configure the stimulus presentation parameters according to the needs of the client to promote optimal motor action based on both therapeutic need and/or the specific research question. The capacity for a person to become engaged in a gaming task and become less focused on the fact that they are being tested may provide a more “pure” gauge of naturalistic ability. As well, a compelling clinical direction involves leveraging gaming features and incentives for the challenging task of enhancing motivation levels in clients participating in rehabilitation.

357 - A Virtual Environment with Simulated Gravity for Balance Rehabilitation of Bedridden Patients and Frail Individuals

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Rehabilitation of physical function and balance in frail individuals and bedridden patients is a challenge for the therapist. Early ambulation following hip fracture has been shown to be directly predictive of extended survival indicating the importance of effective interventions that improve physical function and balance and thereby minimize bed time. Such interventions should preferably involve whole body exercises that challenge coordination and motor function. We have built a 90 deg tilted room environment where a subject "stands" in a supine position while strapped to a frictionless device through a backpack frame and harness that allows free motion in the frontal plane, similar to upright standing. The device is attached to a weight stack through a series of pulleys, which provides a variable gravity-like force that the subject must balance against to remain "upright" in the tilted environment. The room contains common physical objects that are visually "polarized" (well defined "up" and "down", e.g. a chair) to convey to the subject the perception of being upright in a 1-g environment. Healthy subjects, who trained their balance in this supine position on 10 occasions over a two-week period, showed dramatic improvements in upright balance performance including a 50% increase in time to balance on a half cylinder on one leg and a 30% decrease in COP sway velocity while standing on one leg. We expect frail individuals and bedridden patients to be able to safely perform functional balance training in the tilted environment that would transfer to improved function and mobility in an upright position when negotiating gravity. We plan a portable version of this system that would incorporate recently available autostereoscopic 3-D displays, a technique that allows 3-D immersion without the use of glasses, to provide "windows" of a virtual environment around the subject instead of the currently used physical room. A 5-camera, digital image acquisition system, called the Pentacam is being developed to capture 3-D images that can be tailored to the preferences of different individuals. For example, images could be acquired from sites that are familiar to the subject including their own or a relative's indoor or outdoor home environment.

425 - Development of Complex Virtual Environments for Locomotor Training Following Stroke

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Introduction: Virtual reality (VR) provides a flexible and motivating means of immersing people in different environments for rehabilitation that might otherwise be impractical or unsafe. The goal of this research project is to determine the feasibility of developing and using a protocol combining projected virtual scenes with a moving walking surface for the purpose of training locomotor autonomy following a stroke.

Methods: The developed system uses a motorized treadmill (MT) mounted on a 6-degree of freedom, hydraulically driven, motion platform with the subject approximately 2 m in front of a large (2.44 m x 3.05 m) screen. The subject is instrumented for motion capture (Polhemus). The treadmill has been specially designed with a wooden frame to minimize both mass on the moving platform and magnetic distortion of the motion capture system. Virtual scenes were created using commercial software (Softimage) to simulate different natural environments. A street crossing training protocol is presented here. System control and integration of data related to motion capture, platform movement and image rendering (Performer) is administered through the "CAREN" software (Motek BV). The synchronization of treadmill and scene progression is provided by a PID algorithm using real-time position feedback of the subject about a calibrated point in space. The developed training protocol starts subjects at the lowest level with no physical adaptations (i.e., no surface changes or obstacles) and concentrates only on increasing their initial times to cross the street. The temporal criteria are set individually, allowing subjects to move to the next level only when they meet each criterion for at least three crossings. Once subjects reach an established maximum crossing speed, the physical complexity of the environment is increased, first, related to surface changes that are anticipated from the three-dimensional visual scene (using stereo glasses; Crystal Eyes) and experienced through platform movement, and then related to the addition of moving obstacles such as cars (starting with only a few, slow obstructions, but then increasing their number and speed). The same temporal criteria as described above are used to introduce new physical challenges. Subjects targeted are those having suffered a stroke with clinical walking speeds between 0.5 and 0.8 m/s and without perceptual deficits.

Results: Results show the technical feasibility of the virtual environment (VE). A realistic simulation of an actual street found in front of the local rehabilitation institute was successfully created, and subjects were able to fully control their own walking speed both on the treadmill and within the virtual scene. The developed system provided subjects with varying levels of interaction with the scene surface (through the moving platform) and the surrounding objects (including collision detection). In addition, preliminary results are showing the feasibility of using the VE system for locomotor training.

Discussion: VR with a surface interface provides a self-empowering, augmented experience for persons with stroke. The level of presence that subjects feel within this unique VE and the feasibility of the developed gait training protocol are presently being studied. It is expected that locomotor training with such increasingly complex VEs with both physical and visual experiences will allow persons with stroke to increase their locomotor capacity in increasingly demanding environments. (Supported by the CFI and CSN)

Electrode Arrays

030 - A Flexible Two-Dimensional Electrode Array for High Spatial Resolution EMG Measurements of Long (Minutes to Hours) Duration

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Introduction: For non-invasive investigations of single motor unit (MU) properties, EMG systems with a high spatial resolution are used. These systems combine electrode arrays with spatial filters. So far used two-dimensional (2-D) arrays are inflexible and often need to be manually supported. Thus, they are optimised for isometric contractions of short duration. Recently, the study of single MU properties under fatigue becomes increasingly important. For this new field of applications, electrode arrays are needed which can be attached to the subject's skin surface and which follow possible movements during dynamic tasks.

Methods: A minimisation of a 2-D electrode array in size and weight was achieved by a new hardware design. The adaptation of the array to the curvature of the muscle is implemented by its flexibility. The design of the array is based a flexible printed circuit board. To protect the conductor paths against mechanical influences while maintaining its flexibility, the board is imbedded in silicon rubber. 16 pin electrodes with an inter-electrode distance of 5, respectively 10 mm are arranged in 4 parallel rows. To optimise the electrode skin contact, and thus to improve the signal to noise ratio, different electrode shapes have been tested. As a criterion of the contact, the impedance was measured. The tested electrodes consist of steal with gold coating, their diameter ranges from 0.7 to 1.5 mm. Best results were obtained by electrodes with a structured surface.

Results: The new, flexible 2-D electrode array can be attached to the skin of a subject by common medical tape. In consequence, it can easily be placed and removed. The fixation of the array by tape results in a constant and homogenous pressure and thus ensures a stable contact between electrodes and skin.

Discussion/Conclusion: A new 2-D electrode array was designed, who's flexibility and small size allow it to be attached to the skin by conventional medical tape. The easy application procedure fulfils the requirements for long term measurements (minutes to hours) and opens future clinical use.

048 - The Effect of Electrode Configuration on EMG Based Estimation of Muscle Force Using a High-Density EMG Array

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Introduction: In EMG based estimation of muscle force various electrode configurations are applied. There is limited experimental evidence on how electrode configurations affect the EMG signal. High-Density EMG array collects spatiotemporal monopolar signals, thus allows constructing different bipolar electrode configuration over the muscle belly. The aim of this experimental study is to investigate the effect of different electrode configurations in EMG based force estimation. We studied electrode size, interelectrode distance, collection surface and surface density electrodes over the muscle belly.

Methods: Eleven healthy persons performed isometric right-arm extensions over different conditions. Surface EMG of the triceps brachii and force output were measured simultaneously. The EMG consisted of an active monopolar electrode array of 13x10 electrodes. To quantify force estimation quality we computed the root mean square difference (RMSD) between normalized EMG and normalized arm extension force.

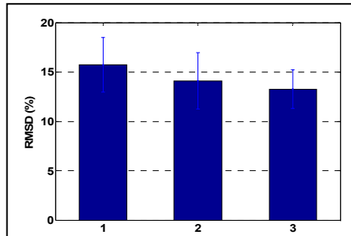

Figure 1: RMSD for three collection surfaces configurations over the muscle belly: small, middle and large (1, 2, 3 respectively) surfaces

Results: The collection surface (Fig. 1) had a significant effect on RMSD ($p<0.01$). Between the small (2.5cm2) and the large (20.5cm2) collection surface RMSD improved by about 16%.

Discussion: The collection surface appeared to be the solely important electrode configuration in EMG based force estimation. A minimal of about 8 pairs of bipolar electrodes, evenly distributed across the whole array, appeared to be necessary. This suggests that a combination of multiple conventional single bipolar electrodes, evenly distributed over the muscle belly, allows the same quality of force estimation as using the whole array.

139 - Preliminary Results on the Use of Equalization Filters for High Spatial Resolution Electrode Arrays

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Introduction: In recent years, surface electrode arrays that can monitor the activity of individual motor units have been investigated. These systems have an inter-electrode distance of 2–5 mm, an electrode diameter ≤ 2 mm, and are usually arranged in an equidistant rectangular grid. These arrays have been used to determine the locations of neuromuscular junctions, measure conduction velocity and non-invasively decompose the EMG signal. Most often, weighted combinations of monopolar electrode potentials are fixed in hardware to produce an EMG signal that is spatially selective. For example, the normal double differentiating (NDD) filter weights five electrodes, selected in the shape of a cross, with the weights +1, +1, –4, +1, +1 (the central electrode uses the –4 weight). We are developing a prototype system that will attempt to achieve both high CMRR and flexible electrode combination via the use of software channel equalization.

Methods: Only monopolar electrode data are acquired by the hardware. In addition, the electrical characteristics (gain and phase response vs. frequency) of each monopolar channel are carefully measured. Thereafter, any weighted combination of the monopolar channels of any set of electrodes can theoretically be derived with high CMRR performance via equalization filters that match the hardware imperfections between the physical channels. A substantial measurement improvement and hardware complexity reduction can be obtained. Thus far, the dominant challenge has been the inevitable presence of broadband background noise in the calibration signal used to measure the gain and phase response of each channel. Our calibration signal is a cosine chirp, sweeping in frequency from 0–2000 Hz. In our prototype hardware, the noise standard deviation is typically 0.5–0.8 uV (referred to the input) — similar to EMG hardware systems reported in the literature. Although this noise level is quite small overall, both real data analysis (from a prototype hardware system) and simulation find this noise level unacceptably high when calibrating equalization filters. In particular, CMRRs of 18–44 dB at 60 Hz (using a bipolar montage) are typical when equalization filters are calibrated directly from the measured data. As a consequence, our present focus is on signal processing methods for removing noise from the calibration recordings prior to determining the equalization filters. We are pursuing two de-noising methods — linear, time-variant (LTV), bandpass filtering and mixing. Both techniques recognize that the input excitation (the cosine chirp) is broadband when analyzed over the entire excitation period, but is localized in frequency at any particular time within the period. Thus, linear time-invariant (LTI) filters are not useful, but filters which modify their characteristics as the chirp frequency changes can be useful.

Discussion of Preliminary Results: A five-channel prototype monopolar array hardware system has been built to evaluate the equalization concept, with a signal generator used to form the input signals. To date, our existing efforts have improved the CMRR (comparing with vs. without equalization) by 30–40 dB. A discussion of our simulation and prototype work, and ongoing research efforts, will be provided.

177 - Spectral Analysis of Electromyographic Signal in Different Positions of Electrodes

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Introduction: The better surface electrode's position to pick electromyographic signals (EMG) up isn't established yet. According to De Luca (1993) preferential position is in the midline of the muscle belly between motor point and myotendonous junction and for Soderberg & Cook (1993) body points or specific measures. Therefore, the objective of this study was to evaluate EMG activity of different positions of electrodes on femoris rectus muscle belly.

Methods: The participants of this study were twenty female human subjects with 19-28 years of age (22,6 ± 2,6) without history of bone, joint and muscle disorders in inferior limbs. For the electrodes's position, the volunteer laid down with inferior limbs in neutral position, anterior region of thigh was shaved and skin cleaned with alcohol 70%. Thigh length was measured through tape measure from superior anterior iliac spine until joint interline of knee (laterals side). The found value was divided by a constant number (9,5) and then obtained a value (X). The motor point of rectus femoris muscle was reference to position of five surface electrodes. It starting in the motor point (electrode M), two electrodes were determinated in distal portion (D) and two in proximal portion (P), being value X to P1 and D1, and 2X to P2 and D2. The motor point was determinated with help of transcutaneous electrical stimulus with intensity in sensitive threshold. After to placed surface active electrodes (with two rectangular parallel pure silver bars (10x2 mm), with a fixed 10-mm distance between the inter-electrodes, 20 gain, 130 dB common mode rejection ratio (CMRR) and 10 GΩ input impedance by Lynx Electronics Ltd.) the volunteer was placed in a Bonet table with fixed trunk to avoid compensations, remaining hip in 90º and knee in 105º. The signal was collected simultaneously in five electrodes during maximal voluntary isometric contraction of five seconds repeated for three times. The EMG signals were recorded by a signal conditioner module, with a 100 gain, second order analog filter, 10,6-509Hz high-pass Butterworth and analog/digital motherboard with 12 bites of resolution of dynamic band and sampling frequency of 1KHz (I model CAD 12/36 of Lynx Electronics Ltd.). After collect, signals were processed in specific routines to amplitude and frequency analysis. The statistic analysis was done through exploratory analysis of data followed Wilcoxon test ($p<0,05$).

Results and Discussion: Individual analysis of signal showed that dynamic band was between 9 and 12 bits, being that median frequency was greater in motor point (80,3±0,03) and smaller in muscle extremities (P2=78,4±0,03 and D2=77,8±0,02). The RMS was smaller in motor point (47,8±0,02) and greater in distal portion (D2=76±0,03 and D1=58,1±0,02).

Conclusion: The results showed that EMG signal is dependent of electrodes position on muscle belly, presenting distinct behaviors to the different variables analyzed of spectrum.

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223- Innervation Zones of the Facial Muscles Estimated by Using Multichannel Surface EMG

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Introduction: The amplitude and frequency of surface myoelectric signals are affected by the electrode location with respect to the innervation zones. This study investigated and clarified the distribution of innervation zones in the extremity and the trunk. The distribution of innervation zones of facial muscles was not investigated because facial muscles are small and complex. These muscles are related to expressions such as smiling.

Methods: The distribution of innervation zones was investigated in 3 subjects for 5 facial muscles such as frontalis, procerus, orbicularis oculi, orbicularis oris, masseter by detecting bi-directional propagation of motor unit action potentials (MUAPs) with the multichannel surface electrode array. The electrode array comprised 6 contacts of silver wire, 1mm in diameter and 4 mm wide. The contacts were arranged in parallel lines at 3.5 mm intervals.

Results: The result was shown as a topographical map, which showed the location of innervation zones and the propagation of MUAPs (Fig.1). In the procerus and the orbicularis oris, the bi-directional propagation of MUAPs was detected and innervation zones could be determined. In the procerus, the innervation zones were distributed in the middle of muscle fiber. In the orbicularis oris, the innervation zones were found along the median line above the upper lip. It was hypothesised that in this case, the muscle fibers run parallel to each other. The conduction of MUAPs was partially confirmed in the frontalis and the masseter; the innervation zones within the entire muscle could not be clarified though some innervation zones were identified. In the orbicularis oculi, innervation zones were not observed. It was concluded that the reason innervation zones were not observed was due to the anatomical characteristics of the muscles: the skin is not parallel to the muscle fibers, the innervation zones are distributed over a wide area of the muscle.

Conclusion: The distribution of innervation zones and the propagation of MUAPs clarified in this study are useful for confirmation of optimum electrode position in the surface electromyogram measurement.

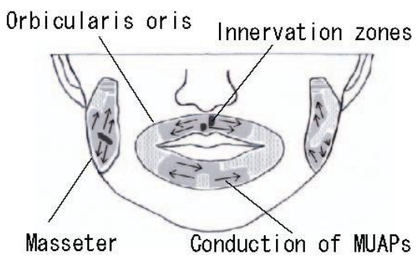

Fig.1. The location of innervation zones and the conduction of MUAPs found in the orbicularis oris and the masseter.

290 - Multifunction Myoelectric Control using a Linear Electrode Array

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Introduction: The use of surface myoelectric signals has evolved into an effective means of control for powered prostheses. To date, reliable control has been elusive with more than four classes of movements [1]. This paper introduces the use of a 16 channel electrode array for myoelectric control. The electrode array allows for a complete representation of the muscles around the circumference of a limb, increasing the information spatially. This 16 channel signal provides greater information, and allows improved accuracy in movement classification and an increase in the degrees of freedom that may be controlled.

Methods: Myoelectric signal data were acquired from four normally-limbed subjects. A six class problem involving hand and wrist control was considered using a 16 channel electrode array and amplifier (EMG16, PRIMA Biomedical & Sport, Mareno di Piave, Italy). The electrode array was placed around the circumference of the forearm, below the elbow at approximately a third of the distance between the elbow and the forearm. Subjects were asked to perform six classes of contractions: wrist flexion, wrist extension, forearm pronation, forearm supination, hand open, and hand close. A random sequence of the six classes was presented to the subjects in a training session. Each contraction was held for five seconds and sampled at 1000 Hz. Time domain feature sets were computed and principal components analysis was performed as described in [1]; these features were provided to a linear discriminant analysis (LDA) classifier.

Results: The accuracy of three trials for each subject was determined for a range of channels. As shown in Figure 1, the results display impressive accuracy, with an average of approximately 95% with only four channels. The influence of the spatial array was investigated by acquiring all 16 channels symmetrically and decimating these channels to realize 16, 8, 4, 2, and 1 channel arrangements. The effect of the number of channels was determined directly since the same contractions were used in each of the different arrangements.

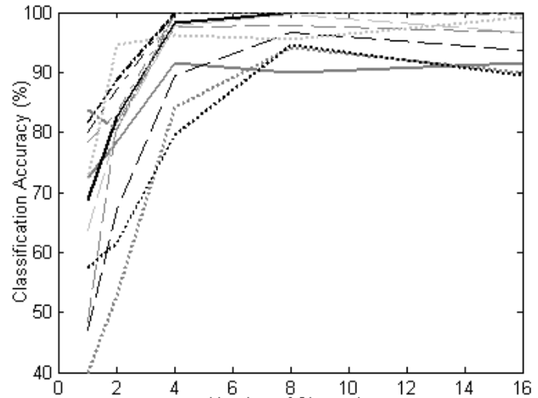

Figure 1: Classification Accuracies

Discussion: The results show a high degree of accuracy for a relatively large number of classes. This degree of accuracy has yet to be achieved with more than six classes of movements. The accuracy of the system using the 16 channel array is also very impressive given the high performance with 4 channels. These results suggest that more difficult control problems, such as increasing the degrees of freedom and eventually simultaneous control of combined motions, can be considered.

[1] K. Englehart, B. Hudgins, “A Robust, Real-Time Control Scheme for Multifunction Myoelectric Control”, IEEE Trans. Biomed. Eng. vol. 50, pp. 1-7, July 2003

337 - Do Array Electrodes Identify Cross Talk?

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Introduction: Clinical decision making based on EMG requires accurate assessment of muscle activity. Nowhere this is truer than in cases of stiff knee gait due to abnormal Rectus Femoris (RF) activity in Cerebral Palsy or Stroke. A recent study has shown that surface EMG of RF is contaminated with cross talk from other components of Quadriceps. Fine wire electrodes can selectively detect the RF activity but the insertion is painful. A method of EMG measurement using array electrodes has been shown to be able to differentiate the cross talk in electrically stimulated muscles. The objective of this study was to investigate if array electrodes could differentiate activity of RF from Vastus Latralis (VL) during voluntary movements.

Methods: Five healthy adults participated in the study. Subjects, comfortably seated, performed knee extensions (specific for VL) for five seconds with right and left legs, serially, at random with either no weights or with 1 kg and 2 kg weights tied around their ankle. EMG from VL and RF was measured with bipolar Ag/AgCl electrodes, with 10 mm diameter and 22 mm Inter-Electrode Distance (IED), on one leg and with adhesive16 channel linear array (IED10 mm) on the other leg. The position of the bipolar electrodes was as recommended by SENIAM. Both array electrodes were located over the respective muscle bellies at the same height. During data analysis four different spatial filters were applied to the array signals: Single and Double Differential (SD, DD) with 10 and 20 mm IED. RMS from the middle three seconds of each contraction was calculated with a 100 ms window. The Crosstalk Index (CI) was defined as the average RMS of RF divided by average RMS of VL. CI was calculated for each contraction from both the bipolar signals and the four sets of spatially filtered signals.

Results:

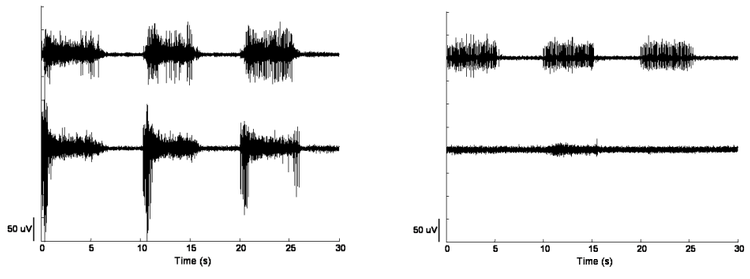

Fig. 1 EMG signals obtained from VL (top) and RF (bottom) contractions during three high Knee Extensions. Left: bipolar signals, right: array signals (spatial filter: SD10).

Bipolar	Array SD10	Array SD20	Array DD10	Array DD20
0.80	0.21	0.32	0.21	0.31

Table 1 The Crosstalk Index for different spatial filters during three KE-high contractions

Discussion: At least during static voluntary contractions the array electrodes appear to be able to eliminate cross talk from the RF EMG. The CI confirms this finding. The CI for bipolar electrodes appears to be much higher than that for array electrodes. The IED of 10 mm is most effective. There appears to be no difference between SD and DD analysis. It remains to be seen if this method of EMG measurement is also applicable in dynamic situations such as walking.

352 - Optical Flow Applied to Multichannel Surface Myoelectrical Signals.

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Introduction: The development of multichannel surface electromyography (MC-SEMG) towards more channels and higher spatial resolution gives the possibility to study the MC-SEMG as images of the potential distribution on the skin. One method to estimate the motion in consecutive images i.e., movement of action potentials, is to calculate the optical flow. The optical flow can be thought of as a vector field describing how the image changes with time.

Methods: An MC-SEMG system (AvtiveOne, Biosemi, Netherlands) with electrodes placed in a 13x10 matrix was used to obtain the multichannel surface myoelectrical signals. The algorithm proposed by Horn and Schunck [1] was used for the optical flow calculations.

Results: The vector field obtained with optical flow gives both visual and automatic estimates of muscle fibre orientation (MFO) and innervation zone (IZ) localisation.

Discussion: Due to its relatively low computational complexity and the visually appealing representation of the myoelectrical activity, the proposed method can be of great aid in the data collection procedure. The optical flow technique can provide guidance on how the electrode device is located with respect to the MFO and the IZ. When used offline, the automatic IZ localisation obtained using the optical flow algorithm is an attractive property. Other possible areas of application are found in the field of physiological studies.

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[1] Horn, B., Schunck, B. Determining optical flow. Artificial Intelligence. 185-203, 1981.

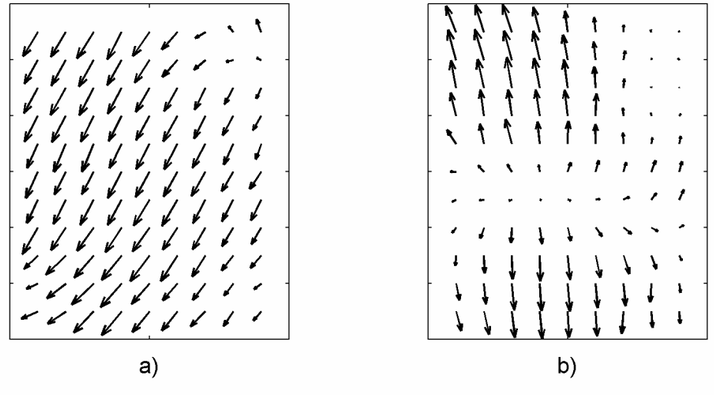

Figure 1. Optical flow obtained from half a second of MC-EMG recordings. In a) the electrode device was placed on the biceps brachii, not parallel to the muscle fiber direction. In b) the electrode device was placed on the trapezius muscle and here the location of the electrode device is over the IZ, which is clearly shown.

477 - Surface Electrode-Array Electromyogram Decomposition Algorithm Based on Independent Component Analysis (Ica) and Template Matching

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Introduction: The purpose of the present study was to develop an algorithm for non-invasive electromyogram (EMG) signal analysis. With this aim, we developed an algorithm that decomposes surface-EMG (s-EMG) into its constitutive motor-unit action potentials trains (MUAPTs).

Methods: The algorithm consists of three major steps; signal pre-processing filtering, application of an Independent Component Analysis (ICA) algorithm [1], and template-matching analysis.

Eight-channel electrode array s-EMG signals were recorded from the biceps short head muscle belly, out of the innervation zone, of eight healthy subjects while performing isometric constant contractions at different force levels ranking from 5 or 10% of their respective maximum voluntary contraction (MVC) up to 30, 50, or 60% MVC.

We selected the recordings of six subjects and analysed them using the algorithm described above.

Results: Single MUAPTs were successfully identified by our algorithm up to 30, 50 and even 60% MVC. An example of the obtained results is shown in Figure 1. In two of the six subjects, it was possible to decompose two MUAPTs.

References:

[1] Comon, “Independent Component Analysis, A New Concept?”, Signal Processing, vol. 36, pp. 287-314, 1994.

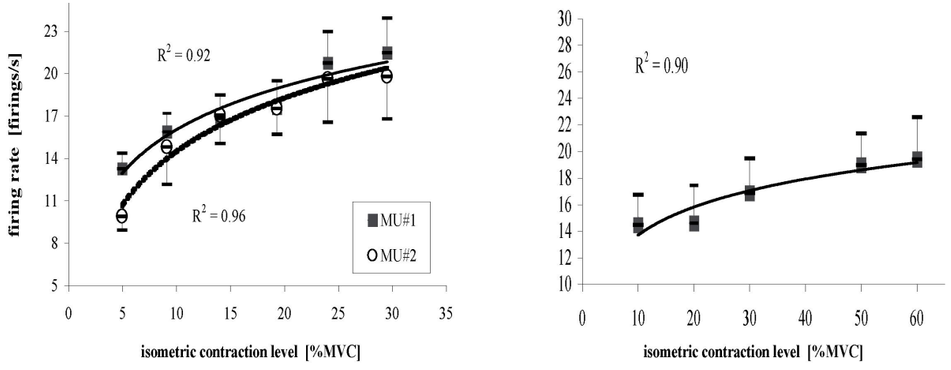

Figure 1: Median firing rate at different levels of isometric contraction for two healthy subjects. Vertical thin lines indicate the s.d. associated to each point (mean s.d.: 2.5)

EMG Modelling & Signal Processing

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020 - Modelling Of Skeletal Motor Unit Innervation Process

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Introduction: The nature of synchronization or the Correlation of Motor Unit Innervation Processes (CoMUIP) has been a topic of interest in the literature. There are contradictory results and confusion about CoMUIP and Motor Unit Common Drive (MUCD) in the literature. A thorough study of the topic will help to explain the contradictions, resolve the confusion and provide important insights about motor control schemes.

Methods: MUIPs were simulated by a network of three Hodgin-Huxley (HH) neurons. Simulation data werer also acquired. Surface EMG signals were recorded by a surface electrode array from healthy human subjects at low to medium contraction levels. The signal was then decomposed to obtain single MUAP trains from which MUIP information can be extracted. CoMUIP was estimated by a Normalized Covariance Function (NCF) and MUCD is estimated by the Common Drive Coefficient (CDC). The estimation errors of the above methods are discussed.

Results: The simulation results suggest that CoMUIP is caused by common synaptic input to two MUs, while MUCD is caused by common modulation of their synaptic inputs. Therefore, the CoMUIP observed in abnormal conditions such as tremor and fatigue may be the results of changes in the synaptic connections of MUs. No significant CoMUIP is found in the experimental results, while significant MUCD is observed. Also, the experimental results show that the observed level of CoMUIP has a negilible effect upon most common quantities extracted from the EMG, such as RMS amplitude and spectral feature.

Discussion: The NCF is proposed to be a new estimator for the CoMUIP. It is proven to be a better estimator than the currently used technique, the Cross-Correlation Histogram, especially for engineering applications and it is also computational efficient. A physiologically realistic simulation model for the MUIP is proposed. It can be used to explore the physiologically origins of CoMUIP and MUCD.

025 - Influence of Fiber Shortening On Estimates of Motor Unit Conduction Velocity and Spectral Frequencies

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Introduction: The study of surface electromyographic (EMG) signals under dynamic contractions is becoming increasingly important. However, the knowledge about the methodological issues that may affect such analysis is still limited. The aim of this study was to analyse the effect of fibre shortening and of a shift between electrodes and muscles on estimates of conduction velocity (CV) and mean power spectral frequency (MNF) from surface EMG signals recorded with electrode arrays.

Methods: Single fibre action potentials were simulated as detected by commonly used spatial filters for different fibre lengths. No physiological modifications were included with changes in fibre length, thus only geometrical artefacts related to fibre shortening, were investigated. CV and MNF were computed from the simulated single fibre action potentials. CV was computed from the time delay of signals from neighbouring detection sites, aligned in fibre direction by the maximum likelihood estimation method applied to signal pairs.

Results: The main findings were 1) CV and MNF are almost equally affected by changes in fiber length, 2) electrode locations close to the innervation zone minimize the sensitivity to fiber shortening but show large sensitivity to muscle shifts relative to electrodes, and 3) sensitivity to fiber shortening depends on the spatial filter for signal detection. An increase of the distance between electrodes and fibres increases the bias of CV and MNF estimates and enhances the variation due to fiber shortening. In case of short fibers, a bias of CV estimates cannot be avoided, irrespective of the electrode location.

Discussion: Since no physiological modifications with fiber shortening were included in the simulations, the relative changes in surface EMG variables reflected methodological effects. These effects are caused by non-travelling components that arise during the generation and extinction of the intracellular action potentials. They may be not recognizable in experimental conditions and misinterpreted as physiologically relevant phenomena.

032 - Modification of Dimitrov's Convolutional Model to Introduce Variation in the SFAP Peak-Ratio

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Introduction: In single fibre action potencials (SFAPs) the ratio between the amplitude of the positive and negative peaks (peak-ratio) varies between 0.6 and 2.2 with regard to experimental observations. Dimitrov's SFAP convolutional model generates SFAPs whose peak ratios vary only slightly around a fixed value of 1.2.

Methods: In certain neuromuscular anomalies a single fibre fires an action potential repeatedly in isolation from the rest of the fibres in its motor unit (MU). These potentials (called fibrillation potentials) can be taken as genuine SFAPs from which analytical models can be contrasted. For our studies we have gathered a bank of 1000 fibrillation potentials from two different muscles, namely the extensor digitorum communis (EDC) and abductor digiti minimi (ADM). For the EDC we have measured peak-ratios ranging from 0.64 to 1.88 (mean = 1.17, std = 0.33) and for the ADM muscle the peak-ratios range from 0.67 to 2.25 (mean = 1.31, std = 0.62). Although the mean values of the peak-ratios of the fibrillation potentials are close to that of Dimitrov's model, their variances are considerably larger. Therefore, some change should be introduced in this model so that SFAPs with such peak-ratios can be generated.

For this purpose, we have modified the IAP (Intracelular Action Potential) model [1] proposed by Dimitrov. (Recall that the IAP plays the role of the excitation signal in this model). The time course of Dimitrov's IAP is divided into three portions. The first portion (the most critical for the SFAP behaviour) is called the rising and is defined by three parameters (A1, A2, A3). We have split the rising in two parts and added an extra parameter (A2b) so that control over the SFAP peak-ratio is obtained.

Results: The peak-ratios obtained for different combinations of A2 and A2b are shown in the following table.

A2	5	5	5	5	5	5	5
A2b	4	4.33	4.66	5	5.33	5.66	6
Peak-ratio	1.50	1.37	1.25	1.18	1.05	0.95	0.80

Introduction of the new parameter A2b will allow the new model to generate SFAPs with peak-ratios ranging from 0.8 to 1.5.

Conclusion: With the inclusion of the new parameter A2b, controlled variation of the peak-ratio is achieved and, therefore, a more realistic SFAP model can be developed. The next step is to apply this result to the simulations of motor unit action potentials (MUAPs). Consequently, the MUAP generated with this new model will be more realistic as well.

References: [1] George V. Dimitrov, Nonna A. Dimitrova. "Precise and fast calculation of the motor unit potentials detected by a point and rectangular plate electrode", Medical Engineering & Physics,1998, pp. 374-381.

041 - Experimental Validation of a Surface EMG Model

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Introduction: An earlier SEMG model (2) has been revised to include muscle-tendon end-effects. Motor unit action potential (MUAP) shape due to electrode location along (x-direction) and above (y-direction) the muscle fibers was also included. The MUAP was expressed as the convolution of two time-dependent functions. The input signal was the second derivative of the intracellular action potential. The second function was the system impulse response (1).

Methods: Thirteen subjects performed 5 maximal static contractions for the elbow flexors. The contractions were 5 seconds in duration at 3-minute rest intervals. Force was measured with the JR3 load cell (JR3 Inc., Woodland, CA). Biceps SEMG was monitored with DE-2.1 (Delsys Inc., Boston, MA) electrodes. The SEMG signals were amplified (1000×) and band-passed filtered (20-450 Hz) using the BAGNOLI-4 (Delsys Inc.) bioamplifier, before A/D conversion at 2 kHz (CODAS, DATAQ Instruments Inc., Akron, OH) on a Pentium III IBM-PC. Mean frequency (MF) was calculated on a 512 msec stationary portion of the signal in MATLAB (The Math Works, Natick, MA). **Results:** The MF for the sample ranged from 72 to 104 with a mean of 90 ± 11 Hz. These values were slightly higher (5 Hz) than those reported by Potvin (3). The resulting synthetic SEMG signals had MFs within the range of the experimental data, and the power spectra closely matched.

Conclusions: A volume conduction model of SEMG activity with physiological parameters for the biceps brachii can produce realistic power spectra. Supported by NSERC.

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047 - Improving EMG Based Muscle Force Estimation Using Principle Component Analysis on a High-Density EMG Array

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Introduction: The reliability of EMG amplitude measurements when predicting muscle activation is an important issue in EMG based force estimation. Theoretically, two important factors influence the EMG signal. First, the location of the electrode arrangement in relation to the muscle fibre architecture. Second, the amount of detected motor units (MUs), contributing to both the EMG and the muscle force. High-Density EMG array allow the collection of monopolar signal to which also deep MUs are contributing. Principle component analysis (PCA) is a method to detect redundant information in overestimated multidimensional datasets. The aim of this experimental study is to analyze whether PCA techniques improves EMG based force estimation.

Methods: Eleven healthy persons performed isometric right-arm extensions over different conditions. Surface EMG of the triceps brachii and force output were measured simultaneously. The EMG consisted of an active monopolar electrode array of 13x10 electrodes. To quantify force estimation quality we computed the root mean square difference (RMSD) between normalized EMG and normalized arm extension force.

Results: Three different electrode configurations (Fig. 1) showed a significant effect on RMSD ($p<0.01$). Bipolar across the whole array improved RMSD of about 30% compared to conventional single bipolar electrodes. Further, PCA improved RMSD by 10%.

Discussion: PCA techniques improved the force estimation quality by 40% compared to conventional bipolar electrodes. In contrast to bipolar electrodes, PCA allows for EMG amplitude estimation irrespective of the architecture of the muscle fibres and muscle orientation.

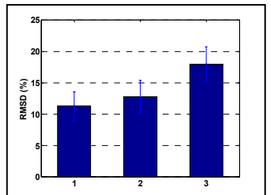

Figure 1: RMSD for three configurations: 1) PCA, 2) longitudinal bipolar over the whole array and 3) conventional bipolar electrodes

067 - A New EMG Signal Decomposition Approach Using Factor Graphs

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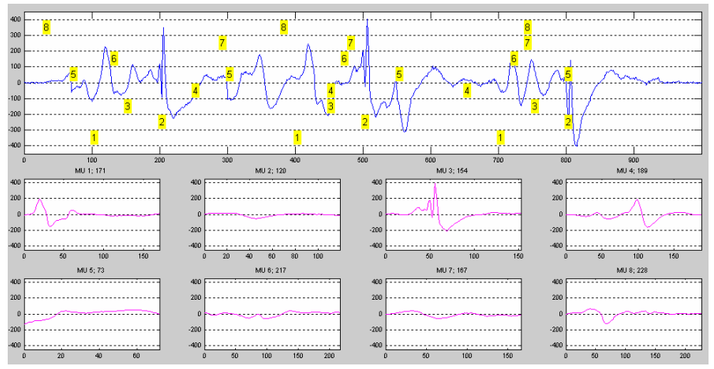
Introduction: Many electromyographic (EMG) signal decomposition methods have been proposed [1]. We developed a new EMG signal decomposition algorithm, which is based on a graphical model (factor graph [2]). In particular, it allows the fast and reliable decomposition of superpositions consisting of many overlapping motor unit action potentials (MUAPs).

Methods: Motor unit firing times are estimated by application of a message-passing algorithm (sum-product algorithm [2]), which operates by passing messages along the edges of the graph. We tried several designs, e.g., various graph topologies, different message types and quantizations, various update schedules, different node functions, and a few noise models.

Results: Our algorithm is capable of decomposing many overlapping MUAPs in a relatively short time. Fig. 1 shows an example: given the one-channel artificial EMG signal and all 8 MUAPs, the algorithm can flawlessly (no missed or false detections, no false classifications) find all firing times within 46 seconds (Java program on a standard PC). We also decomposed an artificial multi-channel signal with 30 concurrently active motor units (not all overlapping at the same time) with good results. Our algorithm can easily be extended to deal with multiple channels. The complexity of the computation is roughly linear in the length of the EMG signal, the number of motor units, the length of the MUAPs, and the number of channels.

Conclusions: The preliminary results are very encouraging: the new algorithm works good and fast, even for many overlapping action potentials. It might already be used as a plug-in for existing algorithms to resolve heavy superpositions that these algorithms can not resolve. We also hope to be able to extract valuable information from multi-channel surface electrode arrays in the near future.



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[2] F. A. Kschischang, B. J. Frey, and H.-A. Loeliger, “Factor graphs and the sum-product algorithm,” IEEE Trans. on Information Theory, vol. 47, pp. 498–519, February 2001.

Fig.1: Simulated EMG signal (top) with numbers indicating the starting points of the individual MUAPs (bottom)

080 - The Influence of Extremity Positions on the Relationship Between Activities of the Rectus Femoris and Vastus Medialis and Torque In Extension of the Knee -A Study of a Method for Approximation of the Relationship Between Surface EMG And Torque to Power Equation

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Introduction: We have investigated a method of evaluating muscle activities by utilizing regression curve of the relationship between articular torque and muscle activities. In the present study with the attention focused on extension of the knee, the relationship between electromyographic (EMG) findings obtained from the Rectus Femoris and the Vastus Medialis and extension torque was approximated to power equation, and the possibility of the relationship being influenced by changes in position of the hip joint was analyzed. The present study was designed to confirm reliability of the coefficient obtained from the approximate power equation and to investigate the possibility of difference in muscle activities due to the change in position being confirmed as change in coefficient.

Methods: The subjects were 10 healthy. Surface electrodes were applied to the following sites: The RF (i.e., the center of a straight line connecting the iliaca anterior inferior with the upper margin of the patella) and the VM (i.e., the position of the movement of the length, which was obtained by dividing the circumference of the thigh in 20 equal parts, medial to the thigh superior to the patella 1/4 of a straight line connecting the iliaca anterior inferior with the upper margin of the patella). The electrodes were discs, each of which was 10 mm in diameter, manufactured with Ag/AgCl. The inter-electrode length was 15 mm, and the data were recorded according to Double Differential. As EMG data, root mean square (RMS) was calculated in 100 msec unit. The data on torque were measured with Biodex. Extremity positions on the measurements were a 90°flexed position of the knee joint with the hip joint in the 90° flexed position and that with the hip joint in the 0° flexed position. Visual feedback was utilized with isometric contraction for the measurement, which was changed by stages from 20%, i.e., the maximum voluntary contraction (MVC), to 80%. The procedure for the analysis was as follows: 1) Data were recorded twice on different days in each of the 10 subjects; 2) the relationship between the recorded torque and RMS was approximated to power equation (y = ax ^b) at each electrode; 3) the reliability of coefficient “b” indicating a curve element in the equation was investigated at intraclass correlation coefficient [ICC (1, 1)]; 4) the influence of individual difference, muscle, and extremity positions on coefficient “b” were assessed by analysis of variance (ANOVA).

Results: As a result of the analysis, ICC values for the RF were 0.85 and 0.72 in flexed and extended positions, respectively, of the hip joint. The VM were 0.88 and 0.81. All values showed high reliability of coefficient “b”. As a result of the analysis of influence of coefficient “b” on muscles and extremity positions, the mean coefficient value for the RF was 0.95 [SD 0.29] in a flexed position and 1.06 (SD 0.39) in an extended position of the hip joint. The corresponding value for the VM was 0.98 (SD 0.36) and 0.98 (SD 0.37). As a result of ANOVA, there was a statistically significant difference in coefficient “b” for the RF between the positions of the hip joint, while there was no statistically significant difference for the VM.

Conclusions: The results of the present study showed that coefficient “b”, which was obtained by approximation of the relationship between torque and data on surface electromyography to power equation, has reliability that is bearable to the analysis as measurement value. Based on this, the relationship between changes in extremity position and the coefficient was analyzed, and the difference in muscle and changes in extremity position were indicated to be reflected by the coefficient. The present results are assumed to have succeeded in clarifying characteristics of the RF, i.e., a diarticular muscle, in comparison with the VM. This suggests the possibility of coefficient “b” acting as an indicator of the evaluation of muscle activity.

101 - On Single Trial Detection of M1 & M2 Stretch Reflex (Sr) Activity

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Introduction: To assess the integrity and functionality of the spinal neural paths is important in clinic. Using the SR is a possible tool to this purpose. The problem in SR analysis is the very small amplitude change in the surface EMG, which is often hidden by background noise.

Methods: Full extension of the Flexor Dorsalis Interosseus (FDI) muscle was applied within 20 ms via a torque motor (200 trials in each subject) and SEMG was recorded. The detection of the changes within the SEMG proceeds on detail signals computed after signal decomposition on scale levels using the wavelet transform to perform the Dynamic Cumulative Sum (DCS) algorithm [1,2].

Results: Typical SR response is shown (Fig. 1 EMG – black, Wavelet details – blue, Decision Curve (DC) – red, DC peaks – red circles, the stretch - violet). M1 and M2 activity can be seen between 40-60 ms and 60-80 ms from the onset of the stretch, respectively.

Conclusion: The changes are located in time. The method makes possible the detection of M1 in individual trials. Additional criteria are needed in order to group the change candidates according to the individual components in order to achieve the estimation of M2 onset.

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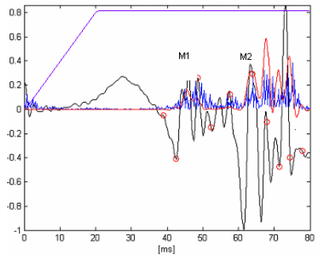

Figure 1. Typical SR response.

103 - A GMM-Based Classification Scheme for Myoelectric Control of Powered Upper Limb Prostheses

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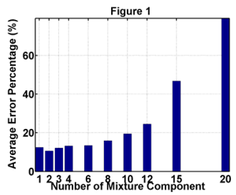
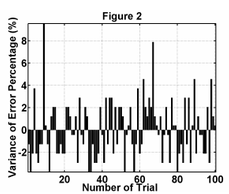
Introduction: Gaussian Mixture Models (GMMs) have become the dominant approach in speaker recognition over the past several years. In this paper, GMMs are applied to develop a continuous classification scheme for myoelectric signals (MES). This work uses pattern recognition to process multiple-channels of MES, with the task of discriminating multiple classes of limb motion. This scheme is expected to demonstrate superior classification rate, less computational complexity and system robustness.

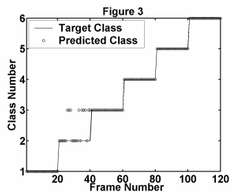
Methods: Data were collected from four forearm MES control sites. Each subject performed six limb motions: wrist flexion, wrist extension, supination, pronation, hand open and hand close. Subjects performed each motion in a predetermined sequence in the training session, and in random order in the test session. Classification was performed using six GMMs (λ1- λ6), using four simple time-domain features. The expectation-maximization algorithm was used to estimate the parameters for each GMM and each test pattern was provided to six GMMs. The class (i) associated with the GMM (λi) that has the highest Gaussian mixture likelihood function was chosen for a given MES feature set.

Results: For a single subject, Figure 1 depicts the % error averaged over 100 trials; Figure 2 depicts the variance of the error over these 100 trials; Figure 3 depicts the target and predicted classes for the test set.

Discussion: These results indicate that mixture number selection is crucial for achieving high classification performance. For this subject the classifier only has problems distinguishing class 2 from class 3.







133 - Muscle Fiber Conduction Velocity Distribution Estimation From Elicited Motor Responses

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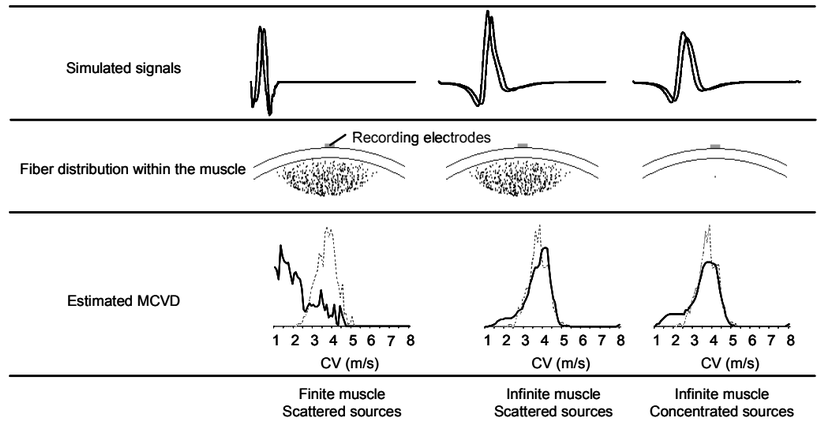
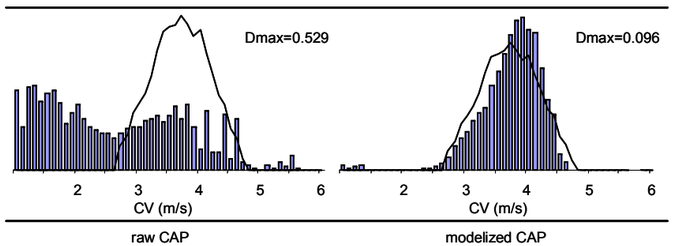
Computing muscle conduction velocity distributions (MCVD) can be of highest interest since modifications in the action potential propagation characteristics do not generally affect uniformly the fibers of a muscle. Since the 1970's, several methods have been proposed for nerve conduction velocity distribution estimation. The aim of the present study was to derive a method applicable for MCVD estimation from the original work of Cummins et al. (Electroenceph Clin Neurophysiol, 46:647-658, 1979). A simulation model was used to assess the performance of the method on elicited motor responses with various controlled features. Several fiber diameter (hence conduction velocity) distributions were generated with various variances and shapes. The estimation quality was assessed by means of the Kolmogorov-Smirnov Dmax statistics. When measuring action potentials from the skin surface, nerves can be considered as infinite line sources; muscles do not. Simulation clearly underlines the negative effect of muscle structure on MCVD estimation from elicited motor responses, mainly due to the boundary effects of the action potential generation and extinction areas, as presented on the following figure.



Several procedures were used to minimize these effects. The results showed that a robust estimation can be produced by modeling the compound action potential extremities (see figure below).



Therefore, MCVD estimates produced from elicited responses are very close to the real distributions when taking into account muscle action potential specificities.

137 - Time-Frequency Analysis of Surface Electromyographic Signals Via Hilbert Spectrum

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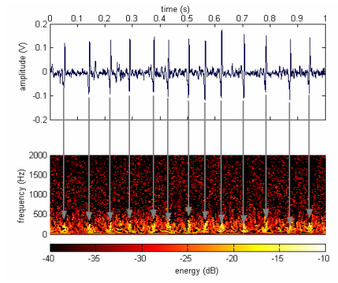
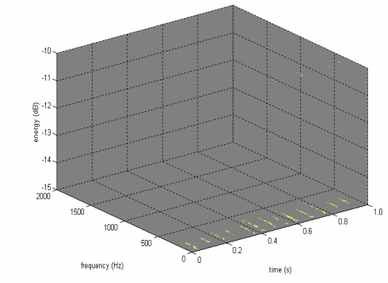
Introduction: This work aims at applying the Hilbert Spectrum (HS) to the investigation of surface electromyographic signals. The results show that this method yields a high-resolution time-frequency-energy plot capable of highlighting the activity of individual motor unit action potentials, a phenomenon often obscured by analyses based on the Fourier Transform (FT) because of their lack of frequency resolution. Furthermore, we introduce a new way of visualising the HS that allows a very precise estimation of firing time of motor units in the frequency domain, indicating therefore that this technique may be successfully applied to the decomposition of EMG signals.

Methods: A pair of surface electrodes, made of silver/silver chloride, composed by parallel bars with inter-electrode distance of 1 cm and 1 cm long, was placed on the posterior deltoid, along the direction of the muscle fibres, of a subject and signals were collected at 4000 Hz during very weak and isometric contractions. The signal was amplified 1000 times and filtered using a pass-band filter with cut-off frequencies set between 10 Hz and 2 kHz. The HS was found for the signal and a contour plot of energy levels in 1 dB bands was obtained.

Results: Fig. 1(a) presents the detected surface EMG signal and its respective HS. The included arrows are added in order to ease the identification of both motor unit action potentials and high-energy activity on the HS. Fig. 1(b) is the contour plot of only the highest energy activities, i.e. energy level above –15 dB, described on the HS.





(a) (b)

Fig 1. (a) Detected EMG signal (top) and its Hilbert Spectrum (bottom). (b) Contour plot of the highest level of energy estimated by the Hilbert spectrum.

Discussion: The results presented in Fig. 1(a) show clearly that the timing of energy peaks is related to the presence of motor unit action potentials, i.e. the HS is capable of detecting the firing of individual motor units. This phenomenon has often been obscured in time-frequency-energy distributions obtained via methods based on the FT because of their inherent lack of resolution. In order to explain better the energy described by the HS we introduce a topographic visualisation of its different levels of energy. Fig. 1(b) shows the contour plot of the highest level of energy and this plot allows us to accurately locate motor unit action potentials at their time of occurrence. These results suggest that the HS may be used as a potential tool for decomposition of electromyographic signals.

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N. E. Huang, Z. Shen, S. R. Long, M. C. Wu, H. H. Shih, Q. Zheng, N.-C. Yen, C. C. Tung, and H. H. Liu, "The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Non-stationary Time Series Analysis," Procedures of Royal Society of London, vol. 454, pp. 903-995, 1998.

163 - Recording of Isometric Shoulder Muscle Activation for Biomechanical Analysis and Clinical Evaluation.

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Introduction: Shoulder muscle activation is recorded by electromyography or estimated by model simulation. Electromyography of muscle force distribution in shoulder motion generally adresses a subset of muscles and is hampered by artificial and non-linear amplitude modulation. Model predictions are therefore difficult to validate. Isometric tasks applying a constant external force in different directions are the solution for clinical application and model validation.

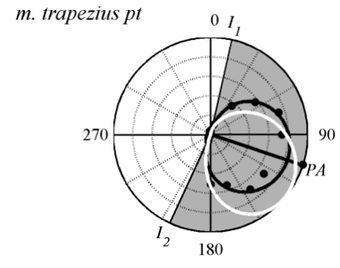
Methods: A force with constant magnitude was actively rotated stepwise in 20 directions perpendicular around the arm; EMG was recorded during each 3 seconds sustained force. The isometric series of EMG-amplitudes expressed a function of the clockwise-rotated force angle. This activation trace was parameterised by least squares function fitting, returning three force direction dependent parameters; activation on- and offset directions and peak activation direction or Principal Action. Comparison of these parameters between recorded EMG and estimated model simulation illustrate the applicability for musculo-skeletal model validation.

Results: (1) In contrast to specific clinical motions e.g. abduction, the method resulted in activation of all shoulder muscles, Fig. 1; (2) The activation of the muscles was not constrained to a potential positive contribution to the external moment. Muscles were activated while contributing to a negative external moment; (3) The estimated sensitivity of the on- and offset and Principal Action was 10° and 4° respectively; (4) Averaged over ten subjects, the 95% confidence interval for inter- day measurements was found to be about + or–5 degrees on a scale of 360 degrees for the principal action and just below + or –10 degrees for the intercepts.

Conclusion: The methodology addresses all shoulder muscles over a substantial segment of force directions. EMG recording allows prediction of muscle force distribution and validation of model based muscle force prediction, Fig. 1. The method also allows for intra- individual measurements on different days with sufficient accuracy so that shoulder muscle co-ordination of patients before and after interventions, e.g. surgery or physical therapy, can be evaluated. This method is a promising tool for both comparing EMG recordings and model simulations, and diagnosis and follow-up of clinical disorders.

Figure Recorded and estimated activation of the transverse portion of the trapezius muscle while exerting a force (20N) in 20 equidistant directions perpendicular to the horizontal right arm.

Recorded activation (black) was estimated from 20 EMG samples (dots). Predicted activation (white) was obtained from model simulation. The grey area indicates the external force directions of recorded muscle activation with a maximum activation (Principal Action) at 108o



164 - Optimal Electromyogram Amplitude Estimation Algorithm for Epoch-Based Applications

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Introduction: Epoch-based electromyogram (EMG) amplitude estimates have not incorporated signal whitening, even though whitening has demonstrated significant improvements for stream-based estimates. Epoch-based algorithms are necessary, for example, when functional electrical stimulation (FES) of one muscle is controlled by voluntary EMG recorded from another muscle, since the voluntary EMG is interrupted (blanked) to remove the stimulus artefact. This paper presents new epoch-based algorithms, for both single- and multiple-channel EMG, which include an adaptive whitening stage.

Methods: The adaptive whitening stage is sequentially comprised of a fixed whitening filter, an adaptive Wiener filter, and an adaptive gain corrector. These processes are cascaded with the noise-rejection stage, present in all EMG amplitude estimators, and then realized using the least squares filter design method. Current stream-based algorithms are implemented using the window filter design method. Since the least squares design method creates optimized filters (which tend to require fewer coefficients), the startup transients associated with the realized filters can be minimized. In epoch-based applications, each data segment can be as short as 13 ms (e.g., FES at 30 Hz, with a 20 ms blanking interval). Applying existing stream-based algorithms is not possible, since the length of the filter startup transients can exceed the duration of the epoch. These transients must be discarded, and the remaining EMG data used to form an amplitude estimate. Therefore, the startup transients must be as short as possible so that enough data remain to produce a valid amplitude estimate.

To evaluate the performance of epoch-based EMG amplitude estimates, biceps and triceps EMG amplitudes were related to elbow torque during force-varying, constant-posture, non-fatiguing contractions via a dynamic linear relationship. Presumably, better EMG amplitudess would yield lower root mean square (RMS) errors in estimating joint torque from the EMG. In all cases, an EMG amplitude-to-torque model was fit (trained) on one contraction trial, then model error tested by applying the model to a separate contraction trial.

Results: Whitening single-channel EMG data provided a 9.1–12.5% improvement in RMS torque error over unwhitened single-channel estimates. Multiple (four) channels of EMG without whitening yielded an 11.5–14.3% improvement over unwhitened single-channel estimates. Multiple-channels with whitening provided an 18%–22% reduction in average error when compared to single-channel unwhitened estimates; and, at a FES stimulation rate of 12.5 Hz (using a 20 ms blanking interval), the average RMS error (at the best filter order) was 7.85% of maximum voluntary contraction. Filter orders ranged from 12–18 using the least squares filter design method (compared to 60 using stream-based algorithms).

Discussion: These results suggest that whitening can be used to improve EMG amplitude estimation for systems that require epoch-based estimates, such as FES. Approximately half of the reduction in error is due to whitening, while the other half can be attributed to the use of multiple-channel EMG. Also of note is that computing whitened single-channel estimates yielded roughly the same average error as multiple-channel estimates without whitening. Filter design via the least-squares design method might also be beneficial in stream-oriented algorithms when lower filter orders are beneficial (e.g., to reduce computational load in real-time applications).

187 - Pattern Discovery Used To Assess Motor Unit Potential Train Validity

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Introduction: An important step in the decomposition of electromyographic (EMG) signals is the assessment of created motor unit potential trains. It is important to determine whether a created train represents the activity of a single motor unit (MU) or if it is a merged train and represents the activity of two or more MUs. Merged trains need to be split to improve decomposition accuracy. Detecting merged trains is straightforward when the trains are full and contain small numbers of errors. However, the task becomes increasingly difficult as the number of inter-discharge-intervals (IDIs) in a train decreases or the number of erroneous IDIs increases. A novel pattern discovery (PD) based classifier was developed to classify a train as either single or merged.

Methods: The activity patterns of MUs produce IDIs that have Gaussian distributions. Therefore, lower coefficient of variation (which is the same as coefficient of variation except it only uses IDIs which are less than or equal to the mean IDI), number of inconsistent IDIs, serial correlation, skewness, and kurtosis were used to represent the distribution of IDIs in a candidate train. During training, the PD classifier used quantized feature values of simulated single and merged trains to calculate adjusted-residuals to discover specific patterns of feature values that have a statistically significant relationship with single or merged trains1. A separate, but similar, test set of simulated trains was created. Patterns discovered during training were located in the feature values of each test train and used to accumulate weight of evidence measures1 to predict if the train was a single or merged train. For comparison, a supervised minimum Euclidean distance (MED) classifier using continuous feature values of the same data sets was implemented and evaluated.

Results: Training was completed using two sets of 1000 simulated trains. One represented single MU activity, the other the activity of two MUs merged. Each train initially modelled 200 discharges on MUs firing with 100 ms mean IDIs with coefficients of variation of 15%. Across each set the level of false detection (FD) error (extra random firings) was constant at 5%, while missed detection (MD) errors (random firing removal) increased from 0% to 75% and 0 to 30% for PD and MED classification, respectively. For aggregate error rates (MD+FD) up to 32%, the classifiers had similar near perfect results. With a 64% aggregate error rate the PD classifier performance was 98% while that of the MED classifier was 60% and with 80% aggregate error rate performance was 94% versus 52%, respectively. MED classifiers trained with a wider range of error rates produced inferior overall performance.

Discussion: The results demonstrate that PD classification is a very effective way of detecting merged trains. It significantly out performs the MED classifier at high error rates. Such a robust method for detecting merged trains with small numbers of IDIs and/or large numbers of erroneous IDIs is very useful for EMG signal decomposition.

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Andrew K. C. Wong and Yang Wang, “High-Order pattern discovery from discrete-valued data”, IEEE Trans. Knowledge and Data Engineering, vol.9, pp. 877-893, Nov.-Dec. 1997

188 - Clinical Electrophysiological Characterization of Muscle Based On Motor Unit Potential Classification Using Residual Analysis and Weight of Evidence

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Introduction: The shapes, sizes and occurrence times of motor unit potentials (MUPs) detected using needle electrodes reflect the structure and activation patterns of the motor units (MUs) active during a contraction and can therefore be analysed to obtain a clinically useful electrophysiological characterization of a muscle. Specifically, the effects of myopathic and neuropathic disorders can be detected. A new method, using standard statistics to characterize MUPs extracted from electromyographic (EMG) signals and based on residual analysis and information theoretic weight of evidence measures, has been applied to attempt to characterize a muscle as normal or as being affected by a myopathic or neuropathic disorder. In this preliminary work simulated EMG signal data was used.

Methods: Using a training set of EMG signals detected from myopathic, normal and neuropathic muscle, extracted MUP feature values (amplitude, duration, number of phases and turns, and thickness) were averaged over the MUPs extracted from each signal and quantized. Adjusted residuals were calculated to discover significant events that represent a relationship between disease involvement and specific values of subsets of MUP features1. A separate, but similar, test set of EMG signals was created. Significant events determined during training were discovered in the average MUP data extracted from each test signal and used to accumulate weight of evidence (WOE) measures1 to predict if the signal was detected from a myopathic, normal or neuropathic muscle. The EMG signals were created by a simulation routine that accurately models the structure and activation of MUs, the affects of disease on individual muscle fibres and MUs, and uses line-source volume-conduction models of clinically used needle electrodes to create composite EMG signals comprised of superimposed trains of individual MUPs.

Results: Training was completed using the MUPs from three sets of 20 simulated, concentric-needle EMG signals, each set detected in myopathic, normal and neuropathic muscles, respectively, during 10%MVC contractions. The myopathic muscles were simulated to have between 30 to 50% of their fibres infected and the neuropathic muscles to have 30 to 50% MU loss. Test data consisted of MUPs from three, similarly composed sets of 10 EMG signals. On average, the simulated state of a muscle was correctly detected 80% of the time with equal accuracy for myopathic, normal and neuropathic muscles.

Discussion: The initial results are promising and demonstrate the usefulness of adjusted-residual analysis and WOE measures. Using training examples these methods focus on the probabilistic relationships between specific MUP feature values and specific disease involvement. Further work using real data and different MUP features is planned.

References:

Andrew K. C. Wong and Yang Wang, “High-Order pattern discovery from discrete-valued data”, IEEE Trans. Knowledge and Data Engineering, vol.9, pp. 877-893, Nov.-Dec. 1997

215 - Frequency Analysis of Eccentric and Concentric Isokinetic Quadriceps Contractions Using Fourier Transform and Wavelet-Based Methods

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Introduction: Selective recruitment of fast twitch motor units for low-intensity eccentric contractions has been demonstrated using fine-wire EMG techniques (Howell et al., J Neurophysiol,1995, Nardone et al., J Physiol, 1989). McHugh et al. (J Sports Sci, 2002) reported similar findings based on FFT-derived estimates of mean frequency (MF) from surface electrodes. However, the validity of these findings is questionable since dynamic contractions do not satisfy the stationarity requirements of the FFT. The Continuous Wavelet Transform (CWT) does not suffer from the same limitation as the FFT, and can be used to analyze the frequency content of dynamic contractions. The purpose of this study was to compare FFT and CWT estimates of MF for analyzing dynamic quadriceps contractions.

Methods: Nine healthy male subjects volunteered to perform maximal voluntary (MVC) eccentric (ECC) and concentric (CON) contractions of the knee extensors, followed by submaximal contractions at 75%, 50% and 25% MVC. All contractions were performed isokinetically at 60°/sec in a dynamometer. Surface EMG data were recorded from the vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF) using bipolar Ag/AgCl surface electrodes. Data were bandpass filtered from 10-500 Hz with a CMRR of 130 dB, and sampled at 1 kHz. Data were analyzed from 30° to 60° of knee flexion. MF was estimated using two different techniques. First, MF was estimated from an FFT-based algorithm, using Welch’s averaged periodogram method (256 point FFT, Hanning window with a window overlap of 128 points). CWT was computed using the Daubechies6 wavelet, at dyadic (power-of-two) scales, and used to estimate instantaneous MF (IMF) over the contraction. The mean value of the IMF was used to compare to the FFT-based MF estimates. The effects of exercise intensity (25%, 50%, 75% and 100% MVC) and contraction mode (ECC vs. CON) on FFT and CWT MF were examined using 4x2 ANOVAs (grouped across muscles) with Bonferroni corrections for pairwise comparisons. FFT and CWT MF estimates were compared using paired t-tests. An alpha level of $P < 0.05$ was considered significant.

Results: For both FFT (Table 1) and CWT (Table 2) MF increased during CON ($P = 0.003$ and $P < 0.001$, respectively), but did not change during ECC ($P = 0.95$ and $P = 0.22$, respectively). MF was significantly greater for ECC vs. CON at 25% MVC ($P = 0.048$ for both FFT and CWT). CWT MF estimates were lower than those of FFT ($P < 0.001$), but very well-correlated ($r = 0.926$, $P < 0.001$).

Mode	25%	50%	75%	100%
ECC	82.8 ± 3.2	83.1 ± 2.8	82.2 ± 3.1	83.0 ± 3.1
CON	75.7 ± 2.3	79.7 ± 2.3	81.1 ± 3.1	84.3 ± 2.8

Table 1: MF (Hz) for FFT estimates (mean ± SEM) mode x intensity interaction, $P = 0.028$

Mode	25%	50%	75%	100%
ECC	60.8 ± 1.6	62.0 ± 1.6	63.1 ± 1.7	63.4 ± 1.8
CON	56.0 ± 1.2	61.4 ± 1.0	62.7 ± 1.7	65.2 ± 1.8

Table 2: MF (Hz) for CWT estimates (mean ± SEM) mode x intensity interaction, $P = 0.004$

Discussion: Analyses showed similar effects of contraction intensity for FFT and CWT MF estimates, though they were different in magnitude, with CWT being lower than FFT. This seems to indicate that FFT may be applied judiciously to analyze dynamic contractions. The difference in magnitude of MF between the two techniques should be kept in mind when comparing MF between studies using the different methods. Both FFT- and CWT-based estimates of MF for 25% MVC were greater for ECC than CON. This indicates preferential recruitment of fast-twitch motor units for submaximal ECC quadriceps contractions.

226 - The Effect of Time Delay Dispersion Filtering On the SNR of Myoelectric Communication Channel

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The previous research work demonstrated that the action potential propagation along nerve and muscle fibres forms a time delay dispersion (TDD), which is determined by many physiological parameters including the length difference between the motor axon branches, the topology of the end-plate, the diameter of fibres, and the conduction velocity distribution among motor units. It has been shown that the TDD functions in effect as a low-pass filter. The purpose of this work is to study the effect of the TDD on the signal transmission performance, as measured by the noise ratio (SNR), of myoelectric communication channel. The SNR is defined as the ratio of the myoelectric signal power to the power of noise calculated in frequency domain. The gross myoelectric signal is simulated by the sum of action potential trains in the presence of superimposed, additive, white, Gaussian noise. It is shown in this computer simulation study that the overall signal transmission performance is improved by the TDD and that a significant improvement in SNR can be achieved by the TDD with the optimal standard deviation of dispersion being the most efficient solution. The results of this study suggest that taking into account the TDD effect would be useful in better understanding of the mechanisms involved in myoelectric signal transmission within the neuromuscular system.

229 - Analysis of Intramuscular EMG Signals With a Decomposition Program

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Introduction: A program intended for the decomposition of electromyographic signals recorded with intramuscular electrodes was developed. The main innovation consists in using a pseudo-correlation index (PCI), which provides a fast and reliable means of comparison between waveforms.

Methods: Decomposition is carried out with two separate processes: classification, which consists in the determination of the constituent motor unit action potentials (MUAPs) and detection, which consists in the localization of the occurrences of each MUAP train component. In this phase, the PCI is a template matching filter technique that uses both phase and absolute value information to locate interference-free MUAPs and also separate superimposed waveforms [1, 2]. The program does not require interactive operator intervention and only a limited number of parameters have to be adjusted over a wide range of signals. The program's performance has been tested with synthetic data and experimental signals recorded with wire electrodes inserted in the biceps brachii muscle during static isometric contractions of at levels ranging from 5 to 30% of the maximum voluntary contraction.

Results: Following some parameter adjustments, the classification module could always detect the accurate number of MUAP constituents and their respective shapes from 25 synthesized signals containing from 4 to 12 trains. As for the detection module, its success rate varied between 59% and 97%. Lower detection rates were mostly associated with badly detected small-amplitude MUAPs interspersed among larger ones. More than 500 experimental signals were analyzed and up to 14 simultaneously active MUAP trains could be identified with reliable firing statistics. For 10 s long recordings of moderate complexity (up to 6 MUAP trains) where the success rate typically exceeds 90%, analysis was completed in less than 10 s on a recent desktop computer.

Conclusion: A decomposition program was developed and satisfactory results were obtained over a broad range of both synthetic and experimental data. The program's accuracy and short processing time can be associated with the use of the PCI that reliably assesses the similarity between waveforms, allowing our template matching scheme to run relatively error-free. Work is under way to improve the detection module's speed, especially by making the resolution of MUAP superimpositions more efficient and to make the classification module fully automatic, i.e. with no need for parameter adjustment. The program could then be used soon for real-time applications on EMG signals of moderate complexity.

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253 - Wavelet-Based Compression of Isometric EMG Signals

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Introduction: Researchers have been turning their attention to the topic of compression of biomedical signals [1] as this becomes an important issue with the continued development of information technology. This work presents an algorithm for compression of electromyographic (EMG) signals, which provides an efficient way to store EMG signals in data banks or to reduce the necessary bandwidth for transmission of these signals.

Methods: A coding algorithm was developed composed of several steps. In the first step, the signal is pre-processed by a time-invariant wavelet de-noising process. Simulations were performed to determine the orthogonal wavelet basis that allows the best representation of the EMG signal. Simulations with several kinds of wavelet transforms, as well as with the Discrete Cosine Transform (DCT), were performed for this purpose. These simulations led to graphical representations of the mean squared error (MSE) and of the amount of preserved energy of the original signal as a function of the number of discarded coefficients. From these plots, we determined that the best basis function for representing the EMG signal was from the Daubechies-4 family of transforms. The de-noising step resulted in a minor loss of signal information. This loss, however, can be controlled by adjusting the degree of de-noising. In the second step, we applied a wavelet orthogonal transform followed by the selection and quantization of the relevant coefficients. Simulations were also performed in this step, and the results confirmed that the Daubechies-4 was the best choice for the coding process. In the last step of the decoding process, we performed entropy coding of the information. The performance of the compression scheme was measured objectively according to two criteria: the compression ratio and the signal to noise ratio (SNR) of the reconstruction.

Results: The results showed that the transform based on the Daubechies-4 family, with a resolution scale of L=8, provided better performance as determined by noise reduction and space domain signal de-correlation. We also verified that the optimal number of discarded coefficients is 93%. It was observed, for the same compression rate, that the Daubechies-4 family leads to a better signal to noise ratio when compared with the DCT and other wavelet families. The evaluation of the efficiency of the compression scheme showed that the compression rate depends on the degree of de-noising. If no de-noising is performed, the compression rate is about 3:1 for a SNR of 30 dB. With optimal de-noising the compression ratio is about 15:1 for a SNR of 30 dB, but the signal is a little more degraded. Thus, in this method the compression rate ranged from 3:1 to 15:1, depending on the degree of de-noising. The user of this compression algorithm can choose the degree of de-noising based on his/her needs.

Conclusion: The performance of de-noising and compression of EMG signals was studied by using wavelet transforms in which parameters such as the mother wavelet and the de-noising threshold were varied. The de-noising algorithm can be adapted to achieve compression rates from 3:1 to 15:1 for a SNR of 30 dB. We observed that the Daubechies-4 family of transforms, with a resolution scale of L=8, resulted in the best performance.

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254 - Wavelet Analysis Of Electromyographic Signals For The Assessment Of Physical Conditioning

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Introduction: The study of muscle fatigue has always been a topic of interest among researchers. The use of electromyographic (EMG) signals to study fatigue in muscle is very common, especially with the development of new time-frequency tools for processing non-stationary signals [1]. During dynamic contractions, the variation in muscle force and muscle length and the changes in the position of the electrodes with respect to the active muscle fibers generate non-stationary signals that are difficult to interpret using traditional methods. The objective of this study is to introduce a new process for assessing physical conditioning, based on the analysis of muscle fatigue during cycling.

Methods: A two-day test was applied to 14 randomly selected subjects (11 males and 3 females). In the first test the subjects pedaled on a Cateye Cs-1000 bicycle simulator starting at a speed of 36km/h. The speed increased 2km/h each minute until exhaustion. This test was used for defining the beginning speed for the real test on the second day which was the third last speed obtained in the first test. On the second test day, two bipolar active surface electrodes were fixed to the vasti lateralis muscle, one on each leg. The bicycle was connected to the simulator and a protocol similar to the one used in the first test day was executed where the individual speed was increased 2km/h for each minute until exhaustion. A trigger system was connected to the crank arm indicating the beginning and the end of each pedaling cycle. A sequence of 256 samples was selected from each of the EMG signals, during each pedaling cycle, at a region with high magnitude, always at the same moment of the cycle, in a fixed portion from the trigger position [1]. This process minimizes the dynamic effect of the activity. The sampled EMG signals were filtered following Berger's method [2]. In this method, the signal is decomposed using a specific discrete wavelet transform, and only 6% of the coefficients are selected. Afterward, a new process is applied, which leads to the Spectral Displacement Coefficient (SDC). The SDC was calculated by summing the kth wavelet coefficients ($\omega[k]$) squared, divided by the respective coefficient index (k). The result was represented by a linear regression and normalized.

Results: We observed that the quicker the installation of fatigue the quicker was the energy translation of the power spectrum to lower coefficients and the quicker was the increase of the SDC. As a result of the data analysis for all the subjects, regression lines with different slopes were plotted. We observed that the slope is directly related to the physical conditioning of each subject. To confirm these findings, another coefficient based on the starting speed and the number of stages achieved, which indicates physical conditioning, was calculated and its correlation with the SDC was determined. The obtained correlation was 0.86.

Conclusion: The high correlation between the SDC and the index used to quantify physical conditioning provides a strong indication that the SDC is a good index for assessing physical performance.

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264 - Robust Estimation of Upper Limb EMGs From Multichannel Intracortical Recordings

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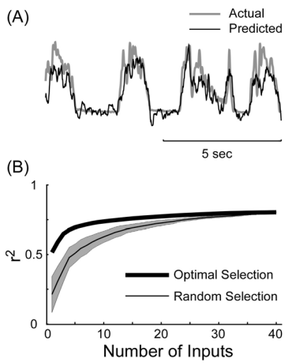
Introduction: The purpose of this study was to develop robust techniques for estimating upper limb electromyograms (EMGs) from multi-electrode intracortical recordings and for determining the unique contributions of each electrode to those EMGs. Recent advances in electrode technology make it possible to obtain simultaneous recordings from multiple cortical neurons. Quantifying the relationship between cortical and muscle activities has the potential to greatly increase our understanding of the primate motor system and also may provide a foundation for developing high-speed brain computer interfaces for the severely disabled. However, these and other potential applications for multi-channel electrodes require techniques for handling the vast amounts of data that can be acquired and for determining the relationship between this data and the signal or functional task of interest.

Methods: A linear multiple-input, single-output (MISO) system was used to predict upper limb EMGs from intracortical recordings. This system was identified using a novel nonparametric algorithm to estimate the impulse response functions characterizing the transfer of information from each cortical recording to each EMG of interest. This algorithm incorporated singular value decomposition to provide robust estimates in the presence of significant measurement noise and signal coupling. An algorithm to determine the unique contribution of each electrode to each EMG also was developed using the properties of Gram-Schmidt orthogonalization. This allowed an optimal set of cortical electrodes to be used the EMG prediction. Algorithm performance was evaluated on data collected from a rhesus macaque monkey during complex reaching tasks. Cortical activity was recorded by a 10x10 electrode grid (Cyberkinetics, Inc.) implanted over the upper limb region of the primary motor cortex; 41 of the 100 available electrodes provided stable recordings. EMGs were measured from the anterior deltoid, biceps, triceps and forearm flexors using custom made, implanted electrodes.

Results: The r2 value between the measured EMGs and those predicted from the cortical recordings ranged from 0.60-0.73 for all muscles. Note that the goodness of fit was evaluated on data not used during the estimation process. A typical prediction for the anterior deltoid is shown in Figure A. This accuracy could be obtained using data from only 10 electrodes, when these electrodes were selected by the newly developed algorithm. This optimal selection process was significantly better than a random selection of cortical recordings (Fig 1B), reducing the number of electrodes needed by more than half for all prediction accuracies up to 92% of the maximum obtainable accuracy. Consistent results were obtained for all muscles during a wide range of movement conditions.



Conclusions: Using the newly developed algorithms, this study demonstrated that a significant amount of upper limb muscle activity is encoded in the primary motor cortex and that this activity can be predicted using a small number of intracortical electrodes. These algorithms may be applied to any MISO problem and could have wide-ranging applications in areas such as cortical mapping and brain computer interfaces.

273 - Surface Electromyographic Spike Activity and Motor Unit Firing Rates at Different Levels of Maximum Contraction

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Introduction: Mean spike frequency (MSF) and mean spike amplitude (MSA) have been shown to be highly correlated with root-mean-square (RMS) amplitude and mean frequency (MF), respectively, of the surface electromyographic (SEMG) signal during maximal effort contractions (1,2). This study evaluated these measures in relation to motor unit (MU) firing rates at different percentages of maximal voluntary contraction (MVC).

Methods: Nine subjects completed two isometric contractions of the dorsiflexors at 40, 60, 80, and 100% of MVC. Contractions were limited to 15 seconds and occurred at 3 minute intervals. Visual feedback was provided to participants through a video monitor. SEMG activity of tibialis anterior (TA) was recorded with Ag/AgCl electrodes. The signal was amplified (2000x), band-passed (20-500 Hz) filtered and sampled at 2.5 kHz. MU activity was monitored with a quadrifilar needle electrode placed near the surface electrodes (3). The MU recordings were band-passed (1 kHz-10kHz) filtered and sampled at 25.6 kHz.

Results: Maximal dorsiflexion strength was 245±63 N. MSF was 150±22 Hz and MF was 141±22 Hz at 100 % MVC. Likewise, RMS amplitude was 311±22 μV and MSA was 659±270 μV. The frequency and amplitude content of the SEMG signal exhibited a quadratic increase ($P<0.01$) while MU firing rates rose linearly from 16±3 to 34±6 pulses per second across the four levels of force ($P<0.01$). There was a high correlation between MSF and MF (0.95; $P<0.01$) and between MSA and RMS amplitude (0.99; $P<0.01$).

Conclusions: MSF and MF were equivalent across the different force levels. The same was true for MSA and RMS amplitude. Both MSF and MF increased in association with MU firing rates.

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298 - Toward a Quantitative Analysis of Voluntary Motor Control: A Voluntary Response Index (VRI) Derived From Surface EMG Recordings During Voluntary Maneuvers

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Background: Following spinal cord injury (SCI), there is often a loss of control over the performance of voluntary movement. For clinical diagnosis and treatment planning purposes, the severity of human SCI is currently assessed through a carefully-developed but subjective quantification scheme, the ASIA (American Spinal Injury Association) impairment scale (AIS). Objective, quantitative methods are needed to assess subtle changes induced by current and planned interventions. We present here results obtained by a systematic comparison of distribution of electromyographic activity recorded in persons with spinal cord injuries to that recorded in neurologically intact subjects.

Methods: For this retrospective study, 67 subjects with incomplete spinal cord injury, ASIA Impairment Scale (AIS)-C (n=32) and -D (n=35) were studied. Surface EMG recorded during a rigidly administered protocol of eight lower-limb voluntary motor tasks was analyzed using the voluntary response index (VRI) that relates multi-muscle activation patterns recorded during a rigidly administered protocol of elementary motor tasks to those of healthy-subject prototypes (n=15). EMG activity from each maneuver is represented by a response vector (RV) comprised of the averaged amplitude of each muscle during the maneuver. A similarity index (SI – range -1 to 1) which is computed by computing the cosine between the individual's RV and a prototype response vector (PRV) formed from healthy subject data for that maneuver and magnitudes of the RVs were compared to clinical examination results reported as the AIS. Magnitude values (|RV|) were normalized (|RV|n) and expressed as a percentage of healthy-subject means to yield a VRIn, to permit combining values for maneuvers with very different normative magnitudes. Receiver operating characteristic (ROC) analysis was performed to determine values which best differentiate AIS-C and AIS-D subjects based on SI and |RV| values.

Results: The VRIn components, |RV|n and SI, well-characterized the patterns of voluntary motor control as judged by expert observers, although values were lower for hip and knee movements than for ankle movements (correlations ranging from 0.8 to -0.1 for eight examiners with varying degrees of experience). Healthy subjects had values close to 1 and 100% respectively. More variability was observed in hip and knee flexion and extension patterns than in ankle dorsi- and plantar flexion, as evidenced in lower values for the SI for hip and knee movements. To characterize the subjects' overall motor control for comparison with the AIS, which is a global score but effectively represents the best side, we combined the two unilateral flexion maneuvers from the side with the highest SI values by averaging the individual SI and |RV|n respectively. The |RV|n and SI had mean values that were 27±32% and 0.65±0.21 respectively for AIS-C subjects. Both magnitude and SI means were significantly larger for the AIS-D subject group at 73±43%and 0.93±0.06 respectively ($p<0.01$). An SI value of 0.85 was found to separate AIS-C and AIS-D groups with a sensitivity of 0.94 and a specificity of 0.81. Further, unilateral VRI values were correlated with the unilateral motor score components of the AIS (0.78, $r<0.01$).

Conclusions: The VRI provides an objective, quantified index of motor control that differentiates healthy subjects from those with SCI and among SCI subjects with varying severity of lesion. Both |RV|n and SI contribute to the differentiation, although the SI provides somewhat better information.

302 - Improved Statistics for the Estimation of Time-Dependent Coherence Using Wavelets

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Introduction: During human voluntary contractions motor unit (MU) discharges tend to be synchronized to specific frequencies due to a number of different descending drives (Brown, 2000). Evidence of these drives may be found in the coherence calculated between individual pairs of MUs as well as between the grouped MU firings and cortical activity. The coherence function provides a frequency dependent, bounded measure of linear association between two time series, taking on a value of 1 for a perfect linear relationship and a value of 0 to indicate independence. The conventional method of coherence estimation is based on Fourier analysis, which is limited to the study of stationary data and provides an overall or average picture of the coherence over the entire time course under study. However electromyographic data is frequently non-stationary and therefore it is necessary to estimate the coherence as a function of time. This is particularly advantageous when tracking the time course of the drives or when studying movement.

Recently a wavelet coherence algorithm was developed that allows the temporal structure of coherence to be studied (Lachaux et al.2002) and estimates the coherence for a specified time and frequency resolution. As the coherence can only provide an estimate of the true underlying coherence, there is an unavoidable trade-off between both the time and frequency resolutions and the statistical power, where for increasing resolution it becomes increasingly difficult to separate spurious coherence from true coherence. Here we introduce additional statistical techniques for wavelet coherence that may be used to analytically determine probabilities of detection (Pd) and probabilities of false alarms (Pf). It is necessary to calculate these probabilities so that wavelet coherence may be reliably applied to real data. The technique is demonstrated on both simulated and real data.

Methods: Surrogate data is used to generate the Pd and Pf for a range of possible combinations of time and frequency resolutions. The generated probabilities are then compared to those obtained using existing analytic expressions for 1-D data. The existing expressions are formulated as functions of the number of non-overlapping windows (nd) in the Fourier estimation technique. We replace nd with a function of the ratio of time-frequency resolution and show that the same formulae may be used to set the probabilities for wavelet coherence.

Simulations and experiments: The improved statistics are applied to wavelet coherence of simulated data with known a priori structure to demonstrate its effectiveness. It is also applied to recorded EEG-SEMG data and to recorded pairs of single MU spike trains.

Conclusions: Wavelet coherence provides a suitable means of tracking the time-frequency structure of coherence between bivariate time series. However for physiologically desirable resolution levels, this technique suffers from poor statistical power. The introduction of analytic formula to determine probabilities of false alarm and probabilities of detection allow one to reliably separate true coherence from spurious coherence and is a necessary prerequisite for the application of the technique to real data.

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303 - Importance of Selecting an Appropriate Q Value In Analyses Of Spine Stability

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Introduction: Muscle stiffness can be estimated by the following equation: k = qF/L, where k=stiffness, F=force, L=length, and q is a dimensionless multiplier (Bergmark, 1989). Values of q range in the literature from approximately 0.5 to 40. One function of muscle stiffness is to provide joint stability. The purpose of this paper is to demonstrate the discrepancy in spine stability levels with q values ranging from 1 to 20.

Methods: Eleven male subjects from the university population performed sets of isometric loading tasks while standing in the neutral posture. Loads were held in the hand/s to provide either flexor or right side lateral bend moments. Linear envelope EMG data was collected from 14 trunk muscles bilaterally, and averaged across all subjects. A 56 muscle spine model was utilized to estimate muscle forces, and subsequently stability levels about each of the three anatomical axes, for the L4/L5 joint. Stability was calculated via the minimum potential energy method. q values, for the determination of muscle stiffness in the stability analysis, were made to range from 1 to 20 in increments of 1.

Results: Stability levels increased in a linear fashion with increasing q values (Figure 1). The slope of increase differed for stability levels about the three anatomical axes. For both flexion and lateral bend moment experimental trials, with q values below approximately 6 and 4 respectively, the spine was most stable about the axial twist (AT) axis. However, as q was increased above these levels, the axis interpreted as most stable changed to the flexion/extension (FE) axis for flexor moment trials and the lateral bend (LB) axis for lateral bend moment trials.

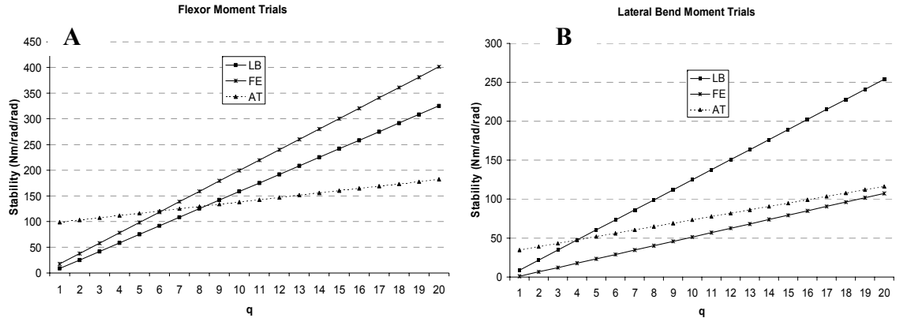

Figure 1. Stability levels about three anatomical axes with q values ranging from 1 to 20 for flexor moment trials (A) and lateral bend moment trials (B).

Discussion: Stability levels increased in a linear manner as the value of q increased. However, the slope of this linearity differed for each of the three axes. The slope of increase was always lowest about the AT axis, and the highest slope was found about the FE axis for flexor moment trials, and about the LB axis for right side lateral bend moment trials. This served to make the dominant axis most stable in both trial types with all q values above 6. However, in determining the least stable axis, and thus the direction in which buckling may be most likely to occur, a q value of 9 served as the transition between the LB and AT axes for flexor moment trials, while the FE axis was found to be least stable for all q values for lateral bend moment trials. Thus, it is essential that an appropriate q value be selected for the purposes of stability analyses, as differing q values may alter our prediction and interpretation of buckling behaviour under given situations.

308 - MUAP Duration Algorithm Based on the Wavelet Transform

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Introduction: Motor unit action potential (MUAP) expresses the electrical activity of the muscle fibers of a motor unit (MU) recorded from a needle electrode. The shape of MUAP waveforms contains valuable information about the state of a muscle, helping to distinguish abnormal conditions. MUAP analysis constitutes a daily-work procedure in clinical electromyography (EMG) for which several waveform parameters have been defined [1]. The length of the MUAP waveform, referred as 'duration', carries very interesting information about the size of the MU, but its manual measurement presents a high variability even to experienced electromyographists. Automatic duration algorithms try to overcome this problem. Current automatic methods use amplitude, and slope criteria [1]. In this work we present a new automatic duration algorithm based on the wavelet transforms (WT) and we compare it with previous approaches.

Material and methods: For our study we used a set of 127 50-ms-long needle EMG records, obtained from 10 subjects and 3 different muscles (tibialis anterior, triceps brachii and first dorsal interosseous) and sampled at 25.6 KHz. The EMG records were wavelet transformed. By selecting a suitable wavelet scale, low and high frequency noise was put aside. The initial and final points of the MUAPs were estimated by regarding the maxima and minima points in the wavelet domain. Duration was then measured as the time interval between these two points. An expert neurophysiologist carried out three independent manual measurements for the initial and end points of every MUAP in the signal set. The average positions of these points among the three measurements constituted our gold standard. Two automatic duration algorithms (MT1) and (MT2) developed at the Department of Clinical Neurophysiology in Turku [1] were also tested for comparison.

Results: Error measurements were computed as the differences between the initial and end points determined by the automatic methods and the gold standard ones. Mean and standard deviation of these errors are given in Table 1 (Units are given in samples).

Method	MT1		MT2		Ours	
	Initial	Final	Initial	Final	Initial	Final
Error Mean (SD)	162.0 (201.0)	-248.6 (291.3)	158.5 (168.5)	-83.9 (139.0)	-5.7 (27.8)	-5.4 (57.4)

Table 1

We can see that our new wavelet-based algorithm was able to detect the MUAP initial and final points much closer (with less bias and variance) to the expert's estimations than MT1 and MT2 approaches did.

Conclusion: Our wavelet-based algorithm thus appears as a very effective way to measure MUAP duration, consistent to experts' intuitive perception.

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333 - Comparing the Use of Signal Whitening and Extreme Highpass Filtering to Improve Surface EMG-Based Muscle Force Estimates

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Introduction: It is generally assumed that raw surface EMG (sEMG) should be high pass filtered with cutoffs of 10-30 Hz to remove motion artefact before subsequent processing to estimate muscle force. The purpose of the current study was to explore the benefits of filtering out much more of the raw sEMG signal when attempting to estimate accurate muscle forces.

Methods: Three groups of subjects were used for the collection of surface EMG signals from the biceps brachii. The first two groups involved 9 male and 9 female subjects attached with pairs of small disposable electrodes (1 cm2, 2.5 cm spacing). The third group included 7 male subjects attached with pairs of larger electrodes (1.77 cm2, 5 cm spacing). Subjects were seated, elbow at 90 degrees and their arm parallel to the table. A force transducer was placed in series with the cable so that the elbow joint moment could be calculated. EMG and force data were collected continuously (1024 Hz) for a 30 second trial. There were four short and one longer isometric contraction to 100% of their maximum voluntary contraction (MVC) and then back down to zero. Both signals were first amplified 1000 times and then stored on computer for further processing. EMG signals were then processed to estimate the maximum moment time-history (relative to maximum). The signals were high pass filtered with 16 different cutoff frequencies ranging from 20 Hz (used as a current standard) to 440 Hz, in increments of 30 Hz. Raw signals were also whitened and adaptively whitened. Each resulting raw EMG signal was then full wave rectified and low-pass filtered and then normalized to that signal's maximum. An iterative approach was used to determine the low pass cutoff frequency and non linear normalization combination that resulted in the lowest RMS error between EMG and force for each HPCF. A two way ANOVA, with repeated measures was used to determine if there was an effect of the gender/electrode combination and to determine if any of the HPCF resulted in RMS errors that were lower than those observed with a 20 Hz HPCF (current standard).

Results: There was a significant effect of HPCF and filter order on RMS error and a significant interaction between the HPCF and order (all $p<0.0001$). No significant effects were observed for gender/electrode combination. For the first order filter, the RMS errors were lower for all HPCFs greater than 20 Hz ($p<0.001$) and 24 of 25 subjects showed at least some improvement in force prediction for cutoff frequencies up to 380 Hz, with the lowest average error at 410 Hz cutoff (13.7% lower, relative to 20 Hz). For the sixth order filter, all cutoff frequencies between 50-230 Hz resulted in lower errors than 20 Hz ($p<0.001$) and all 25 subjects showed at least some improvements with cutoffs of 110 and 140 Hz, with the lowest average errors at 140 Hz (14.1% lower, relative to 20 Hz). For the sEMG signals whitened and adaptively whitened, via autoregressive modelling, the average RMS errors were not significantly different from the lowest average errors with the 1st and 6th order filters.

Discussion: The results indicate that removing up to 99% of the raw sEMG signal power resulted in significant and substantial improvements in biceps force estimates. These findings challenge previous assumptions that the raw sEMG signal power between about 20 Hz and 500 Hz should be used when estimating muscle force. It appears that a much smaller, high band of sEMG frequencies may be associated with force and highpass filtering provides an effective (and easier method than whitening) for removing the low frequency content.

339 - Variability of Single Motor Unit Conduction Velocity During Non-Fatiguing Sustained Contractions

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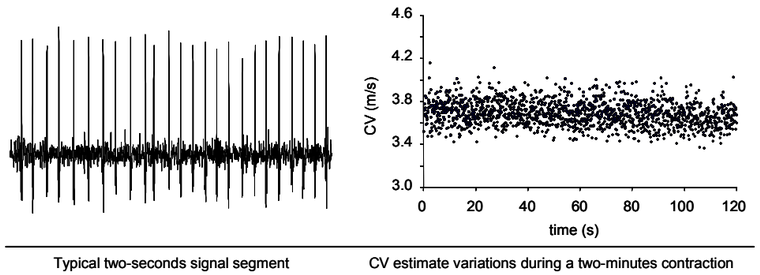
Conduction velocity (MUCV) and inter-pulse interval (IPI) are two fundamental motor unit features. The objective of this work consisted of the identification of the sources of MUCV variance estimated during contractions in stationary conditions.

Single MUAP trains were either simulated or detected on the Biceps Brachii using a three channels Laplacian surface EMG device. EMG signals were recorded during sustained low isotonic isometric contractions. MUCV was computed from the time delay between the same MUAPs identified in two consecutive channels after quadratic interpolation. IPI was estimated from the time delay between two consecutive MUAPs of the same channel. For simulated signals, white noise was added with SNR ranging from 50 to 0 dB. For real signals, SNR was estimated by removing the identified MUAPs from the raw signal and approximating that noise and MU signal were uncorrelated. Coefficient of variation (Cvar) were computed on MUCV series.

MUCV Cvar was directly dependant on the SNR for simulated signals as well as for real signals. MUCV Cvar (about 3% in average) was lower than IPI or amplitude Cvar (about 10%). No correlation of MUCV was found with MUAP amplitude and IPI.



Typical two-seconds signal segment CV estimate variations during a two-minutes contraction

These preliminary results suggest that the MUCV variance estimated during contractions in stationary conditions is only due to SNR.

362 - A Novel Adaptive Filtering Approach for Removing Stimulation Artifact from M-Waves

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Introduction: Stimulation artifact (SA) is a signal superimposed to the recorded evoked potential during electrical stimulation. SA can affect the estimates of the variables extracted from electrically evoked electromyographic (EMG) signals (M-waves). The SA and M-wave strongly overlap for recordings close to the muscle stimulation site. The aim of this study was the development and test of a novel method for removing the SA from the M-wave.

Methods: The algorithm is based on an adaptive filtering technique which processes M-waves detected by a linear electrode array. The reference signal for the adaptive filter is the M-wave detected by the array channel most distant from the stimulation electrode, where the SA and the M-waves are maximally separated. A blanking is applied to this signal to obtain a SA-free M-wave to be used as reference for estimating the M-waves detected close to the stimulation site. The primary signal thus presents significant overlap between the M-wave and the SA. The adaptive element is a neural network that estimates the transfer function between the reference and the primary signal. The neural network training process is performed on the last portion of the signals, where only the M-wave is present. The network extrapolates the mapping learned in this segment to the earlier portion of the signal, reconstructing a SA-free M-wave in the primary channel. The algorithm was tested on simulated and experimental signals. The simulated signals had signal-to-noise ratios (SNRs) of infinity and 20 dB (white Gaussian noise; 100 noise realisations; random initialization of the weights of the neural network) and were sampled at 2 kHz. The experimental signals were collected at 2kHz from the biceps brachii muscle of 12 healthy male subjects during increasing stimulation current from 0 mA to the maximum tolerated by the subject (Imax). The proposed algorithm was applied to the M-waves generated at current levels of 75%, 85%, and 95% of Imax. In case of experimental signals, the performance of the algorithm was evaluated by comparing the shape of the estimated SA to the shape of a SA elicited by a sub-threshold stimulation.

Results: Results for simulated and experimental signals are shown in Table I and II.

Table I: Cross-correlation coefficient ρ between reconstructed and SA-free M-wave from simulations. Distant and closer refer to the results obtained from the most distant (after the reference channel) and closest channels to the stimulation point.

Simulated M-wave ρ (mean ± SD)	SNR = ∞		SNR = 20 dB	
	distant	closer	distant	closer
Oversampling x 1	0.99 ± 0.00	0.71 ± 0.23	0.90 ± 0.11	0.45 ± 0.28
Oversampling x 10	0.99 ± 0.00	0.91 ± 0.05	0.99 ± 0.00	0.95 ± 0.08
Oversampling x 20	0.99 ± 0.00	0.94 ± 0.03	0.99 ± 0.00	0.96 ± 0.10
Oversampling x 40	0.99 ± 0.00	0.97 ± 0.03	0.99 ± 0.00	0.97 ± 0.05

Table II: Cross-correlation coefficient ρ between the estimated and sub-threshold SA (experimental signals). Distant and closer defined as for Table I.

Experimental M-wave ρ (mean ± SD)	75% I_{max}	85% I_{max}	95% I_{max}
distant	0.81 ± 0.15	0.83 ± 0.07	0.76 ± 0.22
closer	0.71 ± 0.17	0.73 ± 0.14	0.65 ± 0.14

Discussion: The method proposed is based on the novel idea to use an adaptive element not to determine the SA to be subtracted to the primary signal but to reconstruct the M-wave. This is possible with the availability of a reference SA-free M-wave, which is detected far from the stimulation site with the linear array technique. The method is promising in removing the SA even in case of extensive superimposition between SA and M-wave.

370 - Toward a Quantitative Analysis of Voluntary Motor Control: The Test-Retest Reliability Of A Voluntary Response Index (VRI) Derived From Surface EMG Recordings

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Background: Test-retest reliability is the consistency of measurements obtained when one person measures the same unit with the same measuring equipment at different times. It is a basic and prerequisite matter and crucial to allow application in the assessment of the central nervous system disorders. We estimated test-retest reliability of the new method, voluntary response index (VRI), to evaluate the motor control pattern recorded from persons with spinal cord injuries (SCI) and healthy subjects. The VRI, analysis of the surface EMG, centred on two features, the magnitude of activation and the degree of similarity (similarity index (SI)) of the sEMG distribution to that of healthy subjects performing the same maneuver (n=15).

Methods: In this retrospective study, 68 subjects with incomplete spinal cord injury, ASIA Impairment Scale (AIS)-C (n=34) and -D (n=34), were studied. In the analysis of the 'same-day' test-retest reliability of each maneuver, three times repeated magnitude and SI were analysed for every maneuver. In this case, five seconds is the minimum gap between maneuvers based on the protocol. Analysis was made for ten volitional maneuvers. In addition, one pair of data from six SCI subjects who finished a retest one week later and one healthy subject who was retested 50 days later were analysed for the 'one-week test-retest' reliability using averaged values from each test for ten maneuvers. Coefficient of stability of the test-retest reliability is expressed as r2 (r is Pearson correlation coefficient).

Results: SCI subjects of AIS-D group showed a little bit higher correlation coefficient value than those of AIS-C group for three times repeated tests during voluntary movements. However, test-retest reliability for all maneuvers exhibited a range from 0.52 as a minimum coefficient of stability to 0.98 as a maximum coefficient of stability (Table 1), which is acceptable for the good reliability. Pearson correlation for the one-week test-retest was 0.90 ($r<0.01$) for magnitude and 0.81 ($r<0.01$) for SI. The Mag variable was more reliable than the SI variable. Five of 10 of the SI variables MAX reliabilities don't get into the acceptable range of over .80 and reliability coefficient for all flexion movements showed slightly higher than all extension movements ($p<0.05$).

Table 1. Coefficient of stability for three repeated maneuvers, r2 (r is Pearson correlation coefficient).

Maneuvers	All subject (n=68)			
	Mag		SI	
	Min	Max	Min	Max
Bilateral hip-knee flexion	0.83	0.93	0.70	0.87
Bilateral hip-knee extension	0.59	0.88	0.67	0.76
Right hip-knee flexion	0.95	0.97	0.64	0.80
Right hip-knee extension	0.84	0.92	0.55	0.79
Left hip-knee flexion	0.50	0.84	0.56	0.71
Left hip-knee extension	0.75	0.90	0.55	0.64
Right ankle dorsiflexion	0.91	0.98	0.73	0.81

Right ankle plantar flexion	0.75	0.97	0.52	0.81
Left ankle dorsiflexion	0.76	0.91	0.67	0.85
Left ankle plantar flexion	0.87	0.93	0.53	0.70

Conclusions: Test-retest analysis showed that both components of the VRI are quite stable measurement for ten voluntary movements over time.

376 - The Influence of a Realistic Limb Geometry on Simulated Surface-Detected Muscle Fiber Action Potentials

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The influence of factors such as subcutaneous fat thickness and electrode configuration on EMG cross-talk has previously been examined using model simulations. However, the effect of limb geometry has not yet been explored. In this study, a finite element model of the upper arm was used to examine the effect of realistic limb geometry on simulated muscle fiber action potentials detected at the skin surface.

The volume conductor model was generated from a series of transverse magnetic resonance (MR) images of the upper arm of a healthy male subject and was composed of skin, fat, muscle and cortical and cancellous bone tissue. The brachial artery and cephalic vein were also modeled. Tissue conductivity and permittivity were both included based on a range of experimental data reported in the literature. A 120 mm long muscle fiber was located within the muscle tissue at a constant depth below the skin surface. The muscle fiber was curved to follow the surface of the model. Surface action potentials were examined at 16 electrode locations around the surface of the simulated limb. Each simulated electrode consisted of two 10 mm x 1 mm silver bars, separated by an inter-electrode distance of 10 mm. The surface potential was examined for muscle fibers located 12 mm, 14.5 mm and 17.5 mm below the skin surface. Action potentials simulated using the realistic subject-specific model were compared with those simulated using an idealized cylindrical model of the limb derived from the same MR images. Using the realistic arm geometry the effect of tissue capacitance on the surface action potentials at each location was also examined. To examine the influence of fiber curvature, action potentials were compared with action potentials simulated using a straight muscle fiber, orientated parallel to the bone. To investigate the effect of blood vessels on the surface EMG signal, the artery and vein were then removed from the model and replaced with fat tissue.

The specific geometry of the limb was found to alter the shape of the surface action potentials, particularly at electrode locations farthest from the active fiber. However, the rate of decay of the EMG amplitude both with increasing fiber depth and radially around the surface of the model was almost identical in the subject-specific and idealized cylindrical models. Including capacitive effects in the model caused a slight phase shift of the surface action potentials with respect to the purely resistive model and a reduction in the amplitude of the fiber start-up and end-effects. These differences were most pronounced at electrode locations farthest from the active fiber. Removing the highly conductive blood vessels resulted in an increase in action potential amplitude at all electrode sites. This effect was greatest at electrodes located directly above the blood vessels. It is concluded that accurate modeling of the limb geometry, tissue capacitance and fiber curvature is important if the specific shapes of the action potentials are of interest. However, when more qualitative features such as the rate of decay of the EMG amplitude are the primary concern, then an idealized cylindrical model provides a close approximation.

399 - EMG Variables and Fiber Type Distribution in Elite Athletes

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Introduction: Muscular composition is usually assessed via bioptic and istochemical analysis. The high cost and the ethical problems associated to such procedures limit their use. In addition, the information obtained from small bioptic specimens is not necessarily representative of the whole muscle. These drawbacks motivate the development of alternative non-invasive methods for fiber type distribution assessment. Functional non-invasive assessment of skeletal muscles is usually obtained with the study of muscle fatigue. One widely used method, consists in the assessment of the maximal voluntary contraction (MVC) and of the inability to repeat such MVC after a fatiguing exercise. An alternative to the study of mechanical variables is the evaluation of the EMG signal and of its modifications during a fatiguing exercise, as function of time and muscle composition. The aim of this work is to assess if it is possible to obtain a non invasive tool for the estimation of muscle composition based on time courses of EMG variables during a fatiguing exercise.

Methods: The variables selected for the EMG approach were the mean frequency (MNF) of the EMG signal spectrum and the conduction velocity (CV). They are correlated, even if not exclusively, with the decrease of pH due to the increase of metabolite products during fatiguing contractions. Two groups of athletes were selected at the extremes of the available spectrum of fiber type distributions. Ten male sprinters (100 m and 200 m) were compared with a group of ten long distance runners with average age of 21.0±2.8 years for group 1 and 20.6±3.9 years for group 2 (NS, Mann-Whitney U test). Since no bioptic data were available, we assumed the maximal type II fiber concentration for the sprinter group and the minimal for the long distance runner group. These assumptions are based on results available from the literature, obtained with invasive techniques (intramuscular stimulation and/or biopsies).

Signals were recorded from the vastus lateralis (VL) and vastus medialis (VM) muscles of the dominant limb of each subject during fatiguing voluntary isometric contractions at 80% MVC sustained for 30 seconds. Linear electrode array technique was used in order to select the proper channel(s) between innervation zone and tendons for estimation of the EMG variables.

Results: Results show significant differences for the CV rates of change (both absolute and normalized with respect to the initial value), that were found always greater in the sprinter (-0.013±0.009 Hz/s and -0.25±0.21 %/s) than in the endurance group (-0.001±0.005 Hz/s and -0.08±0.14 %/s) (VL: p=0.015, VM: p=0.034, Mann Whitney U test). No differences were observed in the CV initial values and in MNF rates of change, while MNF initial values recorded from the VM was found greater (119.6±25.1 Hz) in the sprinter group than in the endurance group (99.2±12.1 Hz, p=0.016 Mann Whitney U test). No statistically significant differences were found in the subcutaneous tissue thickness between the two groups.

Discussion: These findings are in agreement with others already available in which the information about the fiber type was obtained in invasive manner. Moreover these results confirm that it is possible to distinguish different athlete groups on the basis of myoelectric manifestations of fatigue and that CV and MNF can be considered promising EMG variables to be used for a non invasive assessment of the athlete's phenotype.

421 - Effect of Local In-Homogeneities in the Subcutaneous Tissue on Muscle Fiber Conduction Velocity Estimates Assessed With a Novel Analytical Surface EMG Model

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Introduction: most surface EMG models considered space invariant systems. Space invariance in the direction of propagation of the source (action potential) implies that the volume conductor is both homogeneous and geometrically invariant along this direction. For infinite fibers, signal detection from any location along the space invariant direction provides the same potential shape with a delay, which is far from practical cases. The aims of this study were 1) to develop an analytical model of surface EMG generation in a volume conductor with local spherical in-homogeneities (non-space invariant system), and 2) to apply this model for the analysis of sensitivity of CV estimates to local in-homogeneities.

Methods: we considered a planar volume conductor made of muscle tissue (anisotropic) and a fat layer (isotropic). The impulse response of this system without in-homogeneities in the layers will be termed "in-homogeneity free solution" of the problem and was provided previously [1]. The effect of a local spherical in-homogeneity in the isotropic layer is described adding a perturbation term to the in-homogeneity free solution. This term is a series of harmonic functions decaying at infinity [2]. We considered the first two terms of this series, thus obtaining an approximate solution. Moreover, in the case of more than one in-homogeneity, we neglected the mutual effects between the perturbation terms of the in-homogeneities. The approximations introduced can all be evaluated analytically and imply constraints in the selection of the geometrical relations between the source and the in-homogeneities. This selection was performed so that the worst case approximation error was smaller than 5% of the perturbation term. The model was applied to simulate single fiber action potentials detected by double differential filters. CV of the simulated potentials was estimated with a multi-channel approach [3]. The interelectrode distance (IED) was 5 or 10 mm, and the number of EMG channels 2, 3, or 4. In each simulated condition, three spherical in-homogeneities (1 mm radius; conductivity 10 times that of the fat) were located in 25 random positions within a 4 mm thick fat layer.

Results: the CV estimates depended on the location of the in-homogeneities with respect to the fiber and detection electrodes. The variability of the CV estimate in the 25 conditions with random location of the in-homogeneities was significantly affected by the number of channels and IED used for the estimates. The maximum percent variation of CV estimates over the 25 conditions decreased with the number of channels and IED: 19.6% (2-channel), 12.1% (3-channel), 6.4% (4-channel), for 5 mm IED, and 12.0% (2-channel), 5.2% (3-channel), 2.4% (4-channel), for 10 mm IED.

Conclusion: the novel model developed allowed the analysis of the sensitivity of multi-channel CV estimation methods to local tissue in-homogeneities. The degree of variability of CV estimates as well as the effect of increasing the number of channels and IED obtained by the simulations were in agreement and explained previous experimental findings [4]. It is concluded that multi-channel methods for CV estimation significantly reduce the sensitivity of CV estimates to small electrode displacements in the presence of tissue in-homogeneities. This reduces the variability of the measure when performed on the same subject on different occasions, and thus improves reproducibility of the results [4].

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429 - Signal Quality Evaluation in Multichannel Surface-EMG

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Introduction: Signals of low quality are found in multichannel surface-EMG (MC-SEMG) recordings due to power line interference, variations in electrode-skin contact and motion artefacts, etc. Such signals corrupt estimations of variables and degenerate basic relations. Therefore it is crucial that they are excluded from the processing or possibly filtered out. To minimize the problem careful preparations must be done (Clancy et al, 2002). However, using multichannel systems in practice, there is a high risk of getting some signals of low quality, especially during dynamic contractions.

Methods: The proposed method was a modified version of the bivariate boxplot (Goldberg and Iglewicz, 1992). Each channel was characterized by two variables (represented by the X- and Y-axis in figure 1a) calculated in a running time-window. Low quality was detected in each window using a boundary constructed of four quarter ellipses and the quartiles of the variables. The overall quality for all channels was displayed as a quality map. Experimental MC-SEMG data were obtained using a 13 by 10 electrode-grid system (modified ActiveOne, BioSemi, Amsterdam, Netherlands).

Results: Figure 1a) shows examples of three channels detected with poor signal quality during a time-window and b) shows the overall quality map. The method was evaluated by visual examination of the signals and to this extent the performance was satisfactorily.

Conclusions: The proposed method was computer effective and well suitable for an on-line application. In addition, by varying the window length, short- and long-term quality can be evaluated during isometric aswell as dynamic contractions.

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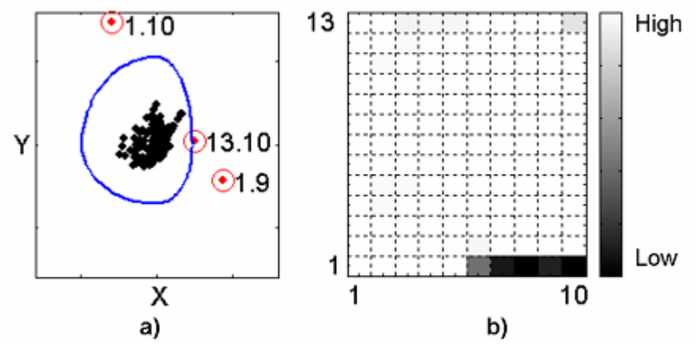

Figure 1. In a), an example of detected channels, characterized by the variables X and Y, with low quality is shown for a time-window. The 13.10 corresponds to an electrode position at row 13 and column 10. The overall quality map for the 13 by 10 channels is shown in b.

434 - Parametric Deconvolution for the Calculation of Dynamic Trunk Stiffness

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Introduction: Spinal stability is related to active stiffness of the trunk musculature1 but accurate measurements of trunk stiffness and dynamics are currently unavailable. Nonparametric methods reveal the system dynamics in the form of an impulse response function (IRF). Once established investigators can often recognize the system structure and order so as to parameterize it, e.g. compute trunk stiffness2. The goal of this study was to establish techniques to quantify trunk kinematic response to force perturbation and determine the accuracy of representing the trunk dynamics as a 2nd-order system.

Methods: Healthy adult subjects (9 males, 7 females) wore a harness with a cable attached to a servomotor such that isotonic external flexion loads of 70 N, 105 N, and 135 N were applied at the T10 level of the trunk. A pseudo-random stochastic force sequence (bandwidth 0-50 Hz, amplitude ± 30 N) was superimposed on the preload and measured (1000 Hz) by a force transducer (Figure 1a). These force perturbations caused small amplitude trunk movements recorded using IRED motion analysis at 200 Hz (Figure 1c). Nonparametric impulse response functions (IRF) of trunk dynamics were determined using a time-domain matrix solution involving the input (force) auto-correlation and the input/output (force/angle) cross-correlation, $C_{xy} = \Delta t\, C_{xx}$ IRF (Figure 1b). 2nd-order behavior was determined by a least-mean-square fit of trunk mass (M), damping (B) and stiffness (K) to $IRF = M\ddot{\theta} + B\hat{\theta} + K\theta$. Force-perturbation data were convolved with the parametric model to estimate movement dynamics. Quality of the model was determined by comparing estimated and observed motion variance accounted for (VAF).

Results: The nonparametric transfer functions indicated that the dynamics of the trunk disturbed by random force impulses could be represented by an underdamped 2nd order system. Mean VAF was 90.8% indicating the model accurately represented active trunk kinematic response. The accuracy of the kinematic representation was not influenced by trunk exertion level, fatigue or gender (Table 1).

Conclusion: This series of studies was the first to apply dynamic systems analyses of pseudorandom perturbations to quantify trunk kinematic response. Nonparametric shape suggests the system could be represented as a 2nd-order system. The high mean VAF values show that this method is accurate and robust against several experimental variables.

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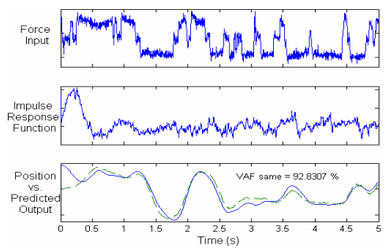

Mean VAF (all trials) = 90.8%	
Gender	**Mean VAF**
Males	90.5%
Females	91.1%
Fatigue	**Mean VAF**
Pre-fatigue	90.5%
Post-fatigue	91.0%
Preload	**Mean VAF**
75N	90.1%
105N	91.2%
135N	90.9%

444 - Observing Time-Frequency Characteristic Changes with Empirical Mode Decomposition on Semg of Lower Back Muscles under Static Loads

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Introduction: Surface EMG is useful to studies of mechanism of functional activities and fatigue in low back muscles. However, as sEMG is non-linear and non-stationary in nature, it is difficult to describe sEMG attributes with conventional linear analytics. Recently, Empirical Mode Decomposition Method (EMD) introduced by Huang et al emerged promising to characterise these non-linear natural signals. EMD is adaptive as it is based on the local characteristic time scale of signals. EMD decomposes the signal into a series of intrinsic mode functions (IMFs). Putting IMFs through Hilbert- transform will reveal instantaneous time-dependent frequencies of IMFs. The final result is an energy-frequency-time distribution, designated as Hilbert-Huang spectrum (HHS). The integral of HHS renders the marginal spectrum of Hilbert spectrum (MSH). This pilot study applied EMD on sEMG of lower back muscles with regard to time-frequency characteristic changes induced by static loads.

Methods: Subjects were 10 male volunteers aged 27.9±8.3. The Biering-sorensen testing (BST) was implemented to induce static load on lower back. Subjects lay prostrate on a test bench with legs and hips fixed so that they could extend their upper bodies and maintain their trunks parallel to the floor for 60 seconds in the air. The sEMG signals from right-side low back erectors of L2-L3 were recorded for 60 seconds. Signals during the first, middle and last 10 seconds were processed with EMD to derive the IMFs. The time-frequency characteristic changes were analysed combining HHS and MSH results.

Results: Under static loading, the sEMG energy mainly concentrated in the range of 10-50Hz with some individual differences. Within this range HHS showed discrete energy concentration. Comparatively, MSH showed 2-4 peaks of high energy density and these peaks showed no obvious shifting with increasing static loading time. The highest energy peak emerged within 11 Hz to 23 Hz (mean=16.3 Hz). Above 50 Hz, the energy distribution showed a random pattern and reduced rapidly with the increasing frequency. The comparison among results from the three 10 second periods were made for HHS and MSH. No obvious time-frequency difference was found in HHS. In MSH, the frequencies where energy density peaked were 17.6±3.5Hz, 15.2±2.7Hz and 17.1±3.8Hz for the first, middle and last 10 seconds. However, these peak frequencies didn't differ statistically. Above the 10-50 Hz range, the probabilities of signal energy attenuated hyperbolically with the increasing frequency. The attenuation accelerated with increasing loading time.

Discussion: Although both describe energy-frequency distribution, MSH is different from FFT intrinsically. MSH represents statistically the accumulation of all signal amplitudes as EMD grasps signal attribute in local domain and needs not assume linearity or time-invariance. The sEMG energy observed in this study concentrated within 10 Hz-50 Hz and this differed from conventional range of 50 Hz-150 Hz. In MSH, 2-4 energy density peaks emerged in domain of 11 Hz-23 Hz and these peaks showed no obvious shifting with increasing loading time. This observation suggests that the attenuation of signal energy above 50 Hz could be due to the gradual decrease of activities of fast motor units. Results of this study suggest that EMD and analysis on HHS and MSH can be used to describe sEMG energy-frequency-time distribution and their changes under static loads. Further efforts are needed to derive parameters to quantify these characteristic changes of muscle activities and fatiguing mechanism.

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445 - Linearly Fitting EMG-Impulse Proportionality in EMG Tuning Analysis of Arm Pointing

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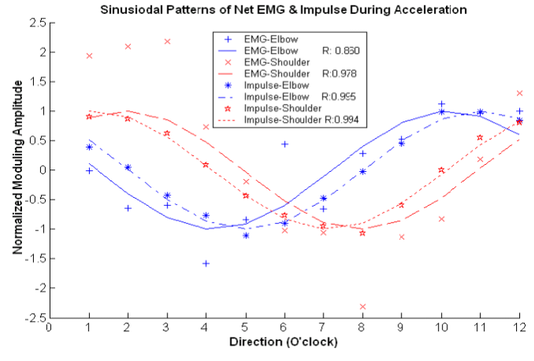
Introduction: sEMG provides us a window to look into CNS control on human motor system. However, due to 3-D geometric structure of muscles, only limited portion of muscle activities can be recorded and its countability could be distorted by noisy circumstance. This incompleteness often leaves our EMG tuning analysis less informative. A statistical approach was exploited in this study to estimate complete group EMG activity of agonist-antagonist muscle pairs corresponding to mechanical joint moment synergism.

Methods: To examine the patterns of joint torque and relevant EMG activation, six subjects performed finger pointing from a center point to 12 targets located according to the hours of a clock in a sagittal plane. sEMG activity from the biceps, triceps and anterior and posterior deltoids were recorded while kinematical marks at shoulder, elbow, wrist and index finger tip were monitored optically. Dynamic muscle torque was calculated by inverse dynamics and torque related EMG was integrated with the gravity-induced portion subtracted. Data from all 12 directions were processed through least-square fitting for their relevant correspondence. The count-clock impulses and flexor EMGs were positively signed whereas clockwise ones signed negatively. In the expression $Y = aX_1 + bX_2 + C$ (1), Y stands for net impulses, X_1 stands for flexor EMGs and X_2 stands for extensor EMGs around a subject's joint. Rewriting (1) as $Y = a(X_1 + b/aX_2) + C$, then $(X_1 + b/aX_2)$ is the proportional weighted summation of the agonist -antagonist muscle activities contributing to torque production and Y is the resultant impulse from these activities. Applying the ratio b/a from (1), another least-square fitting $Y = AX + C$ (2) results in the relevancy between net impulse Y and net EMG X $(X_1 + b/aX_2)$. The linear fitting (2) indicates the proportionality between muscle activity and dynamic output.

Results & Discussion: The net impulses and net EMGs comprehended the motor activities statistically without dealing every neuromechanical detail around the joints. Further analysis for directional tuning yielded consistent modality of key control factors such as initial EMG rising rate, EMG centroid and EMG co-activation. Fig 1 shows the sinusoidal fitting for net Impulse and net EMG with 12 directions. Considering the complexity of neuromuscular system and the noisy background of EMG recording, this statistical linear fitting procedure showed to be a practical method to estimate real world neural control mechanism in a circumstance where data incompleteness and heavy noise could impede analytical investigation.

Fig 1 Sinusoidal fitting for net Impulse and net EMG with directions at both Shoulder and Elbow joints from data of subject S during acceleration.The scattering points are measured values and the lines are regression results. R indicates the relation between regression and measured values. The regression intercept (b_i) and slope(a_i) was used to transform amplitude values Y as: $Y = (Y-b_i)/a_i$



467 - Assessment of the Accuracy of Extraction of the Motor Command through the Pulse Density Demodulation Processing Utilizing Synthetic Electromyogram

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It has been a crucial issue that the amplitude of the rectified and smoothed electromyogram does not proportionally correspond to the degree of muscle contraction in the intense range. However, it is shown in this report that the motor command for controlling the frequency of neural pulse generation for muscle contraction can be extracted accurately by using the pulse density demodulation processing of the electromyogram. In this processing, pulses were detected from as many motor units of a muscle as possible on the interference waveform, and the change in the pulse density was derived. The proportional correspondence to the motor command was restored by supplying to the detected pulse density the number of pulses which were undetectable due to the synchronization among the motor units. As the real motor command cannot be observed, accuracy of the extraction was ascertained by utilizing the synthetic electromyogram. In the computer simulation, the motor command was increased stepwise as shown in the left of Figure 1, and neural pulses were generated by specifying the sensitivity and delay of firing characteristic of each motor unit. The generated pulse density is shown by the upper bold line. By applying the bi-phasic action potential waveform and specifying attenuation caused by the distance of each motor unit from the electrode, the interference waveform was synthesized. The change in detected pulse density averaged through 40 msec running window is show by the lower bold line. The theoretically detectable pulse density with different span of synchronization are indicated by thin lines. They were calculated based on the occurrence probability of the synchronization in the span, which was measured in sampling interval of 1/8 msec. The detected pulse density was supplied by referring to the span of synchronization, which was predicted by the setting of threshold of pulse detection algorithm, and it became reasonably close to the generated pulse density as shown by upper bold line in the right of Figure 1. On the other hand, the change in amplitude of the interference waveform after the both side wave rectified and smoothed through the same running window is indicated by lower bold line. The amplitude showed a theoretically unrestorable deviation from the generated pulse density when it became higher.

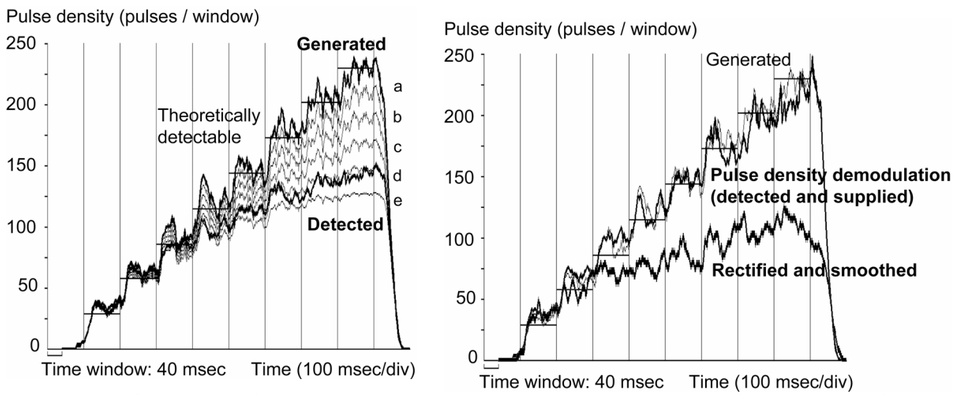

Figure1. Left. Changes in generated, detected, and theoretically detectable pulse density. Span of synchronization: a; 1, b; 2, c; 3, d; 4 and e; 5 sampling intervals.

Right. Comparison between the pulse density demodulation and the rectified and smoothed interference waveform.

468 - Application of the Pulse Density Demodulation Processing To Observed Electromyographic Waveform

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Previously, the present authors ascertained, by utilizing synthetic electromyographic waveform, that the time-varying pattern of the motor command, which controls generation frequency of neural pulses for contraction of a muscle, was extracted with a reasonable accuracy by the pulse density demodulation processing. In this report, possibility of applying the pulse density demodulation processing to the observed electromyographic waveform was examined. The material used was the electromyogram observed by four channel bipolar surface electrodes with 5mmΦ in diameter, which were attached on the adult male soleus muscle. The action was the long distance running on the treadmill with the stride period of 2/3 sec. The extracted time-varying patterns of the successive strides are superposed on the display by adjusting their phases at the time point when the rising slopes crossed a half of average peak amplitude. As the results, the patterns obtained by the pulse density demodulation processing were similar among 14 strides, as shown in the left of Figure 1. Those patterns were running averaged through the square time window of 40 ms. Pulse density was about 100 pulses per 40ms at around the peak. As such amount of perturbation could occur in the repeating running action, those patterns are considered to demonstrate the intrinsic nature of the motor control command for generation frequency of neural pulses. On the other hand, the patterns obtained by the both side wave rectifying and smoothing with the same time window deviated considerably among the strides in their amplitudes and widths, as shown in the right of Figure 1. This is because the envelope of the interference waveform of electromyogram is influenced by the attenuation of action potential due to the distance between each motor unit and electrode, even though the generation frequencies of the neural pulses are the same. Method of predicting the most appropriate pre-processing for each of the observed interference waveforms from their correlation functions was also investigated, in order to improve the performance of the pulse density demodulation processing.

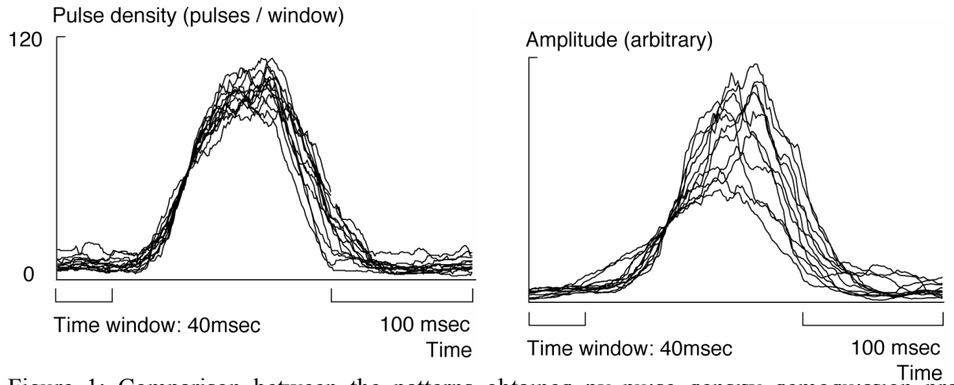

Figure 1: Comparison between the patterns obtained by pulse density demodulation processing (left) and by rectifying and smoothing (right) for the observed electromyogram.

Innovation in EMG

019 - A Novel Electromyographic Technique for the Assessment of the Deep Cervical Flexor Muscles
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Acknowledgment: Supported by SBIRs to Delsys - NASA (NAS9-98035) and the NationalCenter for Medical Rehabilitation Research of NICHD (2R44 HD35412).503 - A Telemetry System for Monitoring Physiological Parameters in Cyclists
503 - A Telemetry System for Monitoring Physiological Parameters in Cyclists

019 - A Novel Electromyographic Technique for the Assessment of the Deep Cervical Flexor Muscles

D. Falla [1], G. Jull [1], A. Rainoldi [2,3], R. Merletti [2], P. Dall'Alba [1]
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Introduction: Of fundamental importance in the cervical spine, are the deep cervical muscles, longus colli and longus capitis, whose histological and morphological design indicate their role in support of the cervical lordosis and the cervical joints. Accordingly, there is a particular focus on these muscles in assessment and in the rehabilitation of patients with neck pain. To date, the deep cervical flexor (DCF) muscles have been studied using techniques such as a) computer modeling b) histological analyses and c) imaging studies. However, activation of the DCF muscles has not been recorded in a neck pain population. Accessibility of the DCF muscles has been the main limitation, which has prevented direct assessment. Several decades ago, fine wire electrodes were used to measure these deep muscles however studies were limited to 'healthy' subjects and so give little information that would direct the development of treatment for patients with neck pain. Given the complexity and proximity of nearby structures such as the lymphatic system, the sympathetic chain, vagus nerve and the carotid artery, the technique of fine wire EMG to detect DCF muscle activity is extremely difficult and highly invasive and thus unsuitable for wider application in neck pain populations. A less invasive, direct measure of the DCF muscles would provide the opportunity to significantly advance current knowledge of the nature of the impairment in these muscles in individuals with neck pain syndromes.

Methods: A novel approach has been developed to directly measure myoelectric signals from the DCF muscles. Following application of a local anaesthetic spray, custom electrodes are inserted via the nose and are fixed by suction to the posterior mucosa of the oropharynx overlying the longus capitis and longus colli muscles. The reliability of the measure was examined by repeated EMG recordings during the performance of staged cranio-cervical flexion, the anatomical action of the DCF muscles. The validity of this technique to detect DCF impairment was evaluated by comparing EMG recordings in neck pain patients and controls during staged cranio-cervical flexion and during postural perturbations.

Results: A strong linear relationship was evident between DCF EMG amplitude and incremental stages of cranio-cerivcal flexion ($p < 0.0001$) confirming accurate detection of DCF muscle activity. Normalized DCF root mean square values demonstrated good repeatability with standard error of the mean values in the range 6.7 to 10.3%. Studies have demonstrated reduced EMG amplitude and delayed activation of the DCF muscles in patients with neck pain compared to controls during staged cranio-cervical flexion and postural perturbation tasks.

Conclusion: A novel technique for recording the DCF muscles has been developed based on established methodology coupled with innovative technology. This method has shown to be a reliable and valid measurement of the DCF muscles. To date, this novel measure has helped to unravel the complexity and multifaceted nature of cervical muscle dysfunction, which occurs in patients with neck pain.

037 - Automatic Speech Recognition Using Myoelectric Signals

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Introduction: A common application of myoelectric signal (MES) classification is control for powered prostheses. In this paper, we discuss an alternative application: automatic speech recognition (ASR). MES ASR can be used as a user interface for a voice prosthesis. MES ASR can also serve as an effective complement to acoustic ASR systems, improving their robustness in noisy environments.

Methods: Acoustic speech and five channels of facial MES were collected from five English speaking males (S1-S5), using a 10-word vocabulary ("zero" to "nine"). Acoustic white noise at six levels of intensity (0, 6, 9, 12, 15, 18dB) was introduced during data collection. Individual word utterances were segmented into 1024ms records, pretriggered 500ms prior to the start of speech. MES classification was performed using a 14-state, left-right hidden Markov model (HMM), using the RMS values and 8 mel-frequency cepstral coefficients as features. HMMs were trained using data from the 0 and 6dB noise level and tested on the remaining data.

Results: Although classification accuracy (Table 1) appears to decrease with increasing noise, this behaviour is dominated by results from S1. If there is an effect of acoustic noise on MES ASR (e.g. Lombard effect), it is small relative to the classifier's variability

Conclusions: Results demonstrate that MES ASR can be used in a standalone system (e.g. voice prosthesis). Insensitivity of MES ASR to a large range of acoustic noise also demonstrates its potential to be an effective complement to acoustic ASR systems, especially in noisy environments.

Table 1 Classification accuracies

Noise	9dB	12dB	15dB	18dB
S1	96.25%	93.75%	92.50%	87.50%
S2	83.75%	85.00%	88.75%	83.75%
S3	90.00%	83.75%	81.25%	82.50%
S4	83.75%	85.00%	83.75%	81.25%

050 - Clinical Decision Support Using Hybrid Fuzzy Analysis Of Quantitative EMG Data

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Introduction: Quantitative EMG (QEMG) provides information useful for diagnosis of muscular disease, which is not yet utilized by many physicians, primarily due to a lack of familiarity with the relationships between values in this new data set and disease state. Introduction of an interpretive tool will allow physicians to better understand and hence more often take advantage of QEMG data. A hybrid system is described which maps significant features discovered in QEMG data using a fuzzy system that characterizes the degree of disease involvement.

Methods: This new hybrid system used techniques from information theory and fuzzy logic systems (FLS) to create input membership functions and associated fuzzy rules for a clinical decision support system based on QEMG data. Marginal entropy based discretization was used to produce membership functions. A pattern discovery system, derived from information theory and based on analysis of adjusted residuals, was used to analyse training data and produce a rule-set describing relationships between QEMG features and disease states. Disease characterizations were then made based on these membership functions and rules. Rule based logic is applied to provide a degree of certainty in the characterization produced. The hybrid rule-based fuzzy logic system was trained using simulated QEMG data and its performance was evaluated against FLSs constructed using total simulation model knowledge and using human expert experience.

Results: Initial verification of this system classifying individual simulated MUPs indicated that the hybrid system, model knowledge and human expert system results were all found to be comparable with overall classification rates of approximately 67.5% correct classification.

Discussion: The hybrid results from the characterization of individual MUPs were encouraging and indicate that the pattern discovery methods combined with fuzzy logic can be useful. Clinically, muscle disease is characterized by combining the characterization of a group of individual MUPs. This approach will be followed by this hybrid system to further refine the analysis through weighted combined voting. The combined classification will be reported to the physician as a final characterization describing the overall state of involvement of simulated tissue, including a degree of confidence in the characterization. Decisions from clinical examinations may be improved by incorporating the system results.

The system is designed to run on a desktop computer similar to those currently provided for quantitative analysis of EMG data.

064 - Relationship between Contact Pressure and Contact Impedance in the Ring Shaped EMG Measurement System

Hiroyuki Manabe (NTT DoCoMo Multimedia Laboratories)
Masaaki Fukumoto (NTT DoCoMo Multimedia Laboratories)

A ring shaped EMG measurement system is proposed (Fig. 1). This system consists of two parts: a ring shaped electrode, which has a preamplifier and is wrapped around a finger; and a main amplifier, which is worn on the wrist. When measuring, the operator presses the finger-mounted electrode against the measurement point. This system can improve usability compared with the conventional electrode, however it was unclear whether the system performance would be kept when the pressure was changed. This paper clarifies the relationship of pressure and contact impedance.

In the experiment, the pressure and impedance between 2 contacts within a ring shaped electrode pressed against a cheek were measured every 1 sec. The contact material is silver, dimension is 10mm x 1mm, and the contact spacing is 10mm. The impedance was measured at 10Hz. The measurement was performed under 2 cases; steady pressure and variable. Since the impedance decreased with contact time, the evaluation was performed using data measured some 5 minutes after contact began.

With steady pressure, the impedance decreased as time passed. With variable pressure, the impedance increased when the pressure was decreased, and decreased when the pressure was increased (Fig. 2). However, the impedance changes due to pressure changes are smaller than the changes seen between 10 minutes steady pressure. This result confirms the effectiveness of the ring shaped EMG measurement system.

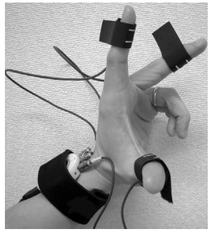

Fig. 1: Ring shaped EMG measurement system

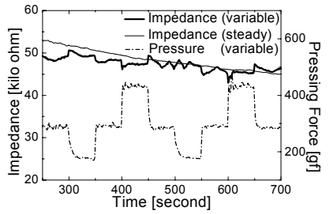

Fig. 2: Relationship between pressure and impedance

119 - The Investigation of Motor Unit Recruitment Using Inhomogeneous Muscle Activation

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Introduction: Studies applying multi-channel surface electromyographic (SEMG) have revealed spatial inhomogeneous activation of muscles in isometric contractions with different force levels. This spatial inhomogeneous muscle activation can be caused by a non-uniform distribution of motor units (MUs). The aim of this experiment was to examine a method to quantify the inhomogeneous activation with multi-electrode SEMG, in order to use SEMG distribution changes to investigate motor unit recruitment strategies.

Methods: Fifteen subjects participated in the experiment. A KINCOM dynamometer, a visual force feedback device and a 130-electrode SEMG grid placed over m. biceps brachii were used in the experimental setup. The subjects performed three isometric contractions with force sinus modulations from 0 to 80 percent of maximal voluntary contraction. First, bipolar root mean square (RMS) of all electrodes was analyzed in time periods of 500ms. Thereafter, correlation coefficients of the RMS values of the bipolar electrode matrix at one time instant with each separate time instant of the entire recorded period were performed.

Results: The RMS of all EMG channels changed in a consistent manner in accordance to the force modification in all subjects. The RMS correlation varied with altering RMS amplitude in all subjects. The RMS correlation changed rapidly at low contraction levels, with minor variation at higher contraction force levels. The change in RMS correlations seems to be divergent in the ascending and descending force levels.

Discussion: The consistent changes in the distribution of EMG amplitude imply that this method is a reliable tool to study spatial inhomogeneous muscle activation, and that recruitment of MUs not are randomly scattered, but evolve in distinct regions of m. biceps brachii. The largest change in RMS correlations at low contraction levels fits with the notion that mainly recruitment of MUs causes force generation at low contraction levels. The asymmetrical RMS correlations in ascending and descending force levels imply the existence of a dissimilar force gradation mechanism in increasing and decreasing force generation.

162 - Using a Mapping Index to Assess Muscle Fatigue

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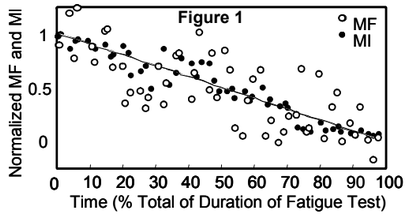
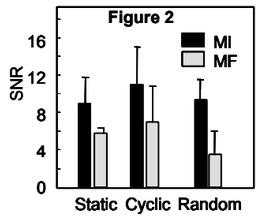
Introduction: This work proposes a promising new muscle fatigue assessment strategy. While preliminary in its development, it can be used to non-invasively assess muscle fatigue even during random contractions in which muscle force and/or joint angle are changing unpredictably. Using a fully connected multilayer perceptron, a mapping function is tuned to generate an estimate of fatigue from a segment of myoelectric signal, given four time-domain features derived from the segment. Tuning is achieved using baseline data segments representing a linear progression of fatigue.

Methods: To test the strategy, 5 participants engaged in two sets of fatigue tests. Each set consisted of a static, cyclic and random test. Data from the first test were used as baseline data to tune the function. Data from the second test were used to test the strategy. A fatigue estimate, the mapping index (MI), was calculated from every 10 sec test data segment, along with a mean frequency (MF) estimate for comparison.

Results: Figure 1 depicts normalized results from the random test for one participant. Figure 2 depicts SNR (Dynamic Range/Variance) results for all three tests averaged across all participants.





Discussion: Results indicate that MI is capable of tracking fatigue with less variability than MF under static, cyclic and random conditions. The variability of MI, even under random conditions, is sufficiently low to validate the strategy as a viable approach to muscle fatigue assessment.

207 - Crosstalk and Coactivation in Bipolar Surface EMG Data: A New Methodology for Detection, Discrimination and Quantification

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Introduction: The occurrence of crosstalk in surface EMG measurements is a well known problem. Different approaches to minimize crosstalk or to completely eliminate it in most cases do not lead to satisfying results. However, crosstalk becomes a serious problem, if the information about the muscular coordination pattern is used for clinical diagnosis or therapy planning. Therefore at the Helmholtz-Institute a methodology has been developed, which allows the determination of a confidence value for the assumption that an EMG signal is not affected by crosstalk. The applicability of this technique has been experimentally validated in several patient measurements.

Patients & Methods: We analysed 28 children, age range 5-10 years, suffering from a lesion of the plexus brachialis nerve. Measurements included the recording of conventional bipolar surface EMG of m. biceps brachii and m. triceps brachii for an elbow flexion, according to the SENIAM standard. In a first step, the EMG phases of muscular activity were determined by an "on"/"off" phase detector. To quantify the likelihood of the occurrence of crosstalk for each patient separately, we introduced a "cross talk risk factor" (CRF). The CRF was calculated only from the "on" phases of the healthy side, based on the energy ratio between the antagonistic muscles. In a second step, a fuzzy system combined the information obtained from the commonly used cross-correlation and the CRF for the muscular active phases on the healthy side. The system then calculates a confidence value for the non-existence of crosstalk in the considered "on" phases for the contralateral (affected) side.

Results & Discussion: Preliminary results show that by utilising a fuzzy combination of cross-correlation and the CRF, the discrimination between crosstalk and coactivation becomes possible. In several case studies actual coactivation on the affected side was detected with high reliability, whereas on the healthy side the confidence value for coactivation was near zero.

228 - New Human Interface Using Surface EMG Signals

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Introduction: We usually use some devices for controlling a computer, a robot or for capturing the motion of the arm. The delay is existed between the movement and the measurement result. It becomes hard to use to this delay for the interface.

EMG signal reflects the muscle tension. We have been developing to estimate the joint torque, equilibrium point and joint stiffness from the EMG signals [1,2,3]. In this paper, we propose the human interface for controlling the robot and playing music.

Methods: We measured a few EMG signals for each joint to estimate an equilibrium posture or torque. Measure EMG signals are rectified and filtered with low cut off frequency. An equilibrium posture or torque was estimated from this filtered EMG signals.

Results:

Fig.1: Robot control

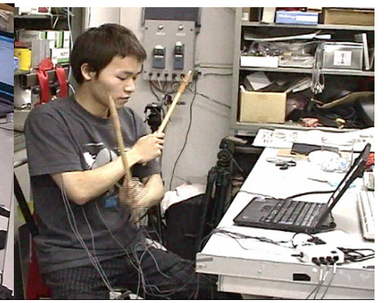

Fig. 2: Playing virtual drum

We show two examples of EMG interface. Figure 1 shows that AIBO robot is controlled by the EMG signals of forearm. The wrist movement was estimated from the EMG signals and the neck angles of the AIBO were controlled to become the same movement. Figure 2 shows that the subject is playing the virtual drum. Three positions of the shoulder and the strike movement were detected by the EMG signals. In this system, hi-hat, bass drum, snare drum and cymbal were simulated.

Conclusion: We proposed new human interface by EMG signals. This interface can do intuitively operation and be used by everybody.

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312 - EMG Pattern Classification Using Fuzzy Logic for Controlling Below-Elbow Myoelectric Hand Prostheses

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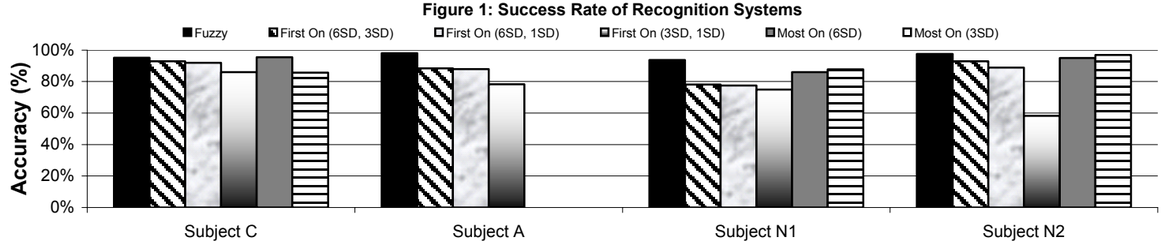
Introduction: We present a fuzzy logic algorithm for sample-by-sample classification of electromyogram (EMG) patterns for controlling trans-radial (below-elbow) externally powered prostheses. Fuzzy logic is advantageous for processing biomedical signals because it allows toleration of imprecise and contradictory data, and allows for patterns within sample data to be easily incorporated into the decision logic, along with expert and informal knowledge of the field. The system we describe has a 46 msec update rate. In contrast to current commercially available technologies that require recognition of a preset co-contraction pattern to switch between controlled states, the described system recognizes and responds to seamless transitioning from one active state to the next.

Methods: Five subjects (3 normals: N1, N2, N3; 1 amputee: A; 1 congenital: C) were examined, one of whom (N3) the real-time behavior of the system was tested on. Three to four control sites were located on each subject's intact arm / residual limb, based upon which motions produced the strongest and most reproducible signals. Automated fuzzy systems consisting of membership functions (using signal statistics) and inference rule bases (using fuzzy clustering) were generated and tested offline for each subject based upon EMG collected during the subjects' performing of the selected motions. Classification accuracies of the fuzzy system were compared to those achieved using conventional two-site EMG analysis. Lastly, we tested the system's real-time classification behavior by instructing subject N3 to repeatedly perform seamless transitions from one contraction state to another, and to deliberately generate motion artifacts to test the system's real-time stability.

Figure 1: Success Rate of Recognition Systems



Results: Figure 1 compares the sample-by-sample classification accuracies of the generated fuzzy systems to that of a "first on w/ hysteresis" algorithm (implemented in some Hosmer Dorrance Corp. systems) and a "most on" algorithm (implemented in Motion Control's Utah Arm). The fuzzy logic based algorithms perform as well as or better than these algorithms in classifying myoelectric patterns, reaching a level as high as 98%. Real-time analysis showed that the system successfully responded to seamless state transitions, only misclassifying EMG patterns 3 out of 170 times. It was observed that altering the inference rule base to effectively increase the fuzzy system thresholds could increase system stability.

Discussion: The fuzzy systems demonstrated the ability to continuously classify successive forearm motions, thus showing feasibility for seamless sequential control. A 46 msec update rate between classifications and a steady stream of correct classifications, as demonstrated in the system's real-time behavior, allow for a 98% classification accuracy to suffice. We believe the concepts demonstrated can be extended to continuous simultaneous classification (recognizing combinations of actions), an advantage not realized by the algorithms based upon a "first on method" or a "most on method" scenario. We believe this can be readily achieved through the addition of membership functions and the implementation of additional rules to cover the EMG patterns present during simultaneous activity of multiple DOFs.

Acknowledgements: Department of Veterans Affairs, Rehabilitation Research and Development Service administered through the VA Chicago Health Care System.

313 - Implantable Myoelectric Sensors (IMES) for Upper-Extremity Prosthesis Control – Independence of Multiple Intra-Muscular EMGs

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[1]VA Chicago Health Care System, Chicago, Illinois, USA.; [2]Northwestern University Prosthetics Research Laboratory, Evanston, Illinois, USA.; [3]Rehabilitation Institute of Chicago, Chicago, Illinois, USA.

Introduction: We are developing a multi-channel/ multifunction prosthetic hand/arm controller system capable of receiving and processing signals from up to sixteen Implanted MyoElectric Sensors (IMES) [1]. The appeal of implanted sensors for myoelectric control is that EMG signals can be measured at their source providing relatively cross-talk free signals that can be treated as independent control sites. Therefore the number of degrees-of-freedom that can be simultaneously controlled and coordinated in an externally-powered prosthesis will be greater than with surface EMG or mechanical control sites. To explore the issue of intra-muscular signal independence and the ability to control them, a single subject experiment was performed in which intra-muscular EMGs were obtained from Supinator and pronator teres, flexor carpi ulnaris and extensor carpi ulnaris, flexor pollicis longus and extensor pollicis, and flexor digitorum sublimas and extensor digitorum communicus. Choice of muscles was based on a desire to be able to independently control a two degree-of-freedom (DOF) wrist, and 3 DOF prosthetic hand [2]. The purpose of the experiment was to demonstrate that: (1) multiple independent control sites could be obtained using intra-muscular recordings, and (2) that an individual has the ability to voluntarily elicit a specific control site independently of the rest of the control sites.

Methods: Two percutaneous fine-wire intra-muscular electrodes, spaced about 15 mm apart, were placed in each target muscle. The location of the electrodes in each muscle was found using a clinical electromyography text [3]. The spacing of the electrodes was chosen to mimic the electrode spacing of the Alfred E. Mann Foundation (Valencia, CA) BIONII® package. The AMF BIONII® package will be use to house our implantable sensor. Once all the percutaneous fine-wire electrodes were located the subject was instructed to elicit a response from each electrode site independent of the other sites and to hold that response for 5 seconds. This task was repeated six times for each muscle. An 8 channel Noraxon Corp., (Phoenix, AZ) telemeter Telemyo 8 system (Sample rate 1400 Hz/channel, 10 Hz highpass cutoff, 500 Hz lowpass cutoff, gain of 2000) was used to collect the EMG data. **Results:** For the actual experiment we were able to locate and acquire data for six ½ differential EMG channels. The second electrode for the differential recording of the supinator failed to function properly so only a single-ended supinator recording was obtained. In all cases the commanded channel could be elicited at a substantially greater level than the other channels. However, the RMS voltage on some of the other channels was non-trivial compared to the commanded channel. The signals seen on the other channels are due to a combination of co-activation and/or cross-talk.

Discussion: While the level of cross-talk is non-trivial, the desired signals still have good signal-to-ratio and therefore more advanced controller systems can be used – such as our fuzzy-logic controller [4]. It is planned to repeat this experiment on more subjects, including individuals with trans-radial amputations.

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329 - The EMG Signal as a Pre-Symptomatic Indicator of Organophosphates in the Body

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Introduction: Organophosphate (OP) cholinesterase inhibitors form the active ingredient of nerve agents such as Sarin and Soman, as well as many of the estimated 25,000 brands of home and agricultural pesticides (1). The horrific effects of nerve agents have been well publicized, but it is not well known that OP compounds are responsible for over 20,000 reported toxic exposures per year in the USA alone (2). Exposure to high concentrations of OP compounds may result in death, and exposure to low concentrations produces a variety of treatable ailments such as muscle fibrillation, muscle cramping, muscle weakness, nausea, irritability, vomiting, diarrhoea, depression, apathy, and memory impairment (3, 4). Consequently, early recognition of the toxicity and timely intervention are important for effective treatment. Presently there are no means for detecting the pre-symptomatic presence of OP compounds. In this study we describe means for providing a pre-symptomatic index.

Methods: OP compounds produce their toxic effect through inhibition of the various forms of cholinesterase, the degradative enzyme for the neurotransmitter acetylcholine, which disturb the propagation of the action potential along muscle fibers (5). We injected daily doses of 10 - 15 ug/kg diisopropylfluorophosphate (DFP) in the right Rectus Femoris muscle of four rhesus monkeys and recorded the Electromyographic EMG) signal from the right and left Vastii Lateralis and Vastii Medialis muscle. Dosing was discontinued at the point of obvious symptoms of cholinergic over-stimulation. We found that as the dosing progressed the EMG signal presented an increasing number of short-duration gaps where the signal was uncommonly silent. An algorithm was designed to count the number of gaps that occurred in the EMG signal, and the number of gaps per second provided a Myo-Chem Index that indicated the degree of toxicity.

Results & Discussion: This phenomenological observation is consistent with the disruption of the propagation of the action potentials. When compared to the severity of the observed overt physiological symptoms, categorized according to a method modelled after Persson et al. (6), the Myo-Chem Index was found to provide an earlier indication of the presence of the OP compound. This observation, in conjunction with the facts that it is objective, quantitative and available in real-time, suggests that the index provides a useful means for protecting individuals at risk to low-level OP compound exposure.

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413 - Comparative Evaluation Case Study of the Abdominal Musculature Between Pregnant and Non-Pregnant Women During Isotonic Movement Through Surface Electromyography

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Introduction: The posture and biomechanic changes suffered during gestation result in, possibly, alterations in the dynamics of the contraction of the abdominal muscles. In this way, it becomes important to establish the recruitment of the abdominal musculature quantitatively, through its electric activity in pregnant and non-pregnant woman and to establish correlations between those two states. Due to the shortage of work published in this area, this study has as objective to evaluate the recruitment of the muscular fibers of the right and left straight abdominal muscles and of the right and left external oblique muscle in pregnant and non-pregnant women, using surface electromyography.

Methods: It was selected randomly within the students of the United Metropolitan University College, a 20 year-old pregnant patient, 39 weeks of gestation, realizing prenatal and a control subject of 20 years, physically active, both being of the same physical size. The patients were evaluated during the movements of trunk flexing, trunk flexing with rotation to the right and trunk flexing with rotation to the left in three series of isotonic contraction with intervals of 5 seconds among the series. The electrodes were put on the straight abdominal muscle two centimeters from the umbilical scar and on the external oblique muscle three centimeters and 45 degrees from the antero-superior ilíac spine.

Results: After the evaluation, it was possible to observe that the values of muscular recruitment during the accomplished movements were larger in the subject control, in other words, in the non-pregnant subject. The values obtained from the pregnant subject in the external oblique muscles right and left and straight abdominal right and left were, respectively: 13,2mv;11,8mv; 27,1mv; 37,6mv. In the non-pregnant subject, the obtained values were: 76,7mv; 75,9mv; 120mv; 106mv for the same movements.

Conclusion: During the trunk flexing, in both patients, the abdominal straight muscle presented larger electrical activity than the oblique external for what was already expected due to biomechanic action of such musculature. But during the trunk flexing with rotation to the left the left external oblique muscle (30,4mv) of the pregnant subject presented a higher value than the external oblique right (21,5mv), Such a fact, not keeping with the literature due to the biomechanic action of this musculature, whose function is rotation of the trunk to the opposite side. But what can actually be observed is that surface electromyography is a very useful evaluation resource in that it was possible to notice differences in the pregnant subject's muscular recruitment and of the non-pregnant subject's in isotonic situations, making possible to affirm that the pregnant subject presents a lesser muscular recruitment when compared to the non-pregnant subject. More research in this area is necessary in seeking to explain the mechanism of gradual loss of abdominal muscular recruitment during gestation, as well as its recovery after childbirth.

418 - Assessment of Muscle Fiber Conduction Velocity from Surface EMG Signals In Dynamic Contractions

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Introduction: muscle conduction velocity (CV) reflects fiber membrane properties. Estimation of CV has been mainly limited in the past to isometric contractions. Its assessment in dynamic exercises poses serious problems related to signal detection and processing which are addressed in this work. The main objectives of the study are 1) to present multi-electrode EMG detection systems specifically designed for dynamic conditions (in particular, for CV estimation), 2) to propose a novel multi-channel CV estimation method for application to short EMG signal bursts, and 3) to validate the methods proposed on experimental signals.

Methods: adhesive linear electrode arrays were developed for detecting surface EMG signals travelling along the muscle fibers during movement. A flexible support carries a linear array of printed silver electrodes, the connector and the interconnecting tracks. The electrodes are coated with a layer of silver chloride. The support is covered with a thin plastic layer that isolates the tracks while leaving the electrode surfaces exposed. A small hole for gel injection is lateral to each electrode. A disposable double-sided adhesive foam with pre-punched rectangular windows is applied on the flexible support, with the windows aligned to the electrodes. The array is placed on the muscle with its adhesive foam facing the skin. The cavities between each electrode and the skin are filled with electrolyte gel (20-30 μl), to ensure a stable electrical contact with the skin. The movement artefacts are minimal with such devices. In dynamic contractions the active motor unit pool may change rapidly over time, thus CV should be estimated from short signal portions (of the order of tens of ms). A CV estimate very local in time poses problems related to signal truncation and variance of estimation. Thus, a new multi-channel CV estimation algorithm was developed for dynamic applications. The algorithm provides maximum likelihood estimation of CV from a set of surface EMG signals with a Gaussian window limiting the time interval in which the mean square error between aligned signals is minimized. The standard deviation of the Gaussian window is selected according to the desired localization in time of the CV estimate. The minimization of the windowed mean square error function is performed in the Fourier frequency domain, without limitation in time resolution and with an iterative, computationally efficient procedure. The methods proposed were applied to signals detected from the vastus laterialis (VL) and medialis (VM) muscles during cycling at 60 revolutions per minute for four minutes (power 150 W). Ten healthy male subjects (age, mean ± SD, 27.4 ± 2.4 yr) participated in the study. CV was estimated from double differential derivations at fixed time instants within the bursts of EMG activity for VL and VM. The Gaussian window applied to the mean square error had standard deviation 30 ms. The trend of CV over time was assessed by the slope of the regression line fitting the CV values obtained from each revolution.

Results: travelling signals along the muscle fibers were recorded with negligible movement artefacts during the cyclic task. The standard deviation of CV estimation (SDE) with respect to the regression line was on average (±SE), over the two muscles, 0.21±0.02 m/s, for estimates from six double differential signals. This value is of the order of the SDE resulting in static contractions. At the beginning of the exercise, CV was 4.80±0.06 m/s and 4.77±0.06 m/s, for VL and VM, respectively. A significant trend (linear regression analysis) of decreasing CV over time, reflecting fatigue, was observed during the cycling task. In the 240 s, CV decreased by 0.62±0.07 m/s and 0.86±0.10 m/s, for VL and VM, respectively.

Conclusion: the innovative methods proposed allow the estimation of muscle fiber CV in dynamic exercises involving fast limb movements, with a new insight into the muscle fiber membrane properties during exercise.

486 - Sweat Test for Electro-Mechanical Stability of the EMG Electrode-Skin Interface

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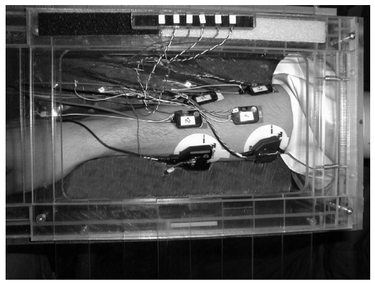
Introduction: Maintaining electro-mechanical stability between the surface EMG electrode and the skin when monitoring motor activity is an important task of the adhesive interface, particularly during vigorous motor activities. Signal noise, movement artifact, and loss of signal fidelity can degrade the EMG signal when sweat and motion are present. R&D efforts to develop more effective EMG sensors and adhesive skin interfaces for such conditions are hampered by a lack of standardized assessment procedures for electro-mechanical stability. This study describes novel assessment procedures for characterizing the electro-mechanical stability of surface EMG sensors under conditions of progressive sweat accumulation on the skin.

Methods: A cycle ergometer configured with a sealed test chamber for the forearm was devised to induce progressive sweat accumulation on the skin where surface EMG electrodes were positioned for evaluating electro-mechanical stability (see Figure). Electrode Peel and Mechanical Disturbance tests were developed and used in conjunction with the sweat test chamber to evaluate the electro-mechanical stability of commercially-available sensors and interfaces, as well as different prototypes. The Electrode Peel test jig used an electric motor geared to provide a pull force to the electrode/interface at a constant velocity and angle (12 in/min; 90 degrees). The device contained a non-compliant load cell that measured the force required to pull the electrode until loss of contact between the detection surfaces of the electrode and the skin occurred. The Mechanical Disturbance test used a custom-made leaf spring mounted to a support surface to deliver normal and shear forces to the forearm. Impulse and sinusoidal forces were produced while the subject grasped the handle of the device. Accelerometers were placed on the forearm to measure the resultant mechanical disturbances and to normalize motion artifacts from the EMG sensors. Two sets of experiments (n=24 healthy subjects) were studied following written informed consent procedures.



Results and **Discussion:** In one set of experiments, contouring the detection surface and using a more aggressive and waterproof adhesive for the interface was shown to increase the adhesive peel force associated with the sweat test protocol. In the second set of experiments, the Adhesive Peel and Mechanical Disturbance tests identified significant differences in electro-mechanical performance for different interface materials (e.g. hydro gels and surfactants) when applied to the same electrode.

Conclusion: The test procedures for quantitative assessment of electro-mechanical stability proved useful in suggesting design modifications to the detection and adhesive of surface EMG electrodes. Such changes may enhance performance under extreme real-use conditions.

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503 - A Telemetry System for Monitoring Physiological Parameters in Cyclists

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Introduction: New technologies based on micro-electronics have been leading to the development of valuable tools for the evaluation of physiological parameters, and for the optimization of athlete training. This work presents a new telemetry system for monitoring force and physiological parameters in cyclists. A previous version of this monitoring system [1,2] allowed for the measurement of forces in the pedals, electromyographic (EMG) signals from selected muscles, the position of the crank arm set, and the electrocardiogram. However this system is based on a cyclist simulator, and has to be used in a laboratory room. Moreover, sometimes the flexion of the cables causes spurious noise and undesirable interference. The new system allows the study of the cyclist performance on an actual outdoor racetrack. The new system uses radiofrequency for transmitting the following signals to a personal computer located far away from the bicycle: the horizontal and vertical forces applied to the pedals, the electromyographic signal, the electrocardiogram (ECG), and the position of the crank arm set.

Methods: The telemetry system consists of two radiofrequency links. The horizontal and the vertical forces on the pedal are measured, digitized and transmitted from the pedal to a receptor in the body of the bicycle. The receptor is connected to a microprocessor, which also acquires the EMG signals from leg muscles, the ECG, and the angle of the crank arm set. These signals are then transmitted to another receptor, which is connected to a personal computer, which receives the data. In this computer, there are programs for saving, displaying and processing the collected data.

Results: The telemetry system has very low power consumption. Moreover, it has a low volume and low weight. Thus, it does not interfere with the cyclist´s technique. An analysis software allows the management and processing of the received data. The communication with the computer is a full-duplex type, which allows the user to send commands to the telemetry system. Some of the features of the software include a diagram illustrating the forces applied to the pedals during the pedaling cycle, the intensity of the EMG signal as a function of time, and tools for fatigue analysis. The prototype is now undergoing a re-design stage, in order to make it more robust, and to make it easily adaptable to any bicycle, without the need for many changes in the bicycle.

Conclusion: The developed telemetry system is a very useful tool for the evaluation of athletes, and for the optimization of their training. Preliminary experiments have attested the good performance of the system. New testing protocols for evaluation of cyclists are being developed.

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Mechanomyogram

028 - Mechanomyographic Amplitude and Mean Power Frequency Versus Torque Relationships During Submaximal to Maximal Isokinetic and Isometric Muscle Actions of the Biceps Brachii

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Introduction The purpose of this investigation was to determine the mechanomyographic (MMG) amplitude and mean power frequency (MPF) versus torque (or force) relationships during isokinetic and isometric muscle actions of the biceps brachii.

Method Ten adults [mean ± SD age = 21.6 ± 1.7 yrs] performed submaximal to maximal isokinetic and isometric muscle actions of the dominant forearm flexors. Following determination of isokinetic peak torque (PT) and the isometric maximum voluntary contraction (MVC), the subjects randomly performed submaximal step muscle actions in 10% increments from 10% to 90% PT and MVC.

Results Polynomial regression analyses indicated that MMG amplitude increased linearly with torque during both the isokinetic (r2 = 0.982) and isometric (r2 = 0.956) muscle actions. From 80% to 100% of isometric MVC, however, MMG amplitude appeared to plateau. Cubic models provided the best fit for the MMG MPF versus isokinetic (R2 = 0.786) and isometric (R2 = 0.940) torque relationships, although no significant mean differences in MMG MPF were found from 10% to 100 % of isokinetic PT. For the isometric muscle actions, however, MMG MPF remained relatively stable from 10% to 50% MVC, increased from 50% to 80% MVC, and decreased from 80% to 100% MVC.

Conclusion The results demonstrated differences in the MMG amplitude and MPF versus torque relationships between the isokinetic and isometric muscle actions. These findings suggested that the time and frequency domains of the MMG signal may be useful for describing the unique motor control strategies that modulate dynamic versus isometric torque production.

033 - Mechanomyographic Time and Frequency Domain Responses of the Vastus Medialis Muscle During Submaximal To Maximal Isometric And Isokinetic Muscle Actions

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Introduction: The purpose of this study was to examine the patterns for the mechanomyographic (MMG) amplitude and mean power frequency (MPF) versus torque relationships during isometric and isokinetic muscle actions.

Methods: Ten adults (mean age ± SD = 22 ± 1 y) volunteered to perform isometric and isokinetic leg extension muscle actions at 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% of peak torque on a Cybex II dynamometer. A piezoelectric crystal contact sensor was placed on the vastus medialis to detect the MMG signal.

Results: Regression analyses indicated that for the isometric muscle actions, the relationships for MMG amplitude (R2 = 0.998) and MPF (R2 = 0.987) versus torque were cubic. For the isokinetic muscle actions, the relationships for MMG amplitude (r2 = 0.927) and MPF (r2 = 0.769) versus torque were linear.

Conclusion: The different patterns for MMG amplitude and frequency may reflect differences in the motor control strategies that modulate torque production for isometric versus dynamic muscle actions.

044 - A Comparison of the Mechanomyographic Amplitude vs. Isometric Torque Relationships from a Piezoelectric Crystal Contact Sensor and an Accelerometer

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Introduction: The purpose of this investigation was to examine the relationship between mechanomyographic (MMG) amplitude and torque during isometric muscle actions, and to compare the patterns of responses obtained from a piezoelectric crystal contact sensor (PEC) and an accelerometer (ACC).

Methods: Eight women (mean age ± SD = 20.4 ± 1.3 y) volunteered to perform isometric leg extension muscle actions at 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% of peak torque on a calibrated Cybex 6000 dynamometer. The PEC (Hewlett-Packard, 21050A) and ACC (Entran, EGAS-FT-10-/V05) were placed adjacent to one another on the vastus medialis to detect the MMG signal. The PEC amplitude, ACC amplitude, and isometric torque were normalized to the highest recorded values.

Results: Polynomial regression analyses indicated that the relationships for MMG amplitude versus torque were linear for the PEC ($r^2 = 0.875$) and ACC ($r^2 = 0.930$). No significant difference ($p > 0.05$) was found between slope coefficients.

Conclusion: The results indicated that MMG amplitude from the vastus medialis was linearly related to isometric leg extension torque production, and that the PEC and ACC provide comparable information regarding this relationship.

072 - MMG and EMG Responses of the Superficial Quadriceps Femoris Muscles During the Wingate Anaerobic Cycle Ergometer Test

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Introduction: The purpose of this investigation was to examine mechanomyographic (MMG) and electromyographic (EMG) amplitude responses of the superficial quadriceps femoris muscles (vastus lateralis (VL), rectus femoris (RF), vastus medialis (VM)) during the Wingate Anaerobic Test (WAnT).

Methods: Six healthy, adult females and four healthy adult males (age 21±1.2 y) volunteered to perform the WAnT on a calibrated Monark 894E cycle ergometer. Bipolar surface electrode arrangements were placed on the VL, RF, and VM. An MMG sensor was placed between the EMG electrodes on each muscle. The EMG and MMG amplitude values (root mean square), as well as power output (PO) across the 30 seconds were calculated. The EMG and MMG amplitude and PO values were averaged and normalized to the highest value found during the test, respectively.

Results: Linear regression analyses showed that EMG amplitude for all three muscles tested (VL, RF, and VM) did not change significantly ($p>0.05$) over the WAnT, but PO and MMG amplitude for all three muscles tested (VL, RF and VM) decreased significantly ($p<0.05$). In comparing slope values of the PO and MMG amplitude from the VL, RF and VM, no significant differences ($p>0.05$) were found.

Conclusion: MMG amplitude can be used to track changes in PO during the want. There is dissociation between EMG and MMG amplitude over the 30-second anaerobic test. EMG amplitude did not change significantly over the 30 seconds, showing that the superficial quadriceps femoris muscles are maximally activated throughout the entire test. MMG amplitude, which is thought to represent motor unit recruitment, decreases over the 30 seconds, showing that there is a loss of muscle fiber contribution.

099 - The Mechanomyogram (MMG) in Monitoring the Muscular Fatigue in the Isometric, Isotonic Contraction

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Introduction: The use of the MMG, which detects muscular vibrations generated by fused individual muscle fibre twitches, has been refined to monitor the muscle fatigue in the isometric isotonic contraction [1].

Methods: Surface electromyogram (SEMG) and MMG were recorded simultaneously from the same motor territory in Biceps (Bp) and Brachioradialis (Brch) of the human (n=18), during sustained contraction at 25 % MVC (maximal voluntary contraction) up to exhaustion.

Results: In SEMG and MMG the MF (median frequency) of the PSD (power density spectra) decreased and the RMS (root mean square) increased with advancing fatigue, from the onset of the contraction. This shows (both muscles, all subjects) a central component of the fatigue [2]. The MF regression slopes of MMG were closer to each other between men and women (Bp 1.55%; Brch 13.2%) than were the SEMG MF slopes (Bp 25.32%; Brch 17.72%).

Conclusion: The MMG signal can be used to indicate the degree of muscle activation and to monitor the muscle fatigue as alternative to the SEMG, when this is not feasible (chronical implants, environments contaminated by electrical noise

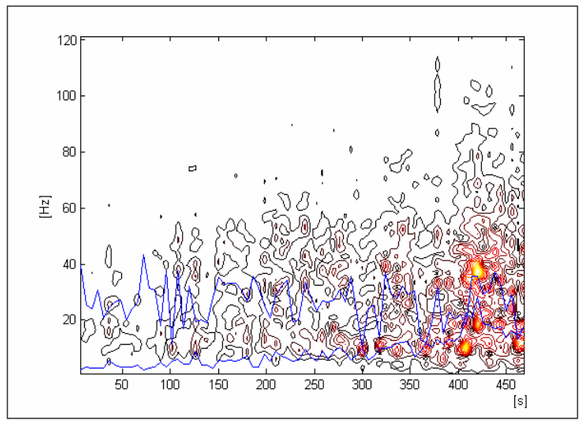

Figure1. MMG PSD plot (Brch). MF (up) decreases.RMS (down) increases

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126 - Peak Torque, Mean Power Output, and Mechanomyographic Responses to Concentric Isokinetic Strength Training of the Quadriceps Femoris

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Introduction: It has been suggested that mechanomyographic (MMG) amplitude may be more closely related to mean power output (MP) than peak torque (PT) during maximal concentric isokinetic muscle actions (Cramer et al. 2000). It has not been determined, however, if MMG amplitude tracks changes in muscle power output with strength training. The purpose of the present investigation was to examine the effects of unilateral concentric isokinetic leg extension training on PT, MP, and MMG amplitude with concentric isokinetic strength training.

Methods: Twenty-one males (mean+SD, age=23+3 yrs; height=182+8 cm; mass=84+13 kg) were randomly assigned into a training (TRN, n=12) or control (CTL, n=9) group. The training group performed six sets of ten leg extensions of the non-dominant limb three days per week for twelve weeks. Training was performed at a velocity of 90°·s-1 on a Cybex 6000 dynamometer. Subjects were tested before the start of the training period and every four weeks thereafter for PT, MP, and MMG amplitude at a velocity of 90°·s-1. A piezoelectric MMG contact sensor was placed mid-thigh over the vastus lateralis muscle during all testing. Separate two-way mixed factorial ANOVAs (week x group) were used to determine differences across the weeks for PT, MP, and MMG with all values normalized to the highest value during the training period.

Results: The results of the two-way ANOVAs indicated a significant increase in PT and MP as a result of the training for the TRN group but no significant change for the CTL group. For MMG there was no significant two-way interaction or main effect involving group, thus the TRN and CTL groups exhibited the same pattern of response over the training period. **Conclusion:** These results indicated that MMG amplitude did not track the increases observed in PT and MP with training. There may be other factors (hypertrophy and/or changes in other muscles) that collectively influenced the MMG signal (some augmenting and some attenuating) that could account for the training-induced increase in PT and MP in the absence of a change in MMG amplitude.

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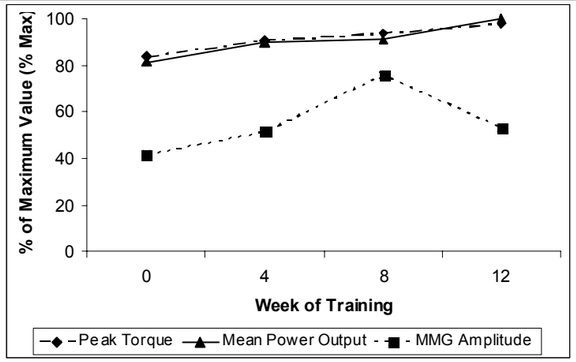

Figure 1. The relationship between PT, MP, MMG amplitude and week for the TRN group.

144 - Mechanomyogram to Assess Motor Unit Fusion Property During Sustained Isometric Contraction

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Introduction: Previous simulation studies have indicated that the mechanomyogram (MMG) amplitude represents the fusion property of active motor unit (MU), caused by the increase of its firing rate or slowing of contractile machinery (Bichler et al. 2001; Orizio et al. 1993; Yoshitake et al. 2002; Kimura et al. 2003). The present study examined the possibility of MMG amplitude analyses to reveal the changes in MU fusion state during sustained isometric contraction in human subjects, for the practical purpose.

Methods: Analyses of MMG signal were conducted in biceps brachii and soleus during the elbow-flexion and plantar-flexion, respectively (n = 8). Elbow-flexion test or plantar-flexion test was chosen at random and administered on 2 separate days. A microphone sensor (10 mm diameter, mass 5 g, bandwidth 5 – 2000 Hz, Daia Medical, Tokyo, Japan) for MMG recording was fixed to the center of the belly of the muscle tested. EMG recording electrodes (Ag / AgCl, 4 mm pick-up diameter, 35 mm inter-electrode) were placed to line-up with the microphone on the longitudinal axis of each muscle, respectively. The subjects maintained isometric contraction at 50 %MVC for as long as possible and data analyses were conducted for the entire contraction time.

Results And Discussion: The slope coefficient of rise in rms-EMG as a function of time for the biceps brachii was significantly greater than that of soleus ($P < 0.001$). On the contrary, the rms-MMG in biceps showed a considerable increase in the initial phase of sustained contraction ($P < 0.05$), but when exhaustion was approached did it begin to decrease significantly ($P < 0.05$). However, such typical decrement of rms-MMG toward exhaustion was observed to much less extent in soleus. This difference could be attributed to the magnificent fusion state of underlying muscle fibers near the exhaustion, caused by the slowing of shortening and relaxation speed and increase in firing rates of active MUs (De Luca et al. 1996), assumed to be typically occurring in biceps, owing to more fatigable MUs. Therefore, the present result suggests the modality of MMG analyses for the assessment of MU fusion properties during voluntary sustained isometric contraction.

On the other hands, the absence of substantial decrease in MMG amplitude near the exhaustion in soleus may indicate the lack of full activation (tetanus) of underlying MUs even at the exhaustion, i.e. the evidence linking central fatigue to the determinant of exhaustion of triceps surae in plantar flexion.

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178 - The Influence of Fatigue on the Efficiency of Electrical-Mechanical Activity of the Superficial Quadriceps Femoris Muscles

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Introduction: deVries (2) identified differences in the surface electromyographic (EMG) amplitude to force ratios between weak and strong individuals where the ratio was greater in the stronger individuals. When examined across a fatiguing task, deVries (3) reported an increase in the EMG:force. The EMG:force ratio or "efficiency of electrical activity", was described by deVries (2) as a physiological-based method for evaluating the functional state of muscle tissue. Recent investigations (3-5) have examined "electromechanical efficiency" in normal and diseased muscle through evaluation of the relationship between the EMG and mechanomyographic (MMG) amplitudes. The EMG:MMG ratio has been reported to be useful in the monitoring of muscle function changes associated with myotonic diseases such as muscular dystrophy (3-5). The purpose of this investigation was to examine the efficiency of electrical-mechanical (EM) activity (EMG:MMG) of the superficial quadriceps femoris muscles during repeated concentric muscle actions at two different velocities.

Methods: Fifteen healthy adults (21.8 ± 1.7 yrs) performed 50 consecutive, maximal concentric muscle actions on a Biodex System 3 Dynamometer at a velocity of 60 and 300°s-1. Bipolar surface electrode arrangements were placed over the mid portion of the vastus lateralis (VL), rectus femoris (RF) and vastus medialis (VM) muscles with a MMG contact sensor placed adjacent to the superior EMG electrode on each muscle. Torque, power, and MMG and EMG amplitude values were calculated for each of the 50 repetitions. All values were normalized to the value recorded during the first repetition and then averaged across all subjects. EM was expressed as the ratio of the normalized EMG amplitude to the normalized MMG amplitude.

Results: Polynomial regression analysis indicated cubic decreases in torque (R2=0.976) and power (R2=0.973) across all 50 muscle actions. At 60°s-1, EM increased linearly (R2=0.690) for the VL and quadratically for the RF (R2=0.737) and VM (R2=0.336). At 300°s-1, EM increased cubically for the VL (R2=0.755), RF (R2=0.858), and VM (R2=0.696).

Conclusion: These findings indicate muscle and velocity-specific relationships in the reduced EM for each muscle across the 50 repetitions. It is possible that EM measurements may provide unique insight into the influence of fatigue on the contractile properties of skeletal muscle including alterations that occur to the intrinsic electrical and mechanical components as well as changes in the muscle-fiber type contributions to torque production across a fatiguing task.

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181 - Biceps Brachii Motor Unit Deactivation and Activation Strategy Investigated by Surface Mechanomyogram

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The aim of this study was to analyze the motor units (MU) deactivation vs activation strategy during isometric efforts from 100% to 0% (down-going ramp, DGR) of maximal voluntary contraction (MVC) and from 0 to 100% MVC (on-going ramp, OGR). To this purpose surface mechanomyogram (MMG) was detected from the biceps brachii muscle belly by means of an accelerometer in ten male subjects, 22 - 30 years old. A visual feed-back provided the actual level of effort, % of the maximal voluntary contraction (MVC), together with the force target. The MMG root mean square (RMS) and mean frequency (MF) of the spectra (estimated by FFT) were calculated on 0.5 s MMG time windows, centred at 5% multiples in the 15-95% MVC range. MMG-RMS. During OGR MMG-RMS increases up to 70% MVC and then a clear decrease takes place. During the DGR the maximum of the MMG-RMS vs %MVC relationship is shifted to 80% MVC. MMG-MF. In both the OGR and DGR the MMG-MF vs %MVC relationship presents three regions with different slopes. The steeper part of the overall relationship starts at 70% MVC and 80% MVC during OGR and DGR, respectively. In the 80-95% MVC range the MMG-RMS was lower and the MMG-MF was higher in OGR than in DGR. Data from the literature suggest that a) MMG-MF may reflects the global MU firing rate (FR), b) the MMG-RMS reduction and the MMG-MF steep increase beyond a given %MVC up to near maximal contraction intensities may be due the high MU global FR attained at this effort levels. Based on our results it can be hypothesised that a) in DGR the global MU FR could be lower than in OGR at near maximal isometric efforts; b) in DGR force reduction is obtained reducing MU FR between 95% to 80% MVC and reducing the level of MU recruitment (REC) between 80% and 15% MVC, c) in OGR REC ends at 70% MVC and FR is the main tool to increase force up to 95% MVC. This suggests that in DGR the de-recruitment threshold is higher than the MU REC threshold in OGR.

Conclusion. MMG time and frequency domain analysis may be a tool to investigate the motor units recruitment and de-recruitment strategies during voluntary isometric contraction.

220 - Instantaneous Mean Frequency vs. Range Of Motion for Surface Electromyographic and Mechanomyographic Signals Recorded During Isokinetic Leg Extensions

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Karlsson, Gerdle, and Akay (IEEE Eng Med Biol, Nov/Dec, 2001, p. 97-105) have recently reported changes in the instantaneous mean frequency (IMF) values of surface electromyographic (EMG) signals across the range of motion (ROM) during isokinetic leg extensions. No previous studies, however, have examined the IMF patterns for both EMG and mechanomyographic (MMG) signals during isokinetic muscle actions. The purpose of the present study, therefore, was to examine the IMF vs. ROM relationships for EMG and MMG signals recorded from the superficial quadriceps femoris muscles during isokinetic leg extensions. Eleven men (mean age + SD = 22 + 1 years) volunteered to perform maximal, concentric isokinetic leg extension muscle actions on a calibrated Cybex 6000 dynamometer at 60º.s-1. Three bipolar surface electrode (Quinton Quick Prep, Ag-AgCl) arrangements, each separated by a piezoelectric crystal contact sensor (Hewlett Packard, 21050A), were placed over the vastus lateralis (VL), rectus femoris (RF), and vastus medialis (VM) muscles to record the EMG and MMG signals, respectively. To avoid the acceleration and deceleration phases, which are typical of isokinetic dynamometers, only the EMG and MMG signal epochs that corresponded to the middle 30° ROM (approximately 120° to 150° of flexion at the knee) were analyzed. The EMG and MMG signals were sampled at 1 KHz and bandpass filtered at 10 – 500 Hz and 5 – 100 Hz, respectively, with a 2nd-order, zero-phase (resulting in a 4th-order response) Butterworth filter. A continuous wavelet transformation (CWT) computed at dyadic scales using the Daubechies-6 mother wavelet was used to determine the IMF values for the EMG and MMG signal epochs. Stationarity of the EMG and MMG signals was analyzed using runs tests (dichotomized with the median value), and polynomial regression analyses were used to examine the patterns of EMG and MMG IMF responses throughout the ROM. The runs tests indicated significant ($p<0.05$) nonstationarity for the EMG and MMG signals of the VL, RF, and VM muscles for all subjects. The following table represents the numbers of subjects (out of 11) that exhibited either a quadratic ($p<0.05$), linear ($p<0.05$), or no significant relationship ($p>0.05$) between EMG and MMG IMF values vs. ROM for the VL, RF, and VM muscles:

	EMG IMF			MMG IMF		
	VL	RF	VM	VL	RF	VM
Quadratic	5	7	5	6	5	6
Linear	4	3	2	3	4	4
No relationship	2	1	4	2	2	1

Most subjects (7 – 10 of the 11) exhibited a significant pattern (quadratic or linear, $p<0.05$) in the EMG and MMG IMF vs. ROM relationships. For EMG, 7 of the 9 relationships that were linear had positive slopes. For MMG, 6 of the 11 that were linear had negative slopes. Except for the EMG IMF of the VM muscle, only 1 – 2 subjects exhibited no significant relationship ($p>0.05$) between IMF and ROM. These results indicated that the EMG and MMG IMF values were not stationary and tended to exhibit nonlinear and linear patterns of change throughout the range of motion, which may be due to the shortening of the sarcomeres and/or altering positions of the recording areas during the muscle action. Given the nonstationarity of the EMG and MMG signals found in the present study, future studies should compare the use of Fourier (which assumes signal stationarity) and wavelet transformations for calculating frequency values and identifying spectral changes in EMG and MMG signals during maximal, concentric isokinetic muscle actions.

257 - Surface Mechanomyography – A Way to Assess Motor Control Changes in Presence of Experimentally Induced Muscle Pain

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Introduction: Under well-controlled conditions, experimentally induced local muscle pain causes no local changes in surface electromyogram (EMG) during isometric low-level contraction though compensatory processes may take place. Pain evoked changes might be detectable in the surface mechanomyogram (MMG) as it is considered to reflect muscle mechanical activity and be complementary to the surface EMG.

The purpose of this study was to investigate the local effect of experimental muscle pain on the MMG and the surface EMG during a range of sub-maximal isometric contractions.

Methods: Twelve healthy subjects participated in the study. Elbow static isometric flexion at 0, 10, 30, 50 and, 70 % of the maximal voluntary contraction (MVC) together with ramp isometric flexion from 0 to 50 % MVC were performed before and during experimental pain. Muscle pain was induced by injections of hypertonic saline into the biceps brachii muscle. Injections of isotonic saline served as a control.

The pain intensity and pain location were recorded. A piezoelectric accelerometer was used to record the surface MMG signal from the dominant biceps brachii muscle. Bipolar EMG surface electrodes were placed on each side of the accelerometer (37 mm apart). Root mean square (RMS) values and mean power frequency (MPF) values of the surface MMG and surface EMG signals were computed over 1 second long epochs without overlapping. The MMG/EMG RMS ratio was also computed.

Results: The mean pain intensity was 3.1 +/- 0.4. Subjects reported local pain (12/12) and referred pain (6/12) following bolus injection of hypertonic saline. For static and ramp isometric contractions, experimental muscle pain induced an increase in surface MMG RMS values ($P<0.02$) and MMG/EMG RMS ratio ($P<0.05$) while no significant changes were observed in the surface EMG RMS values. There were no significant effects of experimental pain on the surface MMG or surface EMG MPF values. For the control session, no significant effects of isotonic saline on the RMS, MPF of the surface MMG or EMG signal and MMG/EMG RMS ratio were found.

Discussion: The present study showed that experimental muscle pain modulates the surface MMG signal amplitude. This increase most likely reflects changes in the mechanical contractile properties of the muscle. This is in line with recent data showing an increased twitch tension in presence of experimental muscle pain [1] indicating compensatory mechanisms to maintain a constant force output in painful conditions. Surface MMG seems to be a useful tool for investigating non-invasively the MU activation strategy resulting from the changes in the neuromuscular system due to experimental muscle pain. Furthermore, surface MMG recordings may be more sensitive than surface EMG recordings and clinically useful for detecting non-invasively increased muscle mechanical contributions during muscle pain conditions.

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263 - Wavelet and Fourier Based Estimates of MMG and EMG Responses to Isokinetic Muscle Actions Yield Similar Results

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Introduction: Frequency domain analyses of electromyographic (EMG) and mechanomyographic (MMG) signals can be used to assess muscle fatigue and study motor unit activation. Fourier based approaches are typically used in these analyses, yet Fourier analysis assumes signal stationarity, which is unlikely during many tasks. Wavelet based methods of signal analysis do not assume stationarity and may be more appropriate for analyzing the frequency content of EMG and MMG signals during dynamic muscle actions. The purpose of this study was to compare standard Fourier analysis vs. discrete wavelet transform (DWT) in assessing EMG and MMG responses of the vastus medialis to isokinetic muscle actions at different torque levels.

Methods: Ten subjects performed concentric isokinetic leg extensions at 30 degrees per second at torque values equal to 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% of peak torque. Simultaneous EMG and MMG recordings were made from the vastus medialis. All signals were sampled at 1000 Hz and stored on disk for subsequent analysis. The data from the middle 30 degrees of range of motion was digitally band pass filtered (EMG: 10-500Hz; MMG: 5-100Hz) and the median power frequency (MPF) was estimated using a DFT and the center frequency was estimated from a Daubechies 4 (D4) wavelet algorithm. All analyses were performed with custom programs written with LabVIEW 6.1 software. The values at each intensity level were normalized to the respective maximum value, and statistically analyzed using: 1) polynomial regression analyses for the mean responses, and 2) intra-subject correlation analyses for individual responses.

Results: Polynomial regression analyses indicated that for the MMG signals, both the D4 center frequency and the MPF resulted in linear increases with increases in torque (D4 center frequency: $R^2 = 0.613$, $p = 0.007$; MPF: $R^2 = 0.768$, $p = 0.001$), with no significant improvement in the model by adding quadratic and cubic components. The slope coefficients were not significantly different ($p>0.05$). For the EMG analyses, both the D4 and MPF approaches showed cubic relationships with normalized torque output (D4: $R^2 = 0.768$, $p = 0.008$; MPF: $R^2 = 0.788$, $p = 0.007$). Intra-subject correlation analyses showed an average correlation (Z transformation) between D4 and MPF responses of 0.71 for the MMG signals and 0.76 for the EMG signals.

Discussion: The results of this study showed that for isokinetic muscle actions, Fourier and wavelet based indices of central tendency of the frequency response result in similar patterns. Therefore, despite the concerns over signal stationarity with Fourier analysis, these findings suggest that Fourier analysis can be used to analyze EMG and MMG signals derived from isokinetic muscle actions.

289 - MMG and EMG Responses Together with Intramuscular Tissue Pressure During Low-Level Static Continuous and Intermittent as well as Dynamic Contractions

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Introduction: The mechamomyogram (MMG) is suggested to be the mechanical counterpart to the electromyogram (EMG) during muscle contraction revealing information on the motor unit contractile mechanisms. The aim of the present study was to analyse the information that may be extracted from these signals during dynamic versus static contractions.

Methods: Eight subjects performed elbow flexions for 1 min in 3 contraction modes resulting in identical time-tension products at two force levels (LOW/HIGH): 1) continuous static (CST) at 5 and 10 %MVC, respectively, 2) intermittent static (IST, 4 s contraction – 4 s rest) at 10 and 20 %MVC, 3) dynamic (DYN, 2 s concentric – 2 s eccentric – 4 s rest) at 10 and 20 %MVC (20° elbow movement). The dynamic contractions were additionally performed without external load, DYN-ZERO. Force, MMG, bipolar surface EMG, and intramuscular pressure (IMP) were measured simultaneously from m. biceps brachii. Mean MMG and EMG rms-values and IMP values were calculated for four 1 s periods corresponding to the contraction phases of the intermittent and dynamic contractions, and the same time wise periods being analysed for CST. Subsequently, the mean of the 1 s periods for all eight contractions in the 1 min elbow flexion period was calculated.

Results: During the DYN-ZERO the MMG was as a mean 0.05 m/s2 and EMG was 4 μV with no difference between the four 1 s periods. MMG for DYN and IST during LOW increased in the first 1s to 8 and 9 m/s2, respectively, and for DYN remained at the same level but for the IST decreased to 5 m/s2 in the following 1 s periods, the difference being significant. The corresponding data for HIGH were 0.12 m/s2 for both DYN and IST, again the value remaining at the same level for DYN but decreasing to 0.06 m/s2 for IST in the two subsequent 1 s periods, the difference being significant. No corresponding differences regarding the first 1 s contraction periods were seen for the EMG. Interestingly, however, the EMG in the concentric phase of DYN was significantly higher than the corresponding value for IST for both LOW: 0.08 vs. 0.05 μV and HIGH: 0.13 vs. 0.08 μV, respectively. During the CST both MMG and EMG signals were lower than the corresponding IST values in line with the lower absolute force levels, and no difference between the four 1 s periods analysed was seen. Mean IMP in DYN was lower than in IST (2.3 vs. 29.5 and 10.9 vs. 42.0 mmHg in LOW and HIGH, respectively). Values in CST were 24.0 and 33.3 mmHg.

Discussion: As expected EMG was higher in the DYN concentric phase because -according to physics- the acceleration of the arm and external weight requests an extra muscle force development with a larger motor unit recruitment. However, the pattern of the MMG was highly interesting, and needs specific considerations to be explained. The interpretation may be that in the first 1 s periods the MMG signal is affected by the contributions of to: 1) large dimensional changes of the muscle while changing its shape during the initial take-up of the slack elastic tissue, and 2) cross-bridge cycling due to shortening of the sarcomeres. Since shortening activity continues during DYN the MMG signal remains high, while the constant muscle length during the IST by then results in a decrease in the MMG signal. During the CST no difference between the 1 s periods would be expected since the contraction was maintained continuously, and thus the time-wise separation between the periods corresponding the static and dynamic contraction phases do not make sense for this contraction mode. The IMP remained low in all contractions and was therefore not likely to have influenced the MMG results, as recent data revealed only high IMP to have a possible effect. These results lend support to the suggestion that the MMG signal reflects aspects of the intrinsic force generation in the muscle fibre.

292 - Fatigue Related Changes In The Mechanomyogram Are Not Due To Changes In Intramuscular Pressure Or Force Steadiness.

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Introduction: Previous studies on mechanomyogram (MMG) have shown an increase in the amplitude of the MMG with fatigue development during prolonged submaximal contractions (1). In low force test contractions this increase in MMG/force ratio could be detected even after 30 min of recovery (3). An increase in MMG could be due to a fatigue related change of the intrinsic mechanical properties of the active muscle fibers. However, it could also be a consequence of an increased intramuscular pressure due to a larger water content in the fatigued muscle or a decreased force steadiness (FS) due to new recruitment of larger motor units. The aim of this study was to evaluate if an increase in MMG could be explained by an increase in IMP or a decrease in FS.

Methods: Seven healthy female subjects, sitting with the upper arm vertical and the elbow flexed 90 degrees, performed static elbow flexion at 10% maximal voluntary contraction (MVC) for 10 min. 5 %MVC test contractions were performed before, and at 10 (R10) and 30 min (R30) recovery. During the 10%MVC and the test contractions force, IMP, using an intramuscular Millar microtip pressure transducer and MMG using an accelerometer were measured simultaneously from the biceps brachii muscle. The coefficient of variation was calculated as an estimate of FS and MMG was analysed for root mean square (MMGrms).

Results: During the 10 minutes sustained contraction at 10% MVC MMGrms showed a significant increase from an initial level of mean (SD) 0.04 (0.02) to 0.11 (0.07) m/s2 in the last minute. IMP on the contrary showed a significant decrease from an initial 39.9 (20.8) to 30.4 (15.4) mmHg. The FS showed no significant change over time, the coefficient of variation being approx 1.5%. During the test contractions MMGrms showed a significant increase from 0.03 (0.01) m/s2 before the fatiguing contraction to 0.07 (0.04) and 0.06 (0.03) m/s2 in R10 and R30, respectively. IMP was around 30 mmHg and FCV was around 1.5% in the test contractions with no significant difference between baseline, R10 and R30.

Discussion: In accordance with previous studies an increase in MMGrms with fatigue was evident in the present study. However, this was not explained by a decrease in FS or an increase in IMP since the former was unchanged and the latter actually decreased. Similarly, a decrease in IMP during a submaximal contraction has recently been reported for the supraspinatus muscle and may be caused by a fatigue related change in load sharing (2). An increase in MMGrms was also in the present study still evident after 30 minutes of recovery, even though no such prolonged effect was found in IMP or FS

Conclusion: the increase in MMGrms with fatigue development was not related to an increase in IMP or a decrease in FS. Therefore, it is likely that the increased MMGrms may represent an impairment of the intrinsic mechanical properties of the muscle fibers.

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296 - Phase Difference in Mechanomyogram Between Knee Extensor Synergists During Maximal Voluntary Contraction

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Introduction: Force fluctuations during a maximal voluntary contraction (MVC) consist predominantly of frequencies below 5 Hz. In contrast, fluctuations in mechanical activity of contracting muscles, when assessed with mechanomyogram (MMG), are mainly composed of higher-frequency components with peak power in the range of 8-12 Hz. Because the external force measured in vivo is the summed forces from multiple muscles, it is possible that individual muscles comprising synergists are activated out of phase, leading to the attenuation of the higher-frequency (8-12 Hz) fluctuations in the externally measured force. The purpose of the study was to determine the temporal association in MMG across synergist muscles, tendon displacement, and limb force during MVC.

Methods: Twelve healthy male subjects (20-33 yrs) performed isometric knee extensions with maximal effort for 3 s in a seated position with the hip and knee joint angles at 100° and 90°, respectively. MMG was recorded by an accelerometer (ASV-2GA, Kyowa Inc, Japan) placed over the belly of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) muscles. Fluctuations in the displacement of the patella tendon were quantified by the anterior-posterior displacement of the skin overlying the patella tendon by using a high-resolution (1 □m) laser displacement sensor (LK-2500, Keyence, Japan). Knee extension force was measured with a strain-gauge force transducer attached to the ankle. MMG from the three muscles, displacement of the patella tendon, and knee extension force were analysed over a 1.5-s period of steady-torque output. The power spectrum density of each signal was calculated using the fast-Fourier Transform. The normalized cross-correlation function (CCF) between each pair of signals was calculated to determine the extent of temporal correlation between the signals.

Results & Discussion: The power spectrum density of the force fluctuations and tendon displacement was concentrated below 5 Hz with no distinct peaks. In contrast, the power spectrum density of MMG was distributed to higher frequencies with distinct peaks at 11.7 Hz (RF), 9.8 Hz (VL), and 9.8 Hz (VM). These peak frequencies in the MMG of individual muscles fall within the frequency range of physiological tremor (8-12 Hz). There was no distinct peak in the CCF between force and MMG of each muscle or between tendon displacement and MMG of each muscle. The lack of distinct peaks in CCF suggests that fluctuations in the mechanical activity of individual muscles are not directly represented in the fluctuations in tendon displacement or force, but are integrated so that fluctuations in the mechanical activity of individual muscles do not appear in the external force. As for the temporal relation in MMG between synergistic muscles, the normalized CCF showed a positive peak without a time lag between RF and VM (0.299 ± 0.140, mean ± SD). However, a negative peak in CCF was found between VL and VM, as well as between VL and RF. The negative peak in the normalized CCF between VL and VM (-0.478 ± 0.268) was significantly greater than that between VL and RF (-0.192 ± 0.128, $P < 0.01$). These results demonstrate the presence of phase difference in mechanical activity among the synergistic muscles during MVC. It is assumed that the large negative CCF between MMG of VL and VM indicates that the physiological tremor components are inversely correlated between VL and VM. The phase difference in the fluctuations in muscle force between the individual synergistic muscles may result in the cancellation of the high frequency fluctuations in the externally measured force during knee extension MVCs.

331 - Catchlike Property Decreases the Amplitude of Mechanomyogram in Humans

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Introduction: Muscle force is enhanced when an extra pulse is applied during an electrically evoked muscle contraction with a constant stimulation frequency ("catchlike property"). An increase in muscle stiffness has been postulated as one of the potential mechanisms (Parmiggiani and Stein 1981), but the effect of an extra pulse on the contractile properties has not been studied. Amplitude of mechanomyogram (MMG) during electrical stimulation depends on the relation between stimulation frequency and contractile properties of the motor units: it is reduced with the development of fusion in humans (Yoshitake et al. 2002). Development of fusion is accompanied by the greater number of cross-bridges, which leads to shorter contractile element with a more elongated series elastic element and greater muscle stiffness. The purpose of the present study was to determine the association between changes in muscle force and MMG amplitude induced by an extra pulse during electrical stimulation in humans.

Methods: The posterior tibial nerve in five healthy men (24 - 30 yr) was electrically stimulated with a train of single rectangular pulses (supramaximal amplitude) under two conditions; 1) constant-frequency trains with an additional pulse 1 s after the onset of stimulation (CATCH) and 2) constant-frequency trains without an extra pulse (CONT). The range of constant stimulation frequencies was 5 - 20 Hz in both conditions. The knee and ankle joint angles were at 180° and 90°, respectively. Plantarflexion force was measured with a force transducer on the foot lever plate. The MMG was recorded from the medial gastrocnemius (MG) and soleus (SOL) muscles by a contact sensor transducer (HP 21050A). The peak plantarflexion force and the average MMG amplitude (root mean square) before (PRE) and after (POST) the extra pulse were calculated in CATCH. These variables were determined in CONT for the same periods. The difference in these variables between PRE and POST was normalized to the corresponding value of PRE.

Results and Conclusion: Plantar flexion force increased and MMG amplitude decreased with the increase in background stimulation frequency for PRE. The force at POST was greater than PRE at 12.5 - 20 Hz for both CONT and CATCH, but the amount of increase in force was greater in CATCH (9.3 - 28.2 %) compared with CONT (3.1 - 18.3 %). MMG amplitude at POST was not different than PRE for the same frequency range in CONT, though it decreased in CATCH (MG: 9.2 - 22.2 %, SOL: 10.8 - 27.9 %). Thus, the decrease in MMG amplitude after an extra pulse in CATCH is not related to the slow increase in force during constant-frequency stimulation, but it is due to the enhanced development of fusion by an extra pulse. The increase in force by an extra pulse was linearly related to the decrease in MMG amplitude in CATCH (MG: $r = 0.67$, slope = -1.4, $P < 0.001$; SOL: $r = 0.62$, slope = -0.62, $P < 0.001$), whereas there was no correlation between these variables in CONT ($P > 0.05$). The results indicate that the enhancement in force induced by an extra pulse is associated with the development of fusion. Our data also suggest that the "catchlike property" may be due to an increase in muscle stiffness in humans.

383 - Study of Muscle Function In Process of Fatigue Generated During Isometric Contraction and in Process of Its Recovery With Use of Both Mechanomyogram (MMG) And Electromyogram (EMG)

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Introduction: MMG and EMG are treated and compared to evaluate muscular fatigue under condition of isometric contraction of various muscular loads. The recovery state after muscle fatigue has not yet been researched, so the recovery state of muscle function was treated. The feature of muscular function in both MMG and EMG during muscle fatigue and the recovery was discussed.

Methods: Ten male subjects attended the experiment. They sat on the chair and the muscle of bicepts brachii was used for evaluation of muscular function, elbow being maintained a right angle. The weight loads of 20%, 40%, 60% MVC (Maximum Voluntary Contraction) under isometric contraction were maintained till limitation to hold weight load in same posture. Before and after weight load, 10%MVC load for 5 seconds was used to measure the muscular function. The waves of MMG and EMG for 10% MVC before and after holding weight load were analysed by Fourier transform in order to evaluate the muscular function. Total power spectrum (TP) and mean power spectrum (MPF) were evaluated in the frequency range from 0 to 60 Hz.

Results: In the process of muscular fatigue, the notable characteristics is that EMG showed the feature in MPF, i.e., the lowering frequency was recognized, and that MMG presented the feature in TP, i.e., TP in load of 20%MVC increased remarkably, but TP for higher weight load of 40% and 60%MVC did not show the large increase. In the process of the recovery, MPF in EMG presented the increase compared to the value before the load, and TP in MMG for load of 20 %MVC significantly decreased to the value before the weight load. In order to evaluate the degree of weight load, it was investigated that impulse, i.e., the product of weight load (i.e., force, F) and period (i.e., t) from the beginning of maintaining till muscular exhaustion, was evaluated or was taken to be constant value. The impulse for 20%MVC indicated the larger value due to the longer maintained period, and impulse for 60%MVC was the smaller value due to shorter period, so that the damage to muscle in lower weight load was stronger than the damage in higher weight load. The tendency in the process of muscular fatigue was significantly proved under the condition of same impulse for three kinds of weight loads; That is, under the condition of same impulse, TP in MMG increased in 20 %MVC load, but quantities of TP in the other weight loads remained constant. EMG under the same impulse did not show such change for three kinds of weight loads. The phenomenon suggested different degree of attendance of kinds of muscles due to the load given.

Conclusion: The characteristics of both MMG and EMG in the process of muscular fatigue and in the process of the recovery were investigated under isometric contraction in weight load from 20% to 60% MVC. MMG denoted the feature in TP presenting energy of the wave, that is, the value increase predominantly for larger impulse. On the other hand, EMG showed the feature in MPF presenting mean frequency of the wave. It was concluded that in the evaluation of muscular function, both MMG and EMG were necessary to detect the muscular function in process of fatigue and of the recovery.

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424 - Frequency Analysis of Mechanomyogram Using Matching Pursuit

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Introduction: Because Mechanomyogram (MMG) occurs with constriction of muscle fiber, MMG reflects mechanical activity of a muscle. The analysis of MMG can be quite useful for the evaluation of muscle contractile properties. The purpose of this study is to clarify a change of a frequency component in muscle force increase. Matching pursuit method can analyze the property of an original signal very precisely.

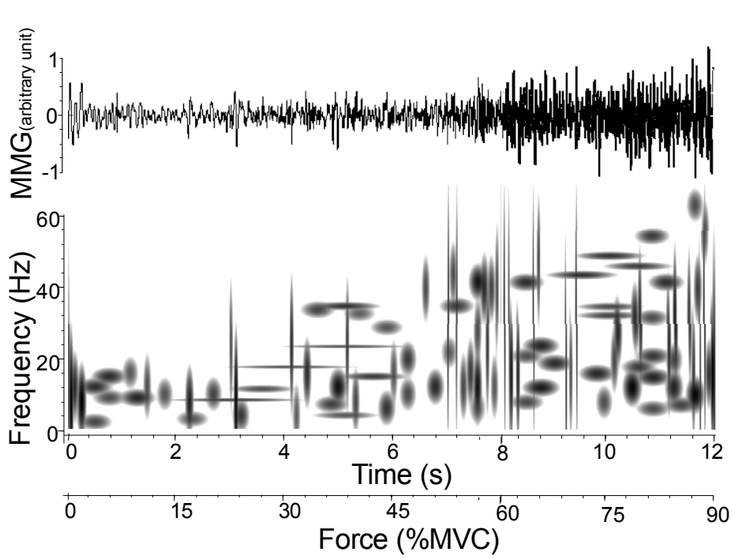
Methods: The target muscle is the biceps brachii muscle. When the subjects increased their isometric elbow flexion force from 0 to 90%MVC in 12 seconds, we measured the MMG, EMG and force with 1000Hz sampling frequency.

Results: Fig.1 shows the measured MMG and the result of frequency analysis. In the range that muscle force is lower than 30% MVC, the frequency component is almost less than 20Hz. However, in the range higher than 30% MVC, the frequency component of 40Hz appeared.

Above 80% MVC, the frequency component around 60Hz is found.

Discussion: When muscle force becomes high, almost all MUs are recruited and become in state of tetanic contraction.

Therefore the compliance of a muscle becomes lower and the high frequency component appears in MMG.



469 - Relations Between Force and Surface Mechanomyogram In Isometrically Contracted Calf Muscles

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Introduction: During steady contractions, small involuntary variations are detectable in the recorded force signal. Shortening of active muscle fibers transmitted via tendenous structures are held responsible for this force mechanomyogam (fMMG). The surface mechanogram (sMMG) on the other hand originates from active fibres in the vincinity of a pickup that undergo dimensional changes. Twitch contractions elicited by electrical stimulation showed a close relationship between force and surface responses [1]. It was therefore expected that some relationship also exits for voluntary contrations.

Methods: A calf dynamometer with sensitive load cell (range 500 N, noise level < 20 mN) was used to capture the fMMG at 20% and 40% MVC levels (30 sec plantar flexions, N= 8). MVC was tested before with a less sensitive dynamometer (range 3000N). Two simultaneous sMMG's were recorded with precise accelerometers (EGAY-5 Entran Inc.) placed over gastrocmenius (left head) and soleus muscles. The amplified signals were sampled (1kHz) with 16 bit AD's and digitally filtered (2 - 40 Hz). To compare the mechanografic signals in the acceleration domain, the force signal was differentiated two times. From power spectra and crosscorrelations three related parameter were calculated: mean frequency (MF), rms-amplitude (AMP) and crosscorrelation coefficient (CC).

Results: Very similar spectral distributions were observed from the force and the two surface signals. Above 20 Hz the desity of the double differentiated force spectra declined more than the surface spectra (MF-force= 14.9 Hz, MF-gast= 20.7 Hz, MF-sol= 17.8 Hz). Increasing contraction level (20 to 40% MVC) resulted in less amplitude increase of the sMMG's (AMP-force +73%, AMP-gast= +41 %, AMP-sol= +57 %). Less similarity was found in time domain: CC-force/gast was 0.21 ±0,07 and CC-force/sol was 0.24 ±0.07. Also the correlation between the two surface signals was relative low (CC = 0.22 ±0.10). When the two surface signals were summed digitally, the correlation to the force signal increased (CC = 0,29 ±0,06 %).

Discussion: In contrast to the recent electrical stimulation study we found only minor signal relations during voluntary contrations. Here we have to consider the architecture of the trizeps surae and differencs in the force-producing mechanism of the two investigated muscles. The gastrocnemius is a two joint muscle with more fast-twitch fibers than the soleus which is a one joint muscle. Both muscles converge at the Achillles tendon were all regional twitch processes are summed mechanically. The relative low CC-values between our sMMGs, show independent twitch processes at the two muscles. It is therefore conceivable that the CC-force values are also low, as we can expect more than two regional twitch processes in all contraced muscles. After digital summation the two regional sMMG's the CC-force value increased, indicating that the fMMG is a compound signal reflecting all actice fibers acting on a joint.

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505 - Mechanomyographic Responses To Postactivation Potentiation In Triceps Surae MusclesEstimation Of Postactivation Potentiation By Mechanomyography

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Introduction: The twitch contraction force is increased after a brief maximum voluntary contraction (MVC). This enhancement is termed postactivation potentiation (PAP) and is prominent in fast twitch fibers. The PAP property associated with the fiber type may be a useful tool to examine the muscle fiber composition. In muscles with plural heads, however, it is difficult to determine a separate force exerted by each muscle head because of the integration of force from all the heads through the tendon. The mechanomyogram (MMG) is relevant to muscle mechanical activity and is detectable on the surface of muscle. Thus, the MMG appears to provide a localized information on the mechanical activity in a given muscle. In the present study, the PAP in gastrocnemius (GAS) and soleus (SOL) muscles was investigated with the twitch force, MMG and EMG to clarify the validity and advantage in the PAP estimation using the MMG

Methods: After the informed consent, six healthy male subjects (22-25 years old) participated in this study. Before and after 10-s MVC of plantar flexion, GAS and SOL were stimulated separately at each muscle surface to induce single twitch contraction. The tibial nerve was also stimulated to activate all the triceps surae muscles (TRS). A rest period of more than 30 min was allowed between the tests. The evoked MMG and EMG were measured on the surface of each muscle belly. The twitch force was measured as plantar flexion force.

Results & Discussion: The EMG amplitude in both muscles hardly changed between pre- and post-MVC. The peak twitch force was increased by 54% and 45% in GAS and SOL, respectively, while the MMG amplitude was enhanced greatly by 133% and 51%. The nerve stimulation to TRS also produced similar MMG responses to the PAP (72% in GAS and 32% in SOL). These results indicate that the MMG is able to reflect more sensitively the PAP with the fiber type compared with twitch force.

Motion Analysis

018 - Comparison of Muscle Activity During Gait in Subjects With and Without Stroke

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Introduction: Chronic cerebrovascular accident individuals with partial paralysis in an inferior extremity typically demonstrate difficulty in voluntarily controlling movement initiation. The purpose of this study was to compare muscle activity and joint moments in the lower extremities during walking between subjects with stroke and control subjects.

Methods: Tests were performed on fifteen subjects with stroke, and fifteen age, gender, and weight-matched controls. Onset and cessation times of lower extremity electromyographic (EMG) activity and joint moments were determined. The electromyographic and angular variation data analysis were collected using pairs of active bipolar differential surface electrodes, and a electrogoniometer, composed by two plastic arms, connected by a linear potentiometer and a 10 KΩ resistance. The sign was pre-amplified in the differential electrode with a 10 times gain and a rejection common mode reason of 80 dB. These components of the system of acquisition of signals had been connected to a conditioning module of signals, where the analogical signals had been filtered with filter pass band of 20 Hz the 500 Hz (frequency of sampling equal the 2000 Hz), and amplified again, with a profit of 100 times, totalizing, therefore a final profit of 1000.

Results: Results demonstrated that subjects with stroke had less ankle mobility, slower walking speeds, longer stance phases, and lower peak ankle dorsiflexion, ankle plantar flexion, and knee extension moments than control subjects. Onset times with respect to heel-strike for the medial gluteus, tibialis anterior, soleus, rectus femoris and medial hamstring muscles were significantly earlier during the gait cycle in subjects with stroke than in control subjects. The cessation times of soleus, tibialis anterior, rectus femoris, and medial hamstring muscles were significantly prolonged in subjects with stroke. Subjects with stroke showed more co-contractions of agonist and antagonist muscles at the ankle and knee joints during stance phase compared with control subjects.

Discussion: These gait changes and co-contractions may allow subjects with stroke to adopt a safer, more stable gait pattern to compensate for diminished sensory information from the ankle. The premature activation of soleus and medial gastrocnemius muscles in subjects with stroke could be contributing to abnormal forefoot plantar pressure distribution. Additional research is needed to clarify the relationship between the premature activation of triceps surae muscles and the forefoot plantar pressure parameters in subjects with stroke.

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073 - Muscle Activity in Shod and Barefoot Healthy Young Subjects During Walking

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Introduction: Human locomotion is due to the three-dimensional movement of multiple segments, caused by the interaction of different forces: muscular and ground reaction force, among others. The aim of this study was to describe the difference in muscle activity of the right leg and spatio-temporal variables between barefoot and shoed walkers at a spontaneous velocity. Barefoot walking can be seen as a walking condition wherein external protection and shock reduction are minimal.

Methods: The muscle activity of the right leg of 10 healthy subjects was recorded while walking at a spontaneous velocity, both barefoot and shoed, with two different types of sports shoes: 1) standard hard shoes, the same ones used for all subjects, 2) soft shoes, belonging to each subject. Five trials for each condition were recorded, and from each trial, three cycles were chosen. 150 cycles for each condition were analysed. The muscle activity was recorded with active electrodes (B&L) from the rectus femoris (RF), vastus medialis (VM), biceps femoris (BF), semitendinosus (ST), tibialis anterior (TA), lateral gastrocnemious (GN) of the right leg. Four B&L footswitches were used to identify the stride phases. The Acquisition System of the EMG signal was the MA 200 Motion Lab System with the following characteristics: output level of the signal was +- 5 volts, passing band of 20 to 1000Hz, CMMR 40db, input impedance of 100 Ohms. The electrical signal was sent by fibre optic cable. The sample frequency was 3000Hz. The raw EMG signal real was processed by means of complete rectification until the LE window, using a mobile window and it was expressed in relation to the normalized walking cycle.

Results: Shoed: 1) the spontaneous velocity of walking was greater depending on the length of the step ($p<0.05$), 2) the stance phase was smaller and the swing phase greater, 3) the maximal amplitude of the LE window was greater for all the muscles analysed with the exception of the gastrocnemious. The increase in the activity was significant for BF,RF, and TA, and this activity took place towards the end of the swing phase for the BF, at the transition stance-swing phase for the RF, and towards the end of the swing phase and also at the beginning of the stance phase for the TA. The TA also showed an important reduction in activity at the beginning of the swing phase.

Discussion: The purpose of the study was to examine how the gait pattern was influenced by changing the underfoot surface conditions. Changing the condition from barefoot to shoed, the velocity of walking, the phases of the gait cycle and the amplitude of muscle activity were significantly altered ($p<0.05$). The profile of the muscular activity was similar in the three conditions. The amplitude was modified either in the stance phase or in the swing phase or in both. The modification of the amplitude at the end of the swing phase could be caused by preparation mechanisms for ground impact. No differences in electrical activity were observed when the subjects walked with different types of footwear. The increase in BF activity could be due to an increased participation on limiting the knee extension when the displacement velocity of the subject was greater. The increase in RF activity can be justified as a response to the shock absorbers of the footwear, which absorb the force transmitted by the subject on the ground and consequently, greater RF activity is required to flex the hip and impulse the leg in the swing phase. The TA intervenes in a more significant way at the end of the swing phase to maintain the dorsal flexion until heel contact with the ground. In the initial support phase, its greater participation regulates firstly the plantar flexion and afterwards it facilitates the dorsal flexion, which has probably been altered by the braking effect of the footwear.
The assistance of Jorge de la Cruz and Jon Bilbao is gratefully acknowledged.

104 - From Intuition to Quantification: Analyzing Movement Dynamics in Patients with Shoulder Impingement Syndrome

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Introduction: The combination of pain and reduced range of motion experienced by patients with shoulder disorders leads to varying degrees of disability and the adoption of compensatory movement strategies. Clinical screening involves the use of simple diagnostic movement tests and is also dependent on the clinician's intuitive understanding of human motion. As such, it precludes the objective evaluation and quantification of the complex movement strategies employed by patients during their daily tasks. This information is however invaluable for objectively assessing the status of patients and the effectiveness of therapy. Three-dimensional motion analysis allows the complex, non-repeatable and non-cyclic movements characteristic of the upper extremities to be objectively and quantitatively assessed.

Methods: The arm movements of 7 healthy subjects and 5 patients with unilateral Shoulder Impingement Syndrome during specific tasks were recorded using an optical three-dimensional motion analysis system. Kinematic analysis was supported by a suitable biomechanical model that divides the body into rigid segments interconnected via ideal joints. Each segment is defined by a triplet of passive infra-red light reflecting markers. The model permits the correlation of the marker paths with limb motion. Simultaneous recording of muscle activity allows the relationship between task-related effects of impairment in the shoulder joint and the related neuromuscular joint co-ordination to be evaluated. Descriptive parameters have been developed which allow the arm movement patterns and their unique features to be analyzed.

Results and Discussion: Results are presented in terms of the changes in joint Cardan angles and muscle activity with respect to time; they graphically represent the characteristic arm movement patterns of individuals or groups. The procedure allows the objective and quantitative evaluation and comparison of arm movement kinematics for a variety of tasks.

123 - Reliability and Validity of a Clinical Video-Based Gait Assessment Tool

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Introduction: Accurate, reliable gait analysis is necessary to develop and assess interventions. However, most clinical gait analysis is performed by observation despite it's poor reliability and sensitivity. This study evaluated the reliability and validity of a video based gait assessment tool (GAT) that is low cost, easy to document, and can be readily used in the physical therapy clinic.

Methods: Seven light reflective markers (shoulder, iliac crest, hip, knee, ankle, heel, toe) were secured to 10 adults without impairments and 10 children diagnosed with cerebral palsy prior to ambulating for 3-5 passes on a walkway while being filmed from a sagittal view. Frame by frame VCR playback was used to identify five phases of gait: initial contact, midstance, toe off, midswing, and initial contact 2. An overhead transparency was attached to the monitor and at each phase of gait a pen was used to mark the position of the light reflective marker. Following each pass, the transparency was removed and joint angles for each phase were measured with a goniometer at the hip (2 different angles were calculated), knee, and ankle. The videotapes were then processed through a PEAK5 2-D Motion Analysis System and joint angles at each identified phase of gait were calculated. The average joint angle for three passes for each phase of gait was calculated from the GAT and the PEAK5 systems and used to find intraclass correlation coefficients (ICC).

Results: The ICC's for all subjects ranged from 0.402 - 0.993. The calculated ICC's were greater than 0.850 for 90% (18 of 20) of the measurements in the pediatric group and 75% (15 of 20) in the adult group. All five ICC's less than 0.850 in the adult group were calculated with regards to ankle motion.

Discussion: Averaged angles derived from the GAT system are highly reliable and consistent with averaged angles derived from the PEAK5 system. The GAT system is a reliable yet inexpensive tool for gait assessment and can assist clinicians in adjusting interventions to meet established goals.

136 - Functional Activity Characteristics of Individuals with and Without Shoulder Disorders

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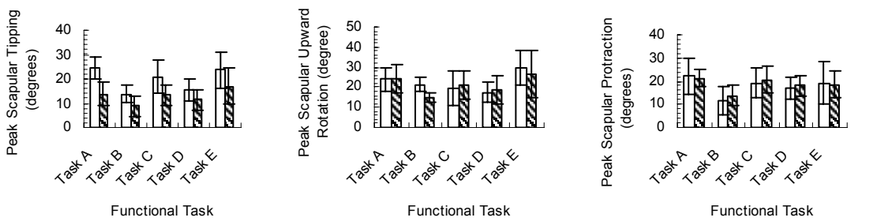
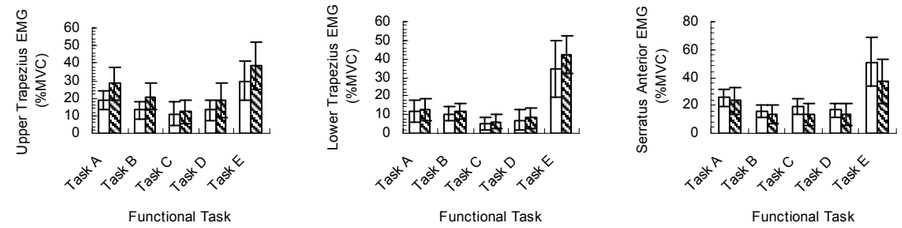
Background: Proper evaluation of functional activities is a key concern for a clinician in diagnostic assessment, outcome measurement, and planning of treatment programs. The present investigation tested the reliability of three-dimensional shoulder complex movements during functional tasks and compared motion patterns between subjects with and without shoulder disorders (SDs).

Methods: Twenty-four asymptomatic male subjects and 21 male subjects with shoulder disorders performed five functional tasks which involved arm reaching and raising activities with their dominant (right) arms. During the functional tasks, three-dimensional shoulder complex kinematics and electromyography data were recorded with an electromagnetic movement measurement system, the FASTRAK, and an EMG system. Intraclass correlation coefficients (ICCs) were calculated to show the reliability of the measurement for each functional task. Two-factor analysis of variance (ANOVA) models with factors of group (subjects with SD or subjects without SD) and task (four functional tasks and shoulder flexion movement) were calculated to determine if a significant kinematic and muscle EMG measurement difference existed between the two groups,.

Results: Shoulder complex kinematics and associated muscular activities during functional tasks can be reliably quantified (ICC= 0.63 to 0.99). Relative to the group without SDs, the group with SDs showed alteration in shoulder complex kinematics (3° to 40°) and associated muscular activities (3% to 10% maximum).

Conclusions: The evaluation method investigated by motion tracking and EMG systems can be used to consistently characterize the functional activities within-session on 3 trials in both subjects with and without SDs. Scapular tipping, scapular elevation, upper trapezius muscle function, and serratus anterior muscle function may have implications in the rehabilitation of patients with SDs.





(A) The subjects used their right arms to place an object at height just overhead. (B) The subjects used their right arms to place an object at shoulder height. (C) The subjects used their right arms to slide a box across a table. (D) The subjects reached to get a salt shaker. (E) The subjects raised their right arms as high as possible.

157 - Analysis of the Righting Reaction of Sitting Balance Against Tilting Stimuli: Study of Difference Between Healthy Persons and Hemiplegic Patients

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Introduction: It is important to analyze the occurrence pattern of the righting reaction of head and trunk in the treatment of patients with sitting balance disorder and to study what stimuli are effective. For the righting reaction in sitting position, the pattern that keeps the head and trunk vertical against perturbation stimuli is considered. The purpose of this study is to clarify the pattern of righting reaction in healthy patients and hemiplegic patients and to analyze the difference between them.

Subject: (1) Nine healthy persons (five males, four females, mean age 22.4 years old) and (2) left hemiplegic patients due to cerebrovascular disease (two males, mean age 68.5 years old) were included in the study. In the patient group, about 9 weeks from onset elapsed and the severity of motor paralysis was moderate enough to manage to keep sitting position. All subjects were informed of purport of the study and the consents were obtained by writing.

Methods: Subjects sat sideways on a tilt table with distal 25 % of thigh length coming out from the end of sitting surface and the following tasks were performed with no legs support. The tilt table was being tilted to 7 degrees at a constant speed, and the measurement was done from a direction to tilt toward left side below (left tilting) in the following order; left, right, right and left. After a gyro sensor was set on the manubrium of sternum of subjects to be vertical against floor face and 3-dimentional angle velocity was determined every 1/60 second for 8 seconds, the velocity was transferred to the angle and maximum value was calculated. Simultaneously, a digital video camera was set backward, and a total of 8 markers were attached to the head, left and right acromions, vertebral column (C7□T7□L3) and left and right posterior superior iliac spine of subjects. Positions at 2-dimentional coordinates were calculated with motion analysis software (DKH, Frame-DIAS2). A statistical test was carried out with one way ANOVA.

Results: (1) Mean values of the measurements with gyro sensor for the healthy person group in left tilting were 0.06 degrees in trunk extension, 0.58 degrees in left lateral flexion, and 0.27 degrees in right rotation and no difference was observed. In right tilting, no difference was similarly observed. On the other hand, for the patient group under conditions of tilting toward affected side (left tilting), mean values were 3.82 degrees in trunk flexion, 0.83 degrees in right lateral flexion, and 1.19 degrees in right rotation, showing large flexion angle. Furthermore, under tilting condition toward unaffected side, trunk extension was seen in 1.66 degrees similar to the healthy persons. (2) In measurement with digital video camera, the deviation of lower part of the trunk angle was 2.72 degrees larger than in other sites in the healthy persons, large deviation was not observed in other sites. On the other hand, in the patient group, the ranges of movements of upper trunk and both shoulders were large, from 2.70 degrees to 3.75 degrees.

Discussion and Conclusion: In righting reaction against perturbation stimuli by tilting tilt table, the movement of lower trunk was mainly seen in the healthy persons and rotation of trunk was hardly seen. On the contrary, in left hemiplegic cases, it was considered that a strategy worked to keep sitting position by trunk flexion against tilting stimuli particularly toward affected side direction. This coincided with a clinical observation, suggesting the usefulness of methodology of this study.

159 - The Relationship Between Ipsilateral Hip Dysfunction and Contralateral Knee Degeneration

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Introduction: We have observed that patients with long-standing hip disorders sometimes developed degeneration or malalignment of the contralateral knee. In this study we developed a model to try to simulate the clinical situation of a patient walking in a compensated Trendelenberg gait pattern.

Methods: Thirty volunteers were recruited for three-dimensional gait analysis conducted under two conditions: free walking (normal walking) and walking in a brace set in abduction of the hip (brace walking). Differences in peak adductor moment in the contralateral knee were used to separate the volunteers into groups: those with decreased adduction moment of the contralateral knee during brace walking (low adduction group) and those who demonstrated high adduction moment of the contralateral knee during brace walking (high adduction group). Kinetics and kinematics of these two groups were compared.

Results: With normal walking, volunteers in the high adduction moment group had increased knee flexion during the stance phase and an increased posterior pelvic tilt. With brace walking, volunteers in the high adduction group flexed the knee and hip more significantly than volunteers in the low adduction group and the pelvis tilted more anteriorly during the gait cycle. Additionally, the position of the foot was significantly further away from the center of body mass in the x direction, and the trunk had larger vertical excursion compared in the low adduction group. The ground reaction force vector was significantly higher in both the vertical and lateral directions in the high adduction group.

Conclusion: It was not possible to increase the average adduction moment of the contralateral knee in all volunteers by wearing a hip brace. However, wearing a brace did separate the volunteers into groups. Differences in normal walking preexisted among the volunteers whose adduction moment increased during brace walking; the differences were knee flexion in stance phase and pelvic tilt. Differences in brace walking in up-and-down movement of the trunk and position of the foot have consequences for the ground reaction force vector and lead to different magnitudes of adduction moment of the contralateral knee.

This study has important clinical implications for patients who require osteotomy of the contralateral knee and/or reconstruction or joint replacement of the ipsilateral hip.

160 - Hand Biomechanics in Healthy Subjects Performing Activities of Daily Living: Analysis of the Movement Patterns of Wrist, Metacarpophalangeal and Proximal Interphalangeal Joints

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Introduction: The use of functional activities to describe upper limbs movements is considered among the most effective methods to assess the extent of a potential injury and the degree of recovery during rehabilitation therapy. The description of upper limb kinematics, however, and particularly hand kinematics, is limited by the non-cyclical nature of these movements, as opposed to gait.

This study, using a cyclical method of assessment of the upper limbs kinematics, describes the similarities in the patterns of upper limbs movements for the wrist, metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joints in 4 healthy subjects performing selected activities of daily living: opening a jam-jar and pouring 200ml from a carton.

Methods: Passive retroreflective markers were attached to the subjects' skin of the elbow, wrist and dorsal side of the hand on anatomical landmarks found by palpation. A twelve infrared cameras optical system was used to capture the spatial coordinates of the markers. The joints movements were calculated using Euler angles.

A functional hand test was used to assess the function of the dominant hand of 4 healthy subjects (AV 33 ± 6ys). Each subject pressed a timer at the beginning (cycle start: 0%) and at the end (cycle end: 100%) of the task and followed the same protocol, which was instructed before the activity started. In addition, the relative position between the objects and the subjects was kept constant during the task as a result of appropriate patterns drawn on the test bench. Each action was repeated 4 times.

Results: The average second MCP joint angles over 4 repetitions and relative standard deviations, are illustrated in figure 1 below for two subjects during the carton-pouring task. The MCP joint was extended at the beginning of the cycle to grasp the carton and afterwards flexed to tighten the grip; this was repeated in reverse to put the carton back on the desk.

Discussion: This study suggested that the wrist, MCP and PIP joint angles yield similar patterns among healthy subjects if the tasks used are cyclical and follow a standardised protocol. The cyclical nature of the task also allowed comparison between the angle patterns during different phases of the action. This approach can be used in rehabilitation to assess a subject's initial condition and progresses through therapy.

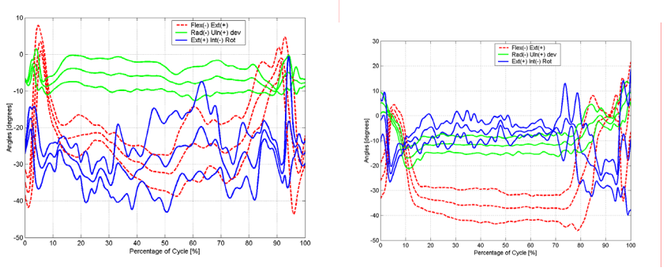

Figure 1. Second MCP joint angles for subject number one and two, average and standard deviation over 4 trials. Activity: pouring from a carton 200ml of water.

184 – Hip, Knee, Ankle Kinematics and Kinetics During Stair Ascent And Descent In Healthy Young Individuals

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Introduction; There is a great deal of research into human walking on level ground. Fewer reports on stair negotiation are evident in the literature, yet we frequently encounter steps/stairs during our daily activities. Understanding lower limb kinetics and kinematics during stair activities is important to further our understanding of lower extremity function and the pathogenesis of lower extremity disorders. The purpose of this ethically approved study was to identify normal functional parameters of the lower limb during stair ascent and descent in young healthy individuals.

Methods; Eighteen subjects, (8 M, 10 F, range 20-39 years) with no history of lower limb injuries, pathology of the back or pelvis, or systematic or neuromuscular disease were included into the study. The laboratory staircase consisted of 4 steps (rise height 18 cm, tread length 28.5 cm). To estimate lower limb kinematics and kinetics, Vicon 3D motion analysis was used (Oxford Metrics Ltd, UK). Temporal gait cycle data and ground reaction forces were recorded using Bertec Force Platform (Model MIE Ltd, Leeds, UK). Kinetic data were standardized to body mass and height.

Results; Significantly (p=0.0001-0.023) greater hip, knee angles and hip, knee and ankle moments were found during stair ascent compared to descent (Table 1). Significantly (p=0.0001-0.023) greater ankle dorsi and plantar flexion angles were found during stair descent compared to ascent. Note the greater change observed in hip flexion during stair ascent compared to stair descent (difference 29°) compared with knee flexion (difference 4°).

Table 1. Means (± SD) of the variables tested during stair ascent and descent

Mean (± SD)	Stair Ascent	Stair Descent
Max hip flexion (°)	63.4 (± 6.86)***	33.92 (± 7.53)
Max knee flexion (°)	93.0 (± 7.53)*	88.61 (± 6.44)
Max dorsi flexion (°)	10.8 (± [illegible])***	20.98 (± 4.76)

*p<0.05 **p<0.001 ***p<0.0001

Discussion; Stair ascent was shown to be the more demanding task when compared to stair descent for healthy young subjects. Our interest lies in the differences of these parameters during ageing and the possible implications of those who have sustained lower limb injuries. The findings from the current study could be used as baseline measures for pathological studies, theoretical joint modelling, and for mechanical joint stimulators.

209 - A Case Study Examining the Effects of Different Types of AFO on an Adult Hemiplegic Subject

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Introduction: Ankle foot orthoses (AFO) are commonly prescribed in patients with drop foot due to hemiplegia. There are a variety of AFO on the market, which can be described as 'off-the-shelve', custom made or orthotics based on functional electrical stimulation (FES). To date no study has examined the different kinematic and kinetic effects of these types of orthotics on hemiplegic subjects. This case study examines effects of these orthotics on an adult hemiplegic subject.

Methodology: Kinematic and kinetic data were collected from a forty-four year old female who suffered a right hemiplegia resulting in a drop foot, 58 months ago, using a Vicon Motion Analysis system and two AMTI forceplates [250Hz]. Kinetic and kinematic data in the sagital plane were analysed. Three walking trials were collected for each of the following conditions: 1) no AFO ;2) with a solid anterior leaf AFO (CAMP); 3) with a solid posterior leaf AFO (Smith & Nephew); 4) with a custom made posterior leaf AFO (Cappagh Hospital, Ireland) and 5) with FES AFO (Osdock stimulator, Salisbury District Hospital, UK). The subject walked at a self-determined walking pace for all conditions. All kinematic and kinetic data was managed as per the system proposed by Benedetti et al. 1998.

Results: At the hip and knee all forms of orthotics affected the saggital joint angles, with the custom made AFO resulting in the greatest change. At the ankle all orthotics cause significant changes to occur at this joint with less variability occurring between orthotic conditions. The greatest effect was observed at heel strike were a change of 8 degrees was noted for all orthotic conditions changing the position of the foot from –4 to +4 degrees. For the moments no major changes were noted between conditions except for the maximum flexion knee moment, which was absent except when the subject wore a custom made AFO.

Discussion: The results of this study would suggest that the forms of orthotics studied in this experiment have beneficial effects on lower limb saggital joint angles bring them to a more normative pattern of movement. The custom-made AFO seemed to be the most beneficial for this patient as it resulted in improved hip, knee and ankle position. The orthotic also generated a maximum flexion knee moment. Further studies need to assess the effects of these forms of orthotics in a larger population of hemiplegic subjects and to asses what characteristics within hemiplegic subjects might indicate which orthotic may be more beneficial.

References:

Benedetti MG, Catani F, Leardini A, Pignotti E, Giannini S, Data management in gait analysis for clinical applications.Clin Biomech 1998 Apr; 13(3): 204-215.

210 - The Effects of Different Types of AFO on Oxygen Consumption

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Introduction: Ankle foot orthoses (AFO) are commonly prescribed in patients with a variety of neuromusculoskeletal disorders. Research examining the effects of wear of an AFO on energy consumption in adult hemiplegic subjects is scarce and has not controlled for the variable of walking speed (1). This study explores the effects of AFO with different leaf forms on the oxygen consumption (VO2) of hemiplegic subjects during controlled walking speed.

Methodology: Six hemiplegic subjects with drop foot took part in this study, mean age 53.8±12.3yrs, mean time post stroke 44±28.9months. Subjects were included in this study if they were able to maintain a maximum walking speed of 1km/hr for the duration of the test and were safe to walk on a treadmill. VO2 was measured using the Sensormedics Vmax229 Metabolic system (Sensormedics Corp., USA). Baseline VO2 was collected during 10 minutes of sitting in a relaxed state. VO2 was then measured while the subject walked on a treadmill for 6 minutes at a speed of 1km/hr for each trial. Three trials were collected for each of the following conditions: 1) No AFO ;2) with a solid anterior leaf AFO (CAMP) ;3) with a solid posterior leaf AFO (Smith & Nephew). The trial order was randomised. The net increase in relative VO2 was collected for the last 2 minutes of each condition. A repeated measure ANOVA was used ($P<0.05$) to compare the three groups.

Results: No significant differences were found for VO2 between conditions. The mean VO2 for the condition of no AFO was 4.9±2.6 Kg/min, anterior leaf AFO 4.3±1.3 Kg/min and posterior leaf AFO 4.0±1.65 Kg/min.

Discussion: Wearing of an AFO in hemiplegic subjects did not cause a significant change in VO2, indicating no effect on energy expenditure, when the effect of speed was eliminated. Further studies need to examine the effects of AFO in a larger population of subjects and also to assess the effects of AFOs on other measures of energy expenditure.

References:

(1) Franceschini M, Massucci M, Ferrari L, Agosti M, Paroli C: Effects of an ankle-foot orthosis on spatiotemporal parameters and energy cost of hemiparetic gait. Clin Rehabil. 2003 Jul; 17(4): 368-72.

211 - The Effects of Different Types of AFO on Hemiplegic Gait

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Introduction: Ankle foot orthoses (AFO) are commonly prescribed in patients with a variety of neurologic and/or musculoskeletal disorders. Research in the area of orthosis wear for hemiplegic subjects has concentrated on temporal data rather than joint kinematics. To the best of our knowledge no literature currently exists, which explores the effects of different leaf forms of AFO on hemiplegic gait patterns.

Methodology: Kinematic data were collected from 23 hemiplegic subjects, mean age 61.4±10.3yrs, mean time post stroke 40.24±35months. Three dimensional kinematic data was collected using a Vicon Motion Analysis system [250Hz]. Kinematic data in the sagittal plane were analysed. Three walking trials were collected for each of the following conditions: 1) No AFO 2) a solid anterior leaf AFO (CAMP) 3) a solid posterior leaf AFO (Smith & Nephew). Subjects walked at a self-determined walking pace for all conditions. All kinematic data was managed as per the system proposed by Benedetti et al. 1998.

A repeated measure ANOVA was used ($P<0.05$) to compare the three groups.

Results: Significant effects were found for the following variables; H3 (Maximum extension in stance phase), H4 (Flexion at toe-off), K1 (Flexion at heel strike), A4 (Flexion at toe-off), A5 (Maximum dorsiflexion in swing) and A10 (Maximum plantar flexion in swing). The variables of A4, A5, A10 and K1 could distinguish between wear of a posterior and anterior leaf AFO. The variables of A10, H3 and H4 could distinguish between not wearing an AFO and a posterior leaf AFO and the variables of H4 and K1 could distinguish between not wearing an AFO and an anterior leaf AFO.

Discussion: Wear of an AFO in the hemiplegic subjects had a significant effect on the movement of the hip, knee and ankle. The greatest effects were seen at toe-off and during the swing phase of the gait cycle. No variable could distinguish if the subject was wearing an AFO and the type of AFO worn, however most variables could distinguish between the different types of orthotics worn and some variables could identify if one type of orthotic was worn. Future research needs to examine if any other kinematic or kinetic variable might be more sensitive to the changes in gait pattern with the wear of orthotics.

References:

Benedetti MG, Catani F, Leardini A, Pignotti E, Giannini S.: Data management in gait analysis for clinical applications. Clin Biomech 1998 Apr; 13(3): 204-215.

224 - Effect of Shoes and Muscle Stiffness and Damping Interactions on Simulated Upper Body Deformation During Running

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Introduction: There are many reports about the influence of shoe and muscle stiffness and damping on the vertical impact force peaks during running. These studies show a little influence on impact force peaks according to the changes in shoe and muscle properties. A running body has many possibilities of forces (external or internal) according to the quality of landing which is the function of normal velocity, geometrical alignment, changing muscles activity, etc. In this study, the human body which was intended in the literature (a simplified mass-spring-damper system). The influence of mechanical properties of the human body and midsole hardness and damping on the vertical deformation of upper body was examined by changing of stiffness and damping ratio. A time related external impact force was assigned to the total body and the short time and long time deformation of upper body were derived. According to the results, it could be concluded that the muscle tuning and the mechanical properties of shoes can be used for considering the affect of impact deformation peaks during running.

Methods: A four degree of freedom mass-spring-damper model was assumed four modelling the human body as a system of rigid and wobbling mass. Some external loads according to previous results, which are shown in the literature. The vertical ground reaction force was applied in some more cycles. In addition, the influence of damping and stiffness of shoe according to the muscle characteristics is considered. The vertical deflection of human upper body mass is considered as criteria for designing a proper shoe for a runner.

Results: According to a dynamic analysis of this four degree of freedom model following results obtained from Sap2000 Nonlinear program. The previous analysis showed an increasing in vertical ground reaction force due to increasing the hardness and damping ratio of shoe-sole (Nigg et all, 2001.p852). According to the obtained results, some other conclusion will be obtained. As it was mentioned before, a cycle of running was used and the duration of considering the impact force is 8 seconds. Therefore, 8 cycles with the following characteristics were used. Duration of each cycle was 1 second. VGRF (Vertical Ground Reaction Force) can be derived according to the fig.3 in the first 0.3 seconds of loading step. The remained 0.7 seconds consider as a zero-loading step. Increasing of hardness of mid-sole has a considering influences on vertical displacement of human body especially the human upper body wobbling mass. However, by considering the other cycles it is shown that assuming of decreasing in vertical displacement of masses according to increasing in shoe stiffness is not correct. Therefore, these results should be considered in designing the mid-sole of shoes. It is derived from the study that all masses have the same behaviour according to applied impact force. An interesting finding of the current study was that the changes in damping had a step-behaviour influence on vertical displacement. It is also shown that the changes of damping have no any influence on rigid body mass. Therefore using damping ratio in designing shoes should be mentioned more and followed after empirical test. It is shown that the interaction of shoe stiffness and damping ratio has not a predictable influence on vertical displacement of human body mass. As the most of human body is assumed to be placed in upper body wobbling mass this mass (M3) can be consider for designing and study the behaviour of human body according to characteristics of shoe mid-sole.

Discussion: The stiffness of mid-sole has more influence in vertical displacement of human masses. However the influence of damping cannot be ignored and will affect the displacement and decrease the dynamic displacement behaviour of human body.

236 - Energy Profiles of Index Finger During Tapping

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Introduction: We investigated the energy profiles of the human index finger during tapping on a keyswitch. The index finger was modeled as a mechanical system with potential and kinetic energy. The system receives mechanical energy from joint work done at the metacarpo-phalangeal (MCP) joint and does work on the keyswitch. We hypothesized that the system energy remains constant during tapping period. This energy transfer might provide new insight to the injury mechanism associated with repetitive finger activities.

Methods: Sixteen subjects (8 m, 8 f; mean: 29 6 years; SD: 5.86 years) tapped with their right index finger at a rate of 50 beats per minute using a Buckling-spring keyswitch from a Supertouch Enhanced keyboard (make force: 0.591N; travel distance: 0.35cm). Fingertip forces were measured with a two-axis force transducer. Keyswitch travel distances were acquired with a manual camera (Nikon Corp.) and use of an infrared LED attached to the cap of the keyswitch. We measured index finger joint kinematics using three individual miniature optic goniometers (Shape Sensors, Measurand Inc.) mounted across the distal interphalangeal (DIP) joint, the proximal interphalangeal (PIP) joint, and the MCP joint. Signals were collected at a sampling rate of 5kHz, filtered, scaled, and processed manually through Matlab (Mathworks) software Joint torques were estimated utilizing inverse dynamic methods. Joint work was estimated through integrating the joint torque with respect to joint angle.

Results: With the wrist supported during index finger tapping, the potential energy of the finger changed by approximately 3 mjoule. The work done to depress keyswitch was around 0.75 mjoule. The kinetic energy profile had 2 maximums: one during the downswing and one during the keyswitch release. Changes in potential energy and joint work dominated the energy profiles. Most of the potential energy and MCP joint work were not converted into either kinetic or work on the keyswitch and hence must be dissipated through other mechanisms. Work is also done on the interphalangeal (IP) joints (see the figure) and on the fingertip pad. Surprisingly, a negative peak of MCP joint work was identified before finger contacting keyswitch, indicating that muscles are doing work against gravity, inhibiting the free downward movement.

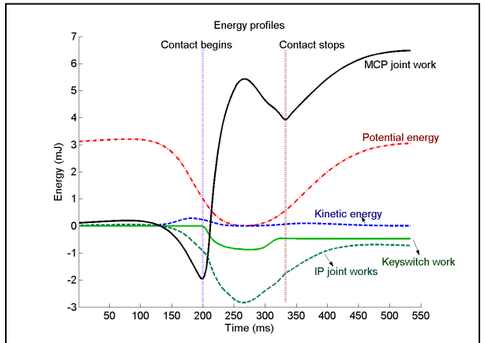

Fig1. Energy profiles during a keystrike

Conclusion: The system energy of index finger during tapping is not constant and is dissipated through the musculoskeletal system.

243 - Effect of the Upper Body Movement During Standing Up

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Introduction: The knowledge of kinesiology concerned with standing up is very important for disabled people. During the treatment of the hemiplegic patient, physical therapists take advantage of kinesiology for analyzing patient movement and teaching suitable moving methods for each patient. Standing up is one of the important movements for the patients to extend for their activities of daily living. The position of the lower extremity and upper body movement velocity are important for standing up. When patients sit on the chair with knee extension, patients cannot stand up slowly. On the other hand, it is easy when patients move their upper body fast. The relationship of the body velocity and lower extremity position is not clear. The purpose of this study is to estimate the velocity of the upper body for successful standing up. Standing up is one of the difficult movements for disabled patients. This study provides one of the causes of failed standing up and makes target velocity clear for successful standing up.

Methods: Seven subjects participated in this study. They did not have any neuromuscular disease and problem of bones and joints. Seven cameras were used to record subjects' performance at the frame rate of 60 frames per second. Three Force Plates were used to collect ground-reaction force and moment data at a sampling rate of 60 Hz. Each segment angular velocity and joint moment were calculated by computer. Electromyography was detected from the para vertebral muscles, rectus abdominis, vastas medialis, biceps femoris, tibialis anterior, gastrocnemius, and soleus. The subjects sat on the chair with knee flexion 80 degrees, and hip flexion 90 degrees for upper body perpendicular. The subjects want to stand up with variety of upper body velocities. The velocity changed from slow to fast as soon as possible. At first, the subjects did not stand up some slow velocities, and then they could stand up some fast velocities. For statistical analyses, Student's t-test was used for comparison of difference between not-successful stand up and successful stand up velocities. The association between velocity and knee joint moment was measured by correlation coefficient.

Results: The upper body velocity of successful sit up was significantly ($p<0.05$) faster than that of unsuccessful stand up.

Discussion: The upper body movement velocity and knee joint angle are important for successful stand up. Subjects can stand up with fast upper body movement during knee extension position. During knee flexion position, subjects can stand up with very slow upper body movement. When upper body moves forward, center of gravity moves to front and lower. The fast movement generates large acceleration of center of gravity. Large acceleration decrease vertical grond reaction force. Therefore, it is easy to stand up with fast upper body movement, even if knee joints are extended. Normal subjects can stand up in any knee joint position. Speedy body movement is difficult for disabled people. Therefore, they have to bend their knee joints to stand up safety.

266 - An Index to Quantify Gait Deviations

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Introduction: Clinical gait analysis aims to quantify and assess the mechanics of walking and identify deviations from 'normal' movement patterns. One reason that objective gait analyses have not been readily accepted in the clinical setting is the vast amounts of data that are produced. Data analysis and interpretation can be time-consuming and is not always practical in the clinical environment. To facilitate the use of clinical gait analyses, the objective of this study was to reduce the data and provide a method of automatic detection of gait abnormalities. One-dimensional scores, or indices of normality were developed based on mature normative gait data. The indices examine differences in the magnitude of motion as well as differences in the pattern of motion between a patient and the normative profile.

Methods: Data were collected from 60 normal children aged 1-13 years and 16 hypotonic children, aged 1- 11 years. A six-camera Vicon 512 motion analysis system and two force plates were used to obtain temporal-spatial, kinematic, and kinetic parameters during walking. Segment inertial parameters were estimated using a mathematical model of the human body (Jensen, 1978). Joint rotations were expressed using Euler angles and an inverse dynamics approach was used to estimate the joint moments and powers. Using the normative data, methods of data reduction were developed based on primary directions of variation from mean behaviour. Joint angles were characterized by their first and second derivatives (Tingley et al., 2002), and kinetic parameters were characterized by the time integral and scaled root-mean-square values of the moment and power curves. Quantifying the variation of an individual's gait data from the mean normative values led to a set of eight one-dimensional scores that classified gait patterns as normal, unusual or extreme based on population percentiles. The indices were tested using the hypotonic gait data collected as part of this study.

Results: To demonstrate the interpretive value of the score system, data for children with walking disorders (hypotonic gait) were entered into the classifier. Kinematic classifiers were found to be more reliable discriminators of clinical gait patterns than kinetics parameters for this specific disorder. Case studies showed agreement between the result of the classifier and subjective graphical interpretation of the hypotonic gait patterns.

Conclusion: Gait analysis data can be reduced to a few one-dimensional indices of normality, which provide researchers and clinicians with a rapid assessment of a patient's movement patterns compared to mean normative data. The score system is comprehensive, incorporating kinematic and kinetic data from multiple planes. Each score can be easily decomposed into their respective subcomponents to identify the origin(s) of an unusual or extreme score. Such models will improve the feasibility of objective gait analyses in the clinical setting.

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297 - Effect of Tai Chi on Gait and Obstacle Crossing Behaviors

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Introduction: Practitioners of Tai Chi (TC), or Taiji, anecdotally report improved balance and enhanced awareness of their surroundings while moving through a given environment. This may partially explain why older TC practitioners may reduce the risk of falling by ~50% (Wolf et al., 1996). This study investigated whether TC experience alters gait behavior and movement strategies while walking on a level surface and over obstacles.

Methods: Fifteen TC practitioners (7 females; 34–66 yrs; 1.5–15 yrs TC experience; same TC master) and fifteen controls matched by age, sex, and physical activity level were tested. Subjects walked at a self-selected (normal) pace along a 9.8 m walkway. Three conditions were tested three times: no obstacle, 10-cm obstacle, and 40-cm obstacle. The obstacle was placed half-way down the walkway. Step kinematics for five consecutive steps were analyzed: two before the obstacle (approach), one crossing (crossing), and two after (recovery). Gait parameters were: AP distance between consecutive steps (step length), ML distance between consecutive steps (step width), speed between consecutive steps (step speed), time in single leg support during the crossing step (support time), and average speed over the five steps (gait speed). Two-way repeated measures ANOVA were used to compare group and obstacle height.

Results: Significant differences were found between TC and controls in support time ($p < 0.001$), gait speed ($p = 0.001$), step length ($p \leq 0.03$), and step speed ($p \leq 0.004$), but not step width ($p \geq 0.4$) (Table 1, Fig 1). TC practitioners had shorter step lengths, slower step speeds and gait speed, and longer support times crossing the obstacle. Increasing obstacle height decreased gait speed ($p < 0.001$) and increased support time ($p < 0.001$). Step speed decreased with oObstacle height ($p < 0.001$), but only for the crossing and first recovery steps. also affected step speed, step length, and step Stance width was significantly greater for the 40-cm obstacle, but only for the first recovery step ($p < 0.001$), but only at select step positions. There was an interaction (group × height) for support time ($p = 0.006$).

DISCUSSION: Our results support the hypothesis that TC experience may alter gait behavior, especially when crossing obstacles. Long-term TC practitioners may use more conservative, but less (?) effective, strategies (slower, shorter steps) during gait and when perturbed. We are currently examining older adults in a longitudinal 5-month TC training program.

Table 1. Support time and gait speed by obstacle height and test group

.Obstacle height (cm)	Single leg support time (s)		Gait speed (m/s)	
	Tai Chi	Control	Tai Chi	Control
0	0.58 ± 0.04	0.54 ± 0.40	1.09 ± 0.15	1.24 ± 0.12
10	0.78 ± 0.09	0.65 ± 0.06	0.98 ± 0.14	1.20 ± 0.12
40	1.02 ± 0.11	0.85 ± 0.10	0.85 ± 0.10	1.05 ± 0.18

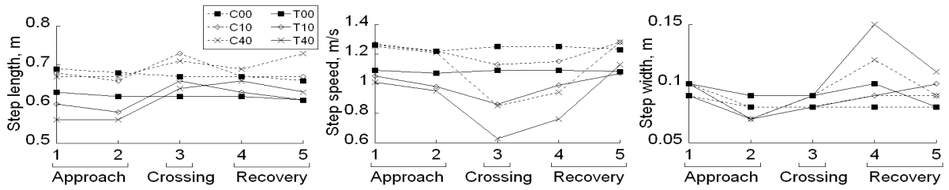

Figure 1. Step length, step speed, and step width as functions of step position, obstacle height (00, 10, or 40 cm), and test group (T-Tai Chi, C-control).

314 - Comparative Analysis Between Abdominal Muscle Recruitment In Each Quarter of Pregnancy Through EMGs.

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Introduction: It is not common to find studies which compare muscle recruitment in pregnancy. The aim of this study is to compare the capacity of recruitment of muscle fibers in abdominal muscles in different quarters of pregnancy through surface electromyography.

Methods: Three pregnant women were selected, one in each quarterly term of pregnancy without associated diseases. The external oblique and rectus abdominis muscles were evaluated by Biofeedback surface electromyography, through the detection of the signal by electrodes, during the movements of trunk flexion, trunk flexion with right rotation and trunk flexion with left rotation, keeping an isometric contraction.

Results: After the evaluation, we noticed that the values of the muscle recruitment during the movements were higher in the first quarterly than in the second, and this one higher than the third quarterly.

Discussion: An EMG evaluation is very useful to establish an evaluation for the different capacities of recruitment of muscle fibers in pregnant women, and in fact, there is a difference in the capacity of such recruitiment in the pregnant women, with progressive decreasing with the evolution of the pregnancy. It is necessary for more studies in this field to increase learning and treatment of pregnancy.

320 - Soft Tissue Artefact Description in Human Knee Motion Analysis by Combining 3D Fluoroscopy and Stereophotogrammetry

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Introduction. Soft tissue artefact (STA) is the most invalidating source of error in human motion analysis. This error is caused by the erroneous assumption that markers attached to the skin surface are rigidly connected to the underlying bony segments. The quantification of STA and of its propagation to relevant biomechanical variables is fundamental for their critical clinical interpretation as well as for the development of reliable compensation methods. The analysis of this artefact on patients with external fixators (Cappozzo et al.,1996) and on volunteers with percutaneous pins (Manal et al, 2002) is limited by the restrictions to skin sliding. In the present study, STA on the thigh and shank was quantified in three dimensions without any constraint to skin motion during the execution of daily living activities. Furthermore, the propagation of STA to knee joint rotation angles was evaluated.

Method. Two subjects, treated by total knee replacement, were analysed during stair climbing, step up/down, and sit-to-stand/stand-to-sit activities with fluoroscopy and stereophotogrammetry. Nineteen and twentyfive reflecting markers were uniformly attached laterally on the skin of the thigh, ten on the shank, and one reflecting/radiopaque on the patella for temporal synchronization. Moreover, three reflecting/radiopaque markers were placed in the fluoroscope field of view for spatial registration. The marker trajectories were reconstructed by means of a stereophotogrammetric system with 5 TV cameras (e-Motion, Padova, Italy). The accurate 3D pose of the prosthesis components was reconstructed from each 2D fluoroscopic projection with an iterative procedure using a CAD model based shape matching technique (Banks, et al. 1996).

Results. Displacement of skin markers in the corresponding prosthesis-embedded anatomical frames was generally larger on the thigh than on the shank. All shank markers exhibited almost the same displacement in the three directions during the execution of different motor tasks. On the contrary, skin markers on the thigh performed differently: markers on the posterior side of the thigh showed the largest medio-lateral displacement, and postero-proximal ones along the longitudinal direction. The standard deviation of the trajectory of each marker calculated for each motor task and each subject, was found up to 31 mm for the thigh and up to 21 mm for the shank. The root mean square difference between knee rotations (Grood and Suntay,1983) evaluated from skin markers and 3D fluoroscopy in percentage of their corresponding range for all motor tasks, was calculated. The ab/adduction and internal/external rotation angles were the most affected by STA propagation, with root mean square errors up to 192% and 117% of the corresponding range, respectively. Furthermore, joint kinematics evaluation was strongly affected by the choice of the cluster of markers. STA was assessed to be subject- and task-specific.

Conclusion. Whereas the calculation of flexion-extension at the knee by means of external markers can be considered acceptably reliable, this is not true for internal-external rotation and ab-adduction. In order to improve the performance of stereophotogrammetric-based human motion analysis, devising validated STA compensation methods is felt necessary.

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321 - Soft Tissue Artefact Compensation in Knee Kinematics by a New Method Based On Double Anatomical Landmark Calibration

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Introduction. Soft tissue artefact was recognised to be the most critical source of error in human motion analysis (Andriacchi and Alexander, 2000). It has been demonstrated to be task and subject specific. Its propagation strongly affects particularly joint angles characterised by a small excursion range, such as knee ab/adduction and internal/external rotation. This can result critical in the exploitation of gait analysis data for clinical decision.

Because of the relevance of this source of error several compensation methods have been proposed in the literature, but most of them are too time-consuming or lack in task and subject specificity.

The purpose of the present work was to describe and validate a new method for the compensation of soft tissue artefact on knee rotations and translations during the execution of selected motor tasks of daily living.

Methods. In the proposed method the compensation is performed interpolating two calibration configurations acquired at the extremes of the motion with respect to knee flexion angle, which was assessed to be the most reliable. The performance of this compensation method on knee rotations and translations was tested on a kinematic data-set obtained by the synchronous combination of traditional stereophotogrammetry and 3D fluoroscopy. This data-set allowed to compare knee kinematics calculated from stereophotogrammetry with traditional single calibration (Cappozzo et al. 1995), with the newly proposed double calibration

Results. The newly proposed method resulted extremely effective on the compensation of soft tissue artefact propagation to knee rotations, in particular mean values of the root mean square error on ab/adduction and internal/external rotation angles decreased from 3.7° and 3.7° to 1.4° and 1.6°, respectively. Mainly, knee translations calculated from stereophotogrammetric data using the proposed compensation method resulted reliable with respect to the fluoroscopy-based gold-standard. The residual mean values of the root mean square error were 2.0, 2.8, and 2.1 mm for anterior/posterior, vertical, and medio/lateral translations, respectively.

Conclusions. The proposed method produced a significant improvement in the calculation of knee joint rotations and, in particular, translations, without making the computational process significantly more time-consuming. The choice of two motor-task dependent calibration postures and the interpolation between the two configurations with respect to the specific flexion angle, made the compensation procedure intrinsically task and subject specific.

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340 - Effect of Design Changes of Military Load Carriage Systems on Gait and Posture: A Case Study

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Introduction: Military personnel are required to carry heavy loads for a large proportion of combat and training. These loads consist of webbing and a Bergen (backpack) resulting in a load carriage system (LCS). Considering the system as a whole is crucial in understanding the effect these loads have on the body. New prototype LCS's are currently being developed in the United Kingdom, this case study endeavours to give some initial insight into the changes the new systems may have on soldier's body posture and gait.

Methods: 3 male military personnel completed 3 load carriage conditions with 2 different LCS's: Current Issue Equipment (standard issue belt webbing + 90 Pattern Bergen) and Prototype Equipment (chest webbing + Airmesh Prototype IV Bergen). An initial control condition (wearing boots, helmet and carrying a rifle – totalling 7.95 kg) was used for comparison purposes. Following this there was a webbing condition (8 kg), addition of the backpack (24 kg) and finally carrying a Light Antitank Weapon (LAW) under the lid of the backpack (10.1 kg). The total weight carried in the final condition was 50.05 kg. A CODA motion analysis system acquired lower limb and upper body angular data whilst participants walked at self selected pace for 7 complete trials in each condition. Mean and 95% confidence intervals were calculated and angles were reported from –20 to 120% stance phase.

Results: Chest webbing resulted in a decrease in forward lean (-1.56 ± 0.33°) throughout stance phase when compared to belt webbing but no other changes in gait or posture measures were noted. Following on from this the Airmesh Prototype showed a trend for reduced forward lean (-1.03±0.23°) when compared to the standard issue 90 Pattern Bergen in the first 50% of stance phase. This trend continued in the LAW condition (-1.07±.36°). The craniovertebral angle (head and neck on trunk) also showed similar changes in the LAW condition (-0.98±0.22°) over the whole of stance phase. Gait parameters (ankle, knee and femur angles) showed little difference between LCS's with the exception of a slightly increased ankle flexion with the Airmesh Prototype.

Discussion: A more upright walking posture is more efficient when carrying load. There is also a reduction in stresses placed on small back and neck muscles. The development of a new LCS design whereby load is transferred to the chest rather than the waist results in a more upright walking posture whilst carrying webbing. During a typical operational/training day for a member of the military, webbing is always worn and therefore means to reduce injury risk and trauma to the body are welcomed. There are also large periods of time when military members are required to carry large loads in backpacks. By allowing use of a hip belt on these packs (Airmesh Prototype), a trend for a more upright posture is observed as well as more of the load being distributed to the pelvis rather than the shoulder region. As well as considering posture whilst carrying loads, balance, field of view and heat transfer are of importance. Another crucial factor is performance of other tasks such as shooting and grenade throwing ability. However, placing loads on the front of the body is not a viable option as often a soldier needs to go to ground, walk for long durations (thermal issues) or quickly remove these loads to engage in battle. For this reason it is important to achieve a trade off that considers all of these underlying performance factors.

355 - Association Between Heelstrike and Kinematic Parameters of Gait – An Indirect Detection Method Without Foot Switches

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Biomechanical analyses of gait commonly relate behaviour of different parameters to the gait cycle, usually defined between two consecutive heelstrikes of the same leg. The heelstrike event is commonly detected with switches or pressure sensors on a shoe, or with a force plate or contact mat placed on the ground. Since such systems may not always be available or applicable we have addressed the question whether the heelstrike event can be indirectly assessed through other events that would substitute as a marker of the gait cycle. Using data from a recent study of balance perturbation during gait along a straight level path in 12 healthy subjects, we have demonstrated that the heelstrike event is consistently associated with the point in time where the anteroposterior linear velocity trajectories of the two shanks intersect. Kinematic data were collected using two Optotrak 3020 optical tracking devices (Northern Digital, Waterloo, Ontario). A rigid body array of six infrared light emitting diodes was placed on the mid-level anterior aspect of each shank and sampled at a rate of 40 Hz. Subjects walked at a pace of 100bpm set by a metronome and gazed at an "X" on the wall at the end of a 12 m walkway that contained a balance perturbation platform with an embedded force plate. The onset of vertical force for the 6th step, which always occurred on the force plate, was used as the reference for the analysis of the kinematic data of the same step. Subjects performed 24 trials of walking, 12 of which included a perturbation in mid-stance. Across all subjects, the anteroposterior shank velocity intersection occurred 35±13 ms after heelstrike was detected with the force plate. Variability within subjects was small with individual standard deviations ranging 4-9 ms. There was no difference between perturbation trials and non-perturbation trials. The intersection of shank velocities appears to be a well-defined kinematic event that occurs consistently and near the real heelstrike event. A calibration step on a force platform may be used to adjust for individual offset between shank velocity intersection and heelstrike, allowing for an indirect detection of heelstrike without the use of foot switches or specific foot markers.

377 - The Partition of Spin Angular Momentum in Human Walking

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Even though ground reaction forces could produce a net torque on the human body, experimental evidence shows that the angular momentum about the center of mass is highly conserved during walking. Using a morphologically realistic (16 links, 32 internal degrees of freedom) human model and kinematic gait data from 10 normal adult subjects, we studied the distribution of angular momentum throughout the body by computing a set of 16 linearly independent angular momentum partitions for each spatial direction using principal component analysis. The first principal components in sagittal, coronal and transverse planes explained approximately 90%, 75% and 85% of the data, respectively (first three combined explained 98%, 95%, and 95%). The scalar product of the first principal components, of the same subject, at slow and moderate walking speeds was typically larger than 0.99 for all three spatial directions. The scalar product of the second principal components at these same walking speeds was only slightly smaller, or 0.99, 0.98, and 0.97 for sagittal, coronal and transverse plane rotations, respectively. These observations suggest that the angular momentum partition is largely invariant to walking speed. We discuss both the speed and subject dependent differences found in the first few principal components. Using the results of these analyses, we suggest a novel control framework for humanoid robots and powered leg orthoses.

393 - Gait Deviations in Sound Limbs of Transfemoral Amputees in Response to Alterations of Sagittal Socket Alignment

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Introduction: Insufficient swing clearance of the prosthetic limb is a major source of gait deviations in transfemoral prosthetic gait, affecting the motion of the sound limb as well as the prosthetic limb. The sagittal alignment of the socket is believed to affect the swing phase of the transfemoral prosthetic gait but not much consistent evidence has been reported. Moreover, little attention has been paid to the deviations of the sound limb movement, which obviously takes more responsibility of the locomotive energy generation, in response to the changes of the socket alignment. We investigated transfemoral prosthetic gait patterns focusing on the changes of the sound limb movement in terms of the vertical displacement of the center of gravity (Vcog). The gait deviations of the sound limb were further examined in three different sagittal socket alignments, which altered the swing clearance of the prosthetic limb.

Methods: Seven fully rehabilitated, male transfemoral amputee subjects (32.1 ± 10.5 years old) and 5 age matched normal males (38.4 ± 16.5 years old) participated in the study. Three dimensional gait analyses were done using an optoelectronic system equipped with 6 infrared cameras and 2 force plates in a university hospital setting. Thirteen reflective markers for walking trials at self selected, comfortable speed and 15 markers for static standing trials were used. The Vcog was estimated from the movement of pelvic markers. Three dimensional joint angles were calculated based on Cardan angles and inverse dynamics was used to calculate the relevant kinetic variables. Three different alignments were tested: the optimal (OA), anterior (AA), and posterior (PA) alignments. The OA was the alignment that the subjects had been using since their successful rehabilitation. The AA and PA were the alignments tilted by 2.6 degrees relative to the OA in the sagittal plane to anterior and posterior directions, respectively. Three free walking trials were measured and averaged for each alignment. At least a week of adaptation period was given for a new socket alignment before the measurement.

Results: The excursion of Vcog of the sound limbs (5.18+/-1.75 cm) in the stance phase was larger than that of controls (3.47+/-0.97 cm, p=0.02 by Mann-Whitney test) or prosthetic limbs (3.91+/-0.98 cm, p=0.01 by Wilcoxon test). The hips of the sound limbs were in abduction positions (-2.62+/-6.79 degree) whereas the controls showed adducted coronal hip angles (4.15+/-5.50) at the moment of the highest Vcog (p=0.04). Slightly higher hip abduction moment was demonstrated in the sound limbs (0.94+/-0.52 Nm/kg) than in the controls (0.71+/-0.27 Nm/kg, p=0.18). The knee or ankle joints of the sound limbs did not show significant deviations. The excursion of Vcog at each alignment revealed an increasing tendency from PA (4.97+/-1.84 cm), OA to AA (5.23+/-1.75 cm) but the differences were not significant, nor were those of the coronal hip angles/moments at each alignment.

Conclusion: The sound limbs of transfemoral amputees show deviated gait patterns especially in the coronal hip joint angle and moment in relation to the increased excursion of Vcog in the stance phase. These deviations were not significantly affected by the alterations of the sagittal socket alignment although some tendency was noted.

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394 - Effects of Lower Extremity Exercise on Balance Recovery from a Forward Fall

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The purpose of this pilot study is to investigate the effects of a lower extremity exercise task on the ability to recover from an impending forward fall. Four healthy, young, male participants denied a history of musculoskeletal or neurological disorders, reported moderate levels of activity, and provided informed consent. The lower extremity exercise consisted of walking on an inclined (15 degrees) treadmill moving at 3.5 mph. Balance was assessed using variables extracted from a balance perturbation task consisting of a forward lean (20% body weight supported) followed by a step-invoking release. During a test session, the participant cycled through 15 consecutive trials, each of which consisted of 600 steps on the treadmill followed by the balance assessment.

During each balance perturbation, foot-floor reaction data were collected using three force plates sampled at 1000 Hz; and foot kinematic data was collected using an optoelectronic motion analysis system sampled at 100 Hz. Foot-floor reaction data was used to calculate peak landing forces, center of pressure (COP) movement and temporal variables including pushoff, liftoff, and landing times. Foot kinematic data was used to calculate step length and step speed for each trial. Linear regression analysis across trials was used to investigate the effects of exercise on the variables used to quantify balance recovery.

Analysis of these variables revealed a 4.1% decrease in landing time, an 11% decrease in swing phase duration, and an 8.3% decrease in peak vertical force. Step length decreased (7.2%) while step speed was observed to increase (3.9%). Differences in COP measures included increases in COP lateral shift, COP distance travelled, and COP speed prior to liftoff (11.7%, 11.3%, and 11.1%, respectively); and decreases in swing phase COP anterior-posterior shift (13.7%), swing phase COP distance travelled (9.0%), and post-landing COP distance travelled (12.4%).

The observed trends suggest an altered step strategy that, following exercise, is characterized by smaller and quicker steps. Decreased COP distance and anterior-posterior shift during swing phase is consistent with the observed reduced step size. Increased lateral COP displacement prior to stepping indicates more pronounced weight transfer due to exercise; however no trends were observed in pushoff or liftoff times due to increased COP speed, suggesting a compensation mechanism that ensures an invariable step preparation phase [1]. Reduced vertical force at landing may be indicative of the decreased strength requirements associated with smaller steps [2], which may be an advantage of the altered step strategy. These findings are consistent with results observed in a similar study on varied step lengths [3], which suggests that performing the step task after exercise may represent an apparent increased balance disturbance level. Thus, a lower extremity exercise, which introduces some level of localized muscle fatigue, reduces the ability to recover from a forward fall in healthy young adults by causing a smaller step, which results in a lower strength requirement, but represents a less effective balance recovery strategy.

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426 - 3D Arthrokinematics of the Human Upper-Cervical Spine: In Vitro Study of Coupled Rotations

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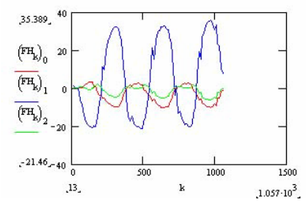
Introduction: Though previous studies analyzed segmental coupled motion in the cervical spine from 2 dimensional registrations, 3 dimensional analysis of motion coupling was only studied sparcely (Amevo et al. 1991; Panjabi et al. 1993; Woltring et al. 1994; Bogduk and Mercer 2000; Hof et al. 2001). This preliminary study focuses on the in vitro registration of upper cervical segmental coupled movements. Therefore, the aim of this study was to collect quantitative information on the kinematics behavior during planar movements of the upper-cervical spinal motion segments.

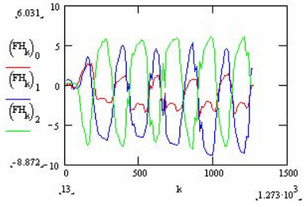
Methods: Three cervical spine specimens were taken from embalmed human cadavers at the level of the first thoracic spine to the head. Each specimen was clamped on a rigid stand to hold T7 in such a way that the cervical spine was fully free to move. 3D electromagnetic tracking sensors were fixed on the head, c1 and c2. Subsequently, each specimen was moved in lateral flexion and rotation. The position and orientation of each sensor were collected. The individual sensor data were used to describe coupled movements by means of the parameters of the finite helical axes (Spoor and Veldpaus 1980) for discrete sampling ranges of the movements between the different bones: i.e. orientation, position, shift along and rotation about the estimated helical axis. At a later stage, the positions of local anatomical landmarks were digitized with a 3D drawing stylus. These anatomical data were used for the definition of local bone embedded co-ordinate systems. To analyze the 3D intra articular kinematics of the cervicocephal and atlanto-axial joints, the finite helical axes were related to a co-ordinate system based on the center line through mastoid processes and the transvers processes of c1 and c2. **Results:** The results are analyzed by the finite helical angles representations. During C0-C1rotation a minimal contra-lateral lateral flexion takes place, while during lateral flexion a relatively large, but in this case asymmetrical rotation takes place.

Results: The results of C1-C2 rotation indicate the primary movement being accompanied with a contra-lateral associated lateral flexion movement on the level of c1-C2. The associated movements are relatively larger during primary lateral flexion than during rotation. The helical angles of specimen two on the level C1-C2 are depicted as a representation. The results of the other specimens show similar coupling patterns although the magnitude of the movements and the association can differ.

C1-C2 Rotation



C1-C2 lateral flexion



Conclusion: These preliminary results show that the segmental coupled movements in the upper cervical spine can be analyzed by means of an electromagnetic tracking device. The results indicate that the associated movements are contra-lateral directed but the number of studied specimens were to few to perform any statistical analysis. Future studies intend to analyze more specimens and to include the study of the shift parameter.

432 - Biomechanical Analysis of Aggressive In-Line Skating: Landing and Balance During A Stall

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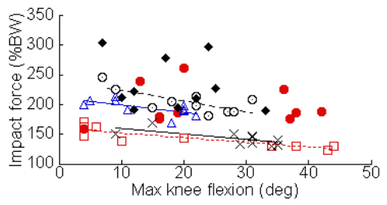
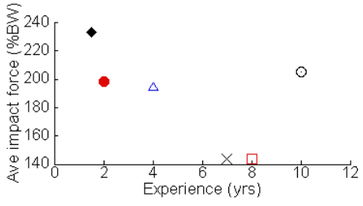
Introduction: Aggressive in-line skating, or trick skating, is a relatively new sport, with only epidemiological data of skate park injuries (Everett, 2002). This novel biomechanical study of aggressive skating focused on the "stall", a balance training activity where the skater repeatedly jumps on an elevated rail and tries to maintain balance. We hypothesized that, to smoothly decelerate the body and minimize impact forces, this exercise emphasizes development of muscle control though eccentric contractions of the lower extremity joints. We also hypothesized that more experienced skaters would minimize impact force.

Methods: Six male skaters (aged 18 - 46 yrs, 1.5 - 10 yrs experience) performed 10 stalls each. Each subject was instructed to jump onto a grind rail, maintain balance (approx. 1-3 s), and jump down. No constraints were placed on landing and balancing techniques, allowing the skater to maintain his unique style of performance. A simply-supported, steel grind rail (5 cm diameter pipe, 178 cm length x 26 cm height) was constructed to sustain no moments at the supporting ends. Peak vertical impact force (as % body weight) was recorded and sampled at 1000 Hz or 2500 Hz. Joint flexion at the knees and hips were determined Maximum joint flexion, immediately after impact, was averaged for the ankle, knee, and hip joints, usingfrom kinematic data collected with a 6-camera motion capture system (VICON 460, Oxford, UK) sampled at 100 Hz. Correlation analyses assessed whether peak impact force was associated with maximum knee joint flexion, immediately after impact, (at the ankle, knee, and hip) or skater experience.

Results: Decreasing peak impact force was significantly correlated with increasing knee flexion in four of six subjects ($r \leq -0.68$, $p \leq 0.016$, Fig. 1. 1 left panel). The two subjects with no correlation between knee flexion and applied impact force ($r \geq -0.24$, $p \geq 0.25$) had the least amount of experience (average of 1.75 yrs vs.as compared to 7.25 yrs for the other four subjects). No significant correlations were found between impact force and ankle or hip flexion. After excluding for a very experienced subject with new skates (circle symbol, right panel), peak impact force was found to significantly decrease as skater experience increased ($r = -0.95$, $p < 0.012$, Fig. 2). Hip flexion/extension behavior appears to be inconsistent between subjects.

Discussion: Our results suggest that more-experienced trick skaters tend to attenuate impact force. This appears to be accomplished partially by increasing knee flexion (or eccentric contraction of the quadriceps muscles) immediately after impact. Less-experienced skaters may be more concerned about maintaining balance, rather than refining their technique to (subconsciously) minimize impact force. For the four most experienced subjects (hollow symbols), impact force significantly decreased with increasing knee flexion (see trend lines for each subject, left panel). If an experience subject with new equipment (circle) is omitted, then average impact force over all ten trials significantly decreases with increasing skater experience (right panel).





436 - Gait Analysis in the Longitudinal Assessment of Patients Suffering From Multiple Sclerosis

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Introduction: It is well known that since its very beginning multiple sclerosis (MS) causes postural instability and early fatigability during even a few minutes walk. These symptoms are particularly bothersome for patients, since limit their walking capability. With the progression of the disease, instability and fatigability are known to worsen. Preserving the walking capability of these patients is of paramount importance to reduce their disability and hence to improve their quality of life. Enrolling MS patients in rehabilitation programs aimed at improving their fatigue resistance and dynamic stability may pursue this goal. This work describes the application of statistical gait analysis to a pilot study carried out on MS subjects to document the effect of a specific rehabilitation program.

Methods: This pilot study was carried out on three subjects affected by MS at an early stage. All of them showed a normal walk, apart from suffering from postural instability during turns and walk start and stop. They also reported abnormal fatigue when standing quietly or after walking a few hundreds of steps. The issue of fatigue is not dealt with in this work. Subjects were examined prior to begin a rehabilitation program specifically developed, immediately after completing it, and four weeks since its termination. The rehabilitation program lasted four weeks, during which subjects exercised five days a week for approximately one hour a day. The objective evaluation of their walking capabilities was carried out by means of a commercial system (Step-32®, DEM, Italy) featuring sixteen channels for recording parameters from different sensors. Subjects were equipped with foot switches (three per foot), knee electrogoniometers, and single differential probes for detecting surface myoelectric signals (SMES) from rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius lateralis (LGSC) muscles. Subjects were asked to walk for approximately 100 – 300 steps at two different velocities, over a length of approximately 12 m. SMES were processed to obtain the activation intervals of the observed muscles. The root mean square value of the signal during muscle-on intervals was discretized over three levels.

Results : Before starting the rehabilitation program, all the subjects were able to walk with an acceptable cadence (45-50 steps/s) and showed a fairly symmetrical gait. All of them showed a percentage of double support significantly higher than normal (18 - 22%) and irregular hyperextension of the knee of the most affected side. From a muscular point of view, subjects showed an irregular knee and ankle control; namely, prolonged activation of knee extensors and flexors and abnormal co-activation of knee and ankle muscles. After completing the rehabilitation plan, all the subjects showed a statistically significant reduction of the double support phase (13 - 15%), a normalization of muscle activity, and a reduction of the knee hyperextension. After 4 weeks since the completion of the rehabilitation program, the double support phase of all the subjects increased significantly, but it remained still lower than at the beginning of the study.

Discussion : Although the number of patients enrolled in this pilot study was small, we obtained very similar results from all of them and we demonstrated that statistical gait analysis allows experimenters to document the patient response to a specific rehabilitation program lasting only 4 weeks. In conclusion, we consider gait analysis as a valuable tool to be applied in clinics on neurological patients with gait disorders.

437 - An Intelligent Procedure to Support the Selection of EMG Probes Location for Gait Analysis

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Introduction: The goal of gait analysis is to provide an answer to clinical questions. In real situations, the number of EMG probes to be used can be higher than ten. Often, inexperienced experimenters decide to use an even larger number of probes, because they want to be sure not to loose relevant information. Such a large number of probes increases the time needed to prepare the patient, his/her discomfort, and makes the interpretation of the results more difficult. This work presents a method that allows also inexperienced users to obtain a probe configuration consisting of fundamental probes only, without loosing important information.

Methods: Basically, the idea is to hypothesize a very complex probe configuration, by considering to place a probe on each muscle that could either cause or being influenced by a specific gait anomaly and then to reduce this configuration to an acceptable number of sensors without compromising the information content. The first probe configuration is obtained by considering the gait anomalies shown by the patient, classified according to the observational gait analysis as proposed by J. Perry. To this end, we defined a table that associates a set of muscles to each specific gait anomaly. The relevance of a muscle to a specific anomaly is quantified as low, moderate, or high. To reduce the number of muscles to be observed, we use a genetic algorithm. First, a population of twenty random probe configurations is generated and then the genetic algorithm creates ten new solutions that are added to the first twenty. A ranking algorithm (Electre III) is used to rank the thirty solutions and then the ten solutions with a lower score are discarded, thus obtaining a new population of twenty solutions. This process is repeated a hundred times and the best solution found is memorized. The entire process is repeated 25 times, thus obtaining 25 possible solutions. For each muscle that is part of a single solution we compute the number of times it appears in the entire group of the 25 solutions. We then consider as “primary” a muscle used in more than 19 solutions over 25 and as “secondary” those muscles used between 12 and 19 times. EMG probes must be placed on primary muscles, while the user places probes on secondary muscles only if the resulting experimental setup is not too complex with respect to the information that could be lost.

Results: Validation of the procedure was performed in two steps. First we obtained twenty random test cases and studied the variability of the solution found by repeating the procedure a hundred times. The hundred solutions differed only in terms of muscles whose relevance was classified as low. The second step consisted in evaluating twenty real cases and comparing the results of the user independent procedure with the choice of an expert. Again, we obtained a good agreement, meaning that the expert solutions and those obtained by our algorithm only differed in terms of muscles with a low relevance.

Discussion: The results obtained so far are encouraging, since the user independent procedure always gives a solution very similar to that of the expert. We believe that this algorithm could be beneficial for assuring inexperienced users to select a proper set of probes by restricting their number to those that are really fundamental. A by-product of this study could be the possibility to train researchers interested in gait analysis in selecting a proper probe set either by comparing their selection with that of the algorithm or by understanding the reasoning that justifies it.

The method has given promising results. Before including it into a commercial gait analysis system we will perform a third test comparing the results of the system with different experts using it during clinical routine examination. Moreover the procedure may be extended to take into account other sensors.

441 - Muscle Activations to Stabilise The Knee Following Arthroscopic Knee Surgery

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Introduction: Arthroscopic partial meniscectomy (APM) patients have increased risk of developing knee osteoarthritis (OA), yet the disease pathway remains unclear. Large knee adduction moments during gait have been associated with knee OA and were recently identified in an APM population. Muscles are hypothesised to support large knee adduction moments via increased activation, but this may increase knee articular loads. This study aimed to investigate the contribution of muscle activation patterns to pathological gait patterns in a population at increased risk of knee OA.

Methods: Gait analysis was performed on 86 APM male patients and 33 healthy male controls (CON). Surface EMG was measured from 10 knee muscles that cross the knee and averaged during various phases of stance. Individual muscle forces were estimated from a preliminary 6 APM and 5 CON subjects using an EMG-driven musculoskeletal model.

Results: APM subjects displayed a 20% greater net activation than CON across stance phase, resulting in a 32% increase in average muscle force (APM=166N, CON=126N, $p<0.05$). Hamstrings activity in the APM group was significantly greater across stance phase (Figure1), resulting in a 77% increase in hamstrings muscle force ($p<0.05$). There was no significant difference in quadriceps activity or quadriceps muscle force.

Discussion: Increased muscle activity to support larger than normal knee adduction loads in APM patients resulted in increased muscle forces, which due to muscle lines of action, are likely to elevate articular loads. Muscles play an integral role in maintaining stability of the knee in pathological gait, which may contribute to the development of knee OA via increased joint contact forces.

447 - Segmentation of Foot Switch Signals in Gait Analysis

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Introduction: Foot switches are utilized to describe foot contact in gait analysis. The number of switches usually ranges from 2 to 4. In our experience, 3 foot switches placed below to the heel, the first, and the fifth metatarsal heads are sufficient in clinical gait analysis. From such a configuration, foot contact may be studied either by eight- or by four-level signals. In statistical gait analysis four-level signals are the usual choice. The first problem that the user must face when studying gait is to identify those gait cycles that are most frequently utilized by the subject to be studied. Although experienced users easily accomplish this task, for inexperienced users this is difficult. Moreover, when several hundreds of steps must be considered, it is very important to have a user independent algorithm able to identify the gait cycles found in the walk to be studied and to present a table in which the frequency of occurrence of each cycle is reported. This work describes an algorithm that identifies all the gait cycles utilized by the subject in a walk and computes a table reporting the specific frequency of occurrence.

Methods: Foot-switch signals are first pre-processed by an anti-bounce filter and then reduced to a four increasing level signal, in which we separate “flat foot contact” (FC), Heel strike (HS), Heel raise (HR), and Swing (SW). First, the algorithm creates a list of elements consisting of three data: the phase type (FC, HS), phase duration, and a flag that marks the elements that could be considered as the beginning of a cycle. The flag is set using the following rule: a valid cycle begins with a decreasing transition (i.e., HS – FC, SW – HS). All one-phase cycles are merged with the cycle that follows. Then, the algorithm computes the mode of the duration of all the cycles consisting of more than two phases and it tries to merge all the two-phases cycles shorter than a given percentage of the mode previously computed with the other cycles. If the number of two-phases cycles decreases, the merge phase described above is repeated. In summary, the algorithm organizes all the cycles, computes their occurrence frequency, and the instant in which each cycle begins.

Results: The algorithm was tested on 20 two-minute walks of normal subjects and 10 of pathological subjects. It was always possible to detect all the gait cycles detected by an experienced user, with the only exception of a few cycles corresponding to the beginning or the end of the walk, which are not of interest for characterizing the walking capabilities of the subject.

Discussion: The algorithm herein described is able to detect all the possible gait cycles a two- or three-minute walk consists of in less than 1s (Pentium IV, 2.4GHz), also providing the frequency of occurrence of each cycle and its initial instant. Since pathological subjects often show more than a single gait cycle, it is important to document all the possible cycles typical of a specific patient associated with their frequency of occurrence: the effect of a rehabilitation program or of surgery could be represented by a modification of the frequency of occurrence of some cycles rather than the complete suppression of some of them. We believe that this algorithm could add valuable information to statistical gait analysis and we experienced its usefulness particularly when applied to patients with an irregular gait such as CP children.

458 - Study About the Impulse's Behaviour During Treadmill Walking with Varying Uphill and Downhill Slopes

FREITAS, T.H., CAMPOS, A.O., AMORIM, L.J., AMORIM, C.F., SERRÃO, N.F., GALHANONE, P.R.

Introduction : The walking pattern can be influenced by several factors, intrinsic as well as extrinsic. Some of the extrinsic factors, as for instance the walking ground's slope, can be used as exercises applied to the patient during the walking rehabilitation or as part of appraisal protocols of daily life activities, since uphill or downhill walking is significantly present in anyone's everyday life (1,2). One of the components that is usually altered in patological walkings is impulse, that's why this study has as an objective to analyse this variable's behaviour in various uphill / downhill slopes, as well as to establish the way in which time and force influence the impulse in such conditions, in order to optimize the utilization of this resource in treatment protocols.

Methods: 8 healthy men and 7 healthy women were used as volunteers (22,5 + 2,5 years old mean age; 172 + 8 cm mean height; 705,85 + 52,36 N mean weight). All participants signed na agreement term, after explanation about the procedure to which they would be submitted. A Gaitway Instrumented Treadmill system, composed by a treadmill with two Kistler piezoelectric force platforms, was used to measure the ground reaction force's vertical component. A 12 bits A/D converter with 1000 Hz sampling frequency was also used. Eleven ten seconds samplings were made with each volunteer in a single day, at 0,83 m/s speed. The first data acquisition was made with no slope (0%) and after that the following data acquisitions were made starting with a -5% downhill slope until reaching 5% uphill slope, with 1% slope increases. The following parameters were analysed : Impulse, first peak force, mid support force, second peak force, time for fist peak, time for mid support, and time for second peak. T-Student test and Polinomial regression were used for data analysis, in order to get the correlation among the various analysed slope values.

Results: All parameters, with the exception of the uphill mid support force, showed statistically significant differences ($p<0,05$) when comparing each downhill sampling with the one at 0% slope, as well as when comparing the 0% slope sampling with each uphill sampling. Impulse decreases with downhill slope's increase and increases with uphill slope's increase. Uphill there also is an increase in second peak force, time for first and second peaks and time for mid support and a decrease in first peak force. On the other hand, uphill mid support force is kept reasonably stable in the studied slope range, but with increased downhill slope there is a statistically significant reduction ($p<0,05$). All other downhill parameters' patterns are opposite to uphill parameters' patterns. In spite of such behaviour, it is important to make it clear that none of studied variables showed a linear behaviour uphill or downhill.

Conclusion: The results suggest that during downhill walking the impulse's decrease is affected by the force parameters as well as by the time parameters and the impulse's increase ocurring during uphill walking can be more related to the time parameters.

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459 - Ground Reaction Force's Vertical Component Behaviour During Walking In Various Uphill And Downhill Slopes

FREITAS, T.H., CAMPOS, A.O., AMORIM, C.F., AMORIM, L.J., MACAU, H.N.; SERRÃO, N.F., GALHANONE, P.R.

Introduction: The ground reaction forces actuate in the body's movement during terrestrial locomotion. There are several extrinsic factors that influence the deambulation behaviour, e.g. ground's slope. Some of such factors, as ascending and descending ramps, are used as exercises applied to patients during the gait rehabilitation process (1,2), or also in daily life activities' appraisal protocols. It is important and necessary to get a better knowledge of such movements' mechanics, in order to optimize their application. This study's objective is to analyse the ground reaction force's vertical component behaviour during treadmill walking in various uphill and downhill slopes, showing this way some differences between the deambulation in inclinated plane and horizontal.

Methods: 7 healthy men and 3 healthy women were volunteers (23 + 3 years old mean age; 174 + 7 cm mean height; 703,35 + 56,63 N mean weight). All participants signed an agreement term, after explanation about the procedure to which they would be submitted. A Gaitway Instrumented Treadmill system, composed by a treadmill with two Kistler piezoelectric force platforms, was used to measure the ground reaction force's vertical component. A 12 bits A/D converter with 1000 Hz sampling frequency was also used. Twenty six ten seconds samplings were made with each volunteer in a single day, at 0,83 m/s speed. The first data acquisition was made with no slope (0%) and after that the following data acquisitions were made starting with a -5% downhill slope until reaching 20% uphill slope, with 1% incremental slope increases. The following parameters were analysed : First peak force, mid support force and second peak force, all normalized by the individual's weight. T-Student test and Polinomial regression were used for data analysis, in order to get the correlation among the various analysed slope values.

Results: The greater the downhill slope the greater the first peak's value of the force's curve and the greater the uphill slope the smaller is the first peak's value, but the force's first peak reduction in uphill slope stops at 15% and, from this point on, there are no statistically significant difference ($p<0,05$) among the slopes. The second peak's value of the force's curve decreases with downhill slope's increase, and increases with uphill slope's increase up to 4% and after that these values start to decrease, becoming at 20% uphill slope very close to the maximum downhill slope (-5%) value, with no statistically significant differences between them ($p<0,05$). Mid support force decreases with uphill slope increases and increases with downhill slope increases, up to 4% downhill slope, then there is a significant decrease in this parameter's values.

Conclusion: A greater force is applied in the foot posterior region heel during downhill walking and, as a consequence, smaller in before foot. What happens uphill is a strong decrease in heel 's force and during mid support, but there is not an increase in before foot's applied force but a decrease, in a weaker way. This shows that during uphill treadmill walking there is no application of a stronger force in before foot's but a great decrease in force application in foot's other regions.

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473 - Effects of Ageing and Degeneration on Regional Coupled Motion in the Cervical Spine

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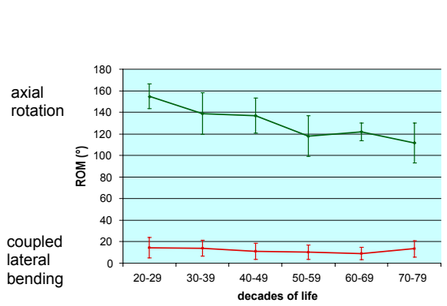
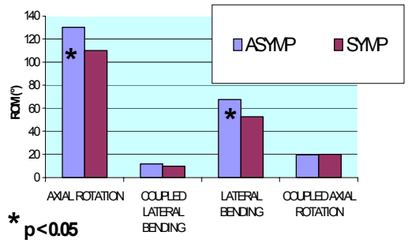
Introduction: Reciprocal coupling effects between axial rotation and lateral bending in the cervical spine results from the morphology of facet joints, vertebral endplates, uncinate processes and intervertebral discs (Penning and Wilmink, 1987; White and Panjabi, 1990, Milne, 1991; Onan et al., 1993). Local mechanisms of coupling exist in the upper cervical spine, related to the particular morphology of the facet joints in this region (Panjabi et al., 1993). The aim of the present study was to observe the effects of ageing and degeneration on regional coupled motion in the cervical spine.

Methods: Kinematics of the cervical spine were investigated in 225 subjects, divided into 5 subgroups: young healthy volunteers (83), sedentary elderly (30), rheumatoid arthritis patients (29), healthy volunteers of different ages (56) and patients with non-acute aspecific neck pain (27). Patterns of coupled motion were recorded using an electromagnetic tracking device (Flock of Birds), steered by additional software (Van Roy et al., 2002).





Results: In general, range of motion (ROM) decreases with age, but important inter-individual differences of ROM and the amount of coupled motion were found in every decades (left-right differences, different types of coupling, differences in amplitude and timing of coupled motion). Although an important decrease of ROM was recorded in the non-acute aspecific neck pain patients group (SYMP), this was not necessarily accompanied by loss of coupled motion. Irregular graphs and loss of coupled motion became more obvious in the RA-group and the group with sedentary elderly. Ipsi-lateral coupled motion was recorded in the majority of the subjects. However, cases of contra-lateral coupling in axial rotation were registered in every subgroup. Contra-lateral coupled lateral bending more frequently occurred in sedentary elderly and in the RA-patients.

Conclusion: Beside ipsi-lateral coupled motion in the cervical spine, also contra-lateral coupling may occur. Ageing often results in diminution of the ROM in the cervical spine, but this conclusion may not be generalised. Loss of ROM in the cervical spine, due to ageing or aspecific neck pain, is not necessarily accompanied by loss of coupled motion. Nevertheless, the probability of the development of degenerative changes in the spine enhances with age; loss of ROM and altered patterns of coupled motion is probably related to morphological degeneration, affecting the function of zygapophyseal joints and intervertebral discs. These effects became obvious in sedentary elderly and in the RA-group.

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485 - Accurate Estimation of Body Segment Kinematics from Inertial Sensor Kinematics

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Introduction: Detailed biomechanical analysis is currently done in fixed laboratory setups. Body kinematics are estimated using 3D position of markers measured with a video based systems. Application of such a set-up is limited by the unnatural environment, the elaborate setup and the limitations in space (to measurement volume) and in time (to short recordings). Also visibility problems of markers limit practical application. In this study a method for accurate human motion analysis applying inertial sensing is proposed and validated. Having already realized methods for accurate ambulatory estimation of 3D orientation and angular velocity and angular and linear acceleration of small inertial motion sensor modules in the Amber projects (e.g. Baten 2002), this paper focuses on the key issue of accurately estimating body segment kinematics from the inertial sensor kinematics, currently the determining factor for accuracy of motion analysis in both inertial sensing as video based human motion analysis.

Methods: In 9 healthy subjects 10 different calibration methods for estimating body segment kinematics from sensor kinematics were compared for 4 sensor locations on the trunk and pelvis and validated against a video based motion analysis method. A calibration typically determines the relative 3D orientation of the sensor module relative to the body segment from a combination of 2 recordings in which the direction of one of the axes of the body segment is known to be directed parallel to gravity or to be parallel to the axis of rotation.

Results Over all subjects and segments the variation in estimated direction $\overline{\alpha}$ of the gravity vector has a mean of 0.4° (SD, +/- 0.2) for 5 subjects and 5 repetitions for the gravity vector and ranged from 2.4° to 6.4° for the rotation axes. The difference in direction with the axes determined by the video system ranged from 10° to 30° with a bony landmark calibration.

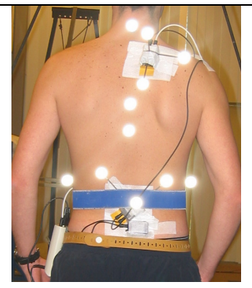

Figure 2. The experimental setup. Visable are inertial sensors attached with tape, Vicon markers placed on bony landmarks on the front and Vicon marker triangles and the supporting brace on the back of the subject.

Discussion A high accuracy and repeatability was achieved with the AMBER method. The large structural difference in orientation with the reference method is probably explained by a mere difference in body segment coordinate frame definition. This notion was confirmed by applying the Amber method to the bony landmark marker data for 1 subject. A difference <5°.in orientation with the inertial sensing based data was found. The Amber method for estimating body segment orientation is applicable to other body segments and was already tested for upper extremities (paper in preparation). In application the Amber method is as sensitive to motion artifacts as any cluster marker based approach. Proper sensor fixation assuring a 'fixed' relation between sensor and body segment orientation is important.

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492 - Gait Risk Factors for Falls in Older Adults: A Dynamic Perspective

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Introduction: Falls are a major public health concern, particularly in the older adult population (1), causing more than one-third of the community living elders to be at risk for fall (2). In order to prevent a fall, elderly adults decrease gait velocity, increase stride frequency (STF), decrease stride length (STL) (3) and thus spend more time with their stance leg on the ground. These strategies are explained as an attempt to minimize energy expenditure (4,5), due to muscle weakness (6) and loss of balance (7). In addition, these patterns may assist in controlling the whole body position and momentum more easily and safely (2,6), and in decreasing gait variability. The present study focuses on the underlying changes in kinematics, which coincide with a reduced stability and flexibility in the coordination of walking. Stability is defined as the ability to overcome perturbations, and flexibility as the ability to adopt new movement patterns following changes in task requirements (8). It was hypothesized that the decreased stability and flexibility observed in the older adults at risk for fall coincides with less lateral sway of the center of gravity compared to healthy subjects.

Methods: Data was collected from two groups: 21 elderly (72.1yr) at risk for fall (FE) who experienced at least one fall six month prior to data collection, and 27 healthy elderly (73.8yr) (HE) who had no history of falls (HE). Subjects walked at their preferred STF while the treadmills' velocity was gradually increased from 0.18 to 1.52 m/s and then decreased in increments of 0.22 m/s. At each walking speed (WS) data was collected for 30s by means of OptoTrak 3020 system. Data analysis focused on stride parameters (STF and STL), center of gravity displacement (frontal and sagittal plane), joints kinematics (ankle knee and hip ROMs) as well as phase and frequency relations between body segments. Possible differences between FE and HE groups at different WS and STF were examined using an ANOVA with repeated measures.

Results: 12 out of the 21 FE subjects (57%) were unable to walk at the fast WS (1.52m/s), whereas all HE subjects (27) walked comfortable at all WS. STF was significantly greater in the FE compared to the HE at all WS. FE showed smaller joints range of motion, decreased stability and flexibility of the coordination during walking, and a smaller center of gravity lateral sway.

Conclusion: The FEs' adapt their walking patterns in order to keep their center of gravity displacement above the base of support minimizing lateral sway.

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500 - Effect of Walking Aids on Muscle Activation in Stroke Patients

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Introduction: The purpose of this study was to investigate changes in muscle activation patterns with respect to timing and amplitude that occur when subjects with stroke walk with and without a walking aid. This knowledge could help therapists in their decision whether or not patients should use a cane or quad stick while walking.

Methods: Thirteen patients suffering from a first unilateral ischemic stroke were included.

Surface EMG of the erector spinae, gluteus maximus, gluteus medius, vastus lateralis, semitendinosus, gastrocnemius and tibialis anterior of the affected side were measured during three different conditions: 1) Walking without a walking aid, 2) walking with a cane, 3) walking with a quad stick. Timing and amplitude parameters of the activation patterns were quantified, using an objective burst detection algorithm (Roetenberg et al, 2003) and statistically evaluated.

Results: Results show statistically significant and clinically relevant effects in burst duration of both erector spinae (fig.1) and tibialis anterior when walking with a cane. The amplitude of especially the vastus lateralis and tibialis anterior drops when walking with a cane and quad stick.

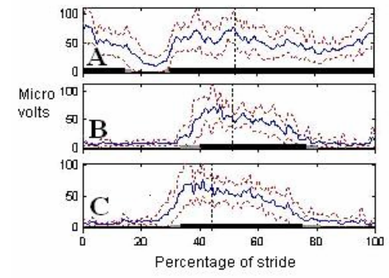

Fig. 1

Typical example: changes in muscle activation pattern of the stride normalized Smooth Rectified EMG (SRE) of the erector spinae is presented for the three different walking conditions.

A presents the sEMG of the erector spinae when walking without an aid, B when walking with a cane and C when walking with a quad stick.

Along the y-axis the amplitude of both raw sEMG and SRE in microvolts is presented. Along the x-axis of the stride normalized SRE graphs, the timing as derived from the burst detection algorithm is shown in black and gray lines. The median on and off time is presented in a black solid bar connecting the median on time with the median off time. The somewhat smaller little grey bars indicate the 25 and 75 percentiles of the median on and off times. The dashed vertical line represents toe off.

Discussion: Results indicate that use of a cane should be considered when therapy given to stroke patients is aimed at achieving normal muscle activation patterns.

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Motor Control

013 - Spatio-Temporal Evaluation of Neck Muscle Activation During Postural Perturbations In Healthy Subjects

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Introduction: Detection of the spatio-temporal aspects of myoelectric signals during postural perturbations can be utilized to analyze muscle recruitment and enhance our understanding of neuro-motor control strategies. Feed-forward muscle activation is one central nervous system strategy, which can be detected with analysis of the temporal aspects of the electromyographic (EMG) signal. Feed-forward postural responses are a mechanism employed by the central nervous system to regulate motor control of muscles and contribute towards the maintenance of stability. Extensive evidence of feed-forward activation of limb and trunk musculature in response to perturbations is available in the literature. However, there is a paucity of studies that have investigated spatio-temporal aspects of neck muscle activation during postural perturbations. The purpose of this study was to examine the spatio-temporal activation of the sternocleidomastoid (SCM) and cervical extensor (CE) muscles with respect to the deltoid muscle onset during rapid voluntary upper limb movement in healthy volunteers. The repeatability and reliability of the spatio-temporal aspects of the myoelectric signals were also examined.

Methods: Ten subjects performed bilateral and unilateral rapid upper limb flexion, abduction and extension in response to a visual stimulus. EMG onsets and normalized root mean square (nRMS) values were calculated for the SCM and CE muscles. Subjects attended three testing sessions over non-consecutive days allowing the repeatability and reliability of these measures to be assessed.

Results: The SCM and CE muscles demonstrated feed-forward activation (activation within 50 ms of deltoid onset) during rapid arm movements in all directions. The sequence and magnitude of neck muscle activation displayed directional specificity, however the neck flexor and extensor muscles displayed co-activation during all perturbations. EMG onsets demonstrated high repeatability in terms of repeated measure precision (nSEM in the range 1.9-5.7%). This was less evident for the repeatability of nRMS values.

Conclusion: The results of this study provide a greater understanding of cervical neuromotor control strategies and a reference framework to be used for comparison with symptomatic subjects. During bilateral and unilateral upper limb perturbations, the SCM and CE muscles demonstrate feed-forward co-activation. It seems apparent that feed-forward activation of neck muscles is a mechanism necessary to achieve head stability for the visual and vestibular systems, whilst ensuring stabilization and protection of the cervical spine.

040 - Holding an Object Between Fingers While Moving the Arm: A Simulation Based on the λ Model for Motor Control

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The question of how the nervous system controls the grip force acting on an object while moving the arm was addressed in several studies. It is usually assumed that the grip force is controlled in an anticipatory way based on internal models that directly program and specify muscle forces. We explored the possibility that this task might be performed without invoking internal models and computations of forces. Using the λ model for motor control, we simulated the arm movement and grip force in different conditions and compared the results of the simulation with experimental data available from the literature. We first produced elbow movements in a horizontal plane that were combined with the precision grip of a rigid block between the index finger and the thumb. We also considered how the system can equalize the forces acting from the finger and thumb on the block to stabilize its position. The modulations of the grip forces during arm movements were simulated based on equations of motion and equations based on the λ model. Results showed that the kinematic and kinetic patterns of modelling resembled the experimental data. We also considered the possible role of finger mechanoreceptors in the control of precision grip as an essential control element of the task. This assumption is consistent with other studies showing the influence of cutaneous afferent information from fingers on the force applied to the object. Our simulations faithfully reproduced the grip modulation during elbow movement. The results suggest that basic characteristics of the task performance can be reproduced reasonably well by using the λ model that does not rely on the ideas of internal models and direct computations of forces.

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069 - Corticomotor Inhibition During Passive Movement: Relationship to Movement Parameters

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Introduction We have previously shown in healthy adult subjects that during rhythmic passive movement of the index finger (30 deg. range of abduction and adduction at 1Hz), the amplitude of the motor evoked potential (MEP) of the first dorsal interosseous muscle (FDI) is significantly reduced compared to rest (Edwards et al. 2002). In the present study we have investigated the relationship of the inhibitory effect to passive movement parameters.

Method The experimental protocol examined how soon into passive movement this inhibition develops, whether the degree of inhibition is modulated by the phase or speed of movement or by repeated movement, and how soon after cessation of movement corticomotor excitability returns to normal.

Results MEP amplitude showed the greatest reduction as the finger passed through the mid-range position (FDI lengthening) but was not attenuated during FDI shortening. Amplitude was significantly reduced at speeds down to 0.125Hz (mean reduction 20±12%StErr). Inhibition was present during the first movement cycle (50±6% reduction in MEP amplitude at 0.25Hz), and did not vary over a 1-minute period of movement. MEP amplitude had returned to baseline resting values within 1sec of movement cessation.

Conclusions These findings confirm that even at relatively slow speeds, rhythmic passive movement can attenuate MEP amplitude. This effect occurred at a time when the FDI was undergoing lengthening, and was sustained across repeated movement cycles and rapidly reversed on movement cessation. The results suggest that activation of sensory afferents by passive movement, most likely muscle spindles, can have an inhibitory effect on the corticomotor pathway.

Reference

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074 - Effects of Contralateral Limb Activity at Different Intensities and Arousal on Steadiness of Knee Extensor in Young Men and Women

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Introduction: This study aimed to determine whether static muscle contraction in the contralateral limb at different intensities and arousal in response to an electric shock (ES) would affect the steadiness of ipsilateral knee extensors, and whether males would respond differently to females to these stressors.

Methods: Ten males and ten females who were healthy and physically active, aged 19-33 years, gave their consent and participated in the study. Sitting in a test chair with each leg strapped to a load cell, subjects performed a series of unilateral and bilateral maximal and submaximal static voluntary knee extensions. The steadiness of the left leg, as indicated by the coefficient of variation (CV = Standard Deviation / Mean) of the torque production, was assessed when performing a 15-s contraction at 10, 30 or 50%MVC level, while the right leg performed a 10-s contraction at 10, 30 or 50%MVC which started 5 s after the left leg. An electric shock (10 pulses of 100-200mA, at 25Hz) was applied to the right knee 5 s into its contraction. Subjects were advised to focus on maintaining the left leg torque against the target level according to a visual feedback on computer screen. An analog scale was used to evaluate the level of arousal before and after each level of contraction and the ES. Repeated measures ANOVA with Bonferroni adjustment was used to evaluate the effects of the treatments. The experimental procedure was approved by the University Human Research Ethics Committee.

RESULTS: The statistical analysis detected significant interactions ($P<0.05$) between left leg torque level, right leg torque level and electric shock on muscle steadiness. The post-hoc analysis showed that the CV of the left leg torque did not increase when the left leg muscle contracted alone, but was significantly affected by the right leg contraction at 30-50%MVC levels. The electric shock superimposed over the right leg contraction significantly elevated the arousal level, and affected the CV of the left leg particularly at 10%MVC, however did not induce additional impairment of muscles steadiness at higher contraction intensities. Similar patterns of response were found in the male and female subjects.

DISCUSSION AND CONCLUSION: It has been reported that the level of arousal affects the steadiness of hand muscles in a pinch task [1]. It is also known that contralateral activity affects ipsilateral performance. The present study further demonstrated that moderate levels of static knee extension in the contralateral limb would impair muscle steadiness (CV) of the ipsilateral limb in the precision task. The results also indicated that increased arousal level affected the steadiness of large muscle group, particularly at low level of static contraction. However, in general no significant difference was found between males and females in maintaining muscle steadiness at moderate levels of static knee extension.

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079 - Localization of Three-Dimensional Distribution of Muscle Activation Using Muscle Functional Magnetic Resonance Imaging

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Introduction: The purpose of this study was to examine the localization of three-dimensional distribution of activity in the triceps surae muscle during calf-raise exercise using muscle functional magnetic resonance imaging (mfMRI).

Methods: Six male subjects performed unilateral dynamic standing calf-raise exercise for five sets of 10 repetitions with 1 min rest between sets. Immediately before and after exercise, the calf muscles were imaged on a 0.3-T AIRIS MR imaging machine (Hitachi Medical, Co., Japan). Transverse relaxation time (T2)-weighted (mfMRI), consecutive axial spin-echo images (repetition time 2500 ms, echo time 25 and 80 ms, slice thickness 10 mm, slice interval 10 mm, field of view 270 mm, number of excitations 1, scan time 5 min 30 sec) were obtained from the head of fibula to the end of tibia via the extremity coil. The total number of sections obtained for each subject was 32-39. MR images taken at rest and after exercise bout, and T2 values between mean + SD of the preexercise images and mean + SD of the postexercise images were considered elevated. An amira software (Template Graphics Software, Inc., USA) was used for three-dimensional volume rendering of individual triceps surae muscle with elevated T2 values in MR images, before calculating in relative area of muscle activation.

Results: The lateral gastrocnemius and soleus muscles demonstrated uniformly distributed activity along the length of the leg as evidenced by elevated T2 values in the MR images. On the other hand, there was a greater activation of the medialis gastrocnemius (MG) in the distal end (58.0%) compared with the proximal end (41.2%).

Conclusion: The present results indicate nonuniform muscle activation within the MG along the length of the leg.

100 - On the Hand Muscles Activation in Position Perturbed Adaptive Reaching In Human

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Introduction: The hand muscles activation and evoked eye saccade were investigated in position perturbed reaching in human.

Methods: Healthy (14), right-handed people (18-22) reached (after a beep) a dowel indicated by a LED. Jumps of the target occurred to left or right at random, before (after) the hand lift. The trajectory of hand joints, occulographic signal and SEMG from hand muscles, were recorded [1].

Results: A saccade is evoked (perturbation to saccade latency 170+-20 ms) and the hand trajectory is properly corrected in all perturbed trials. Activation of hand muscles occurs synchronous with the saccade.

Conclusion: Feed-forward models seem to drive the hand trajectory in reaching, in cooperation with kinematic coordination patterns, triggered by visual information.

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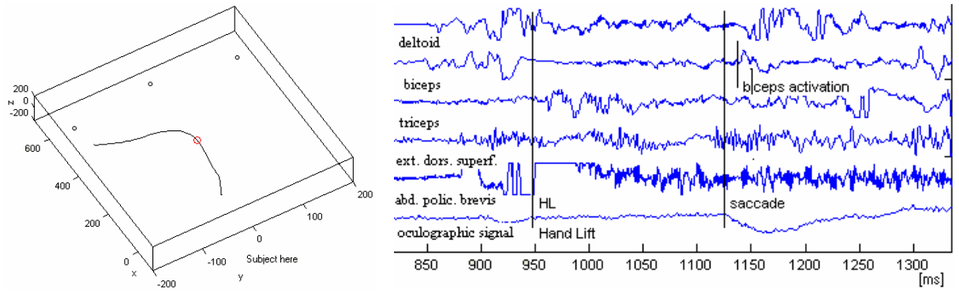

Figure 1. Left – 3D wrist trajectory in perturbed trial: the saccade is shown. Right-Biceps and Triceps activation (SEMG) occurs, synchronous with the saccade, to slow down the hand and to correct the trajectory.

117 - The Control of Trunk Movements after Tripping

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Introduction: Trips and slips are the most prevalent causes of falls in both young and older adults. A successful recovery of a trip implies that the forward rotation of the body is sufficiently reduced. Given the large mass of the trunk, adequate control of the trunk momentum is crucial in this respect. The aim of the present study was to establish which trunk movements occur after tripping and how these movements are controlled by the activity of hip and trunk muscles.

Methods: Ten males (42 (SD 3.7) years) repeatedly walked over a platform in which 21 obstacles were hidden. Each subject was tripped over one of these obstacles during mid-swing of the right foot in at least 5 trials. Kinematics, dynamics and muscle activity of the major hip and trunk muscles were measured. To determine obstacle contact, the A-P acceleration of the obstacle was measured. The instant of landing after the trip was determined from the ground reaction force.

Results: After a trip, trunk flexion increased due to the impact with the obstacle (extra flexion 17˚, SD 2.4˚). In addition, displacements outside the saggital plane occurred (9˚ (SD 3.5˚) right rotation, 1˚ (SD 0.8˚) lateral bending).

In response to tripping, co-activation of the abdominal and trunk muscles was seen. This reduced the flexion movement of the trunk before the foot was placed on the ground for almost all subjects, indicated by a negative (=extension) or zero trunk angular velocity at landing. Subjects appeared to anticipate the landing of the blocked foot by increasing especially the activity of the erector spinae muscles. In most subjects, this anticipation was adequate, as no increase in trunk flexion was seen due to the impact force at landing. In trials where subjects showed an increased trunk flexion after landing, the ground reaction force was directed posterior of the L5S1 joint, which causes a large flexion moment on the trunk.

Conclusion: After tripping, large trunk movements were seen outside the saggital plane. The trunk muscles co-contract in response to the impact with the obstacle to brake or even reverse the trunk movement. Trunk movements at landing are controlled by specific anticipation of trunk muscle activity and by proper placement of the foot.

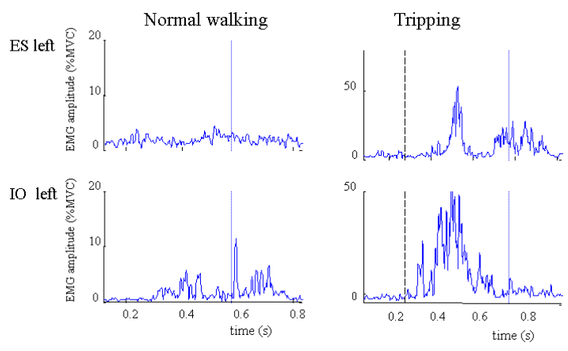

Fig 1: Trunk muscle activity of a typical subject in normal walking and tripping. Both time series started at toe off of the right foot. The dashed line represents the instant of tripping. The dotted line represents the instant of landing. (ES = erector spinea muscles, IO = internus obliquus muscle)

125 - Impairment of Coordination During Bimanual Arm Swinging In Adults With Hemiparesis

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The coordination of bimanual movement is governed by a distributed network of brain areas. Perturbation of one arm during rhythmical bimanual movement disrupts intermanual coupling (phase relationships) and results in phase resetting in healthy subjects. However, such coupling may be impaired following stroke due to damage of specific brain structures as well as changes in the neuromuscular properties of the paretic arm. Our goal was to investigate the synchronization of both arms during bimanual swinging in the presence of external perturbation in patients with hemiparesis due to stroke. Nine healthy subjects and 12 patients with chronic hemiparesis participated. While standing, subjects swung their arms in a reciprocal manner (anti-phase) for 15s during which time, movement of one arm was unexpectedly and transiently (150 ms) arrested. The arrest occurred twice during the forward phase of swinging and twice during the backward phase at approximately ±10° with respect to mid-swing. Kinematic data were collected from 22 markers placed on the arms, trunk and legs (Vicon). The oscillatory period, relative phase within and between arms and the phase differences before, during and after perturbation were calculated. In healthy subjects, perturbation resulted in an increase in the cycle period in both the arrested and non-arrested arms in the cycle following the perturbation. In contrast, in participants with hemiparesis, perturbation resulted in a complete disruption of the intermanual coordination such that both arms moved with different frequencies after the perturbation. The period of the arrested arm became significantly shorter than that of the non-arrested arm. This resulted in independent movement of each arm and a transition from anti-phase to in-phase motion immediately after the perturbation that took more than 1 cycle to reverse back to the anti-phase pattern. Results show that the ability to rapidly regain bimanual coordination by “resetting” the movement of the non-arrested arm was disrupted in patients. This suggests that stroke-related brain damage results in a disruption in the central control of the timing of bimanual movement affecting both the affected and non-affected arms.

132 - Index Finger Coordination During Tapping Across Different Postures

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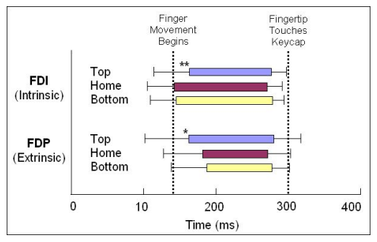
Introduction: Motor control sets the internal exposure of musculoskeletal tissues to physical load, which may contribute to the development of musculoskeletal disorders during computer keyboarding work. Therefore, we characterized the muscle activities (EMG) of index finger tapping across three typing postures commonly used during typing. We assessed the temporal and amplitude relationship (i.e., timing and magnitude, respectively) between internal (i.e., EMG) and external exposures (i.e., force, kinematics). We hypothesized that differences in EMG patterns exist across the three typing postures.

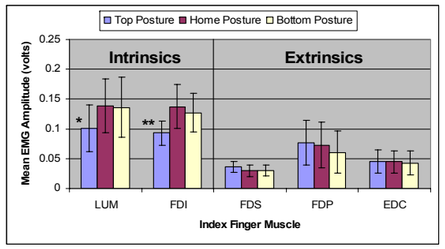
Methods: Sixteen subjects (8 male, 8 female; Mean: 29.44 years, SD: 5.86 years) tapped across three postures: 1) Top position (QWERTY row), 2) Home position (home row), and 3) Bottom position (bottom row). Subjects tapped with their index finger at a rate of 50 beats per minute on a Buckling-spring keyswitch from a Supertouch Enhanced keyboard (make force: 0.59N; travel distance: 0.35cm).

Fine wire EMG bipolar electrodes were inserted into five index finger muscles- two of which were intrinsic (1st lumbricalis and 1st dorsal interossei) and three of which were extrinsic (flexor digitorum superficialis, flexor digitorum profundus, and extensor digitorum communis). A two-axis force-torque transducer mounted underneath the keyswitch measured fingertip forces in the sagittal plane. Three individual miniature optic goniometers (Shape Sensors, Measurand Inc.) mounted across the distal interphalangeal (DIP) joint, the proximal interphalangeal (PIP) joint, and the metacarpophalangeal (MCP) joint measured the index finger joint kinematics. A personal computer recorded all data at 5kHz.

Results: Differences in EMG patterns for the extrinsic muscles were found to vary temporally (onset, offset, and duration) across the three postures, but not in amplitude. However, for the intrinsic muscles, differences in EMG amplitude existed across the three postures. And only the 1st dorsal interossei was found the have differences in both amplitude and temporal patterns across the three postures.

Conclusion: These data suggest that for the given task of index finger tapping on a keyswitch, a combination of amplitude changes for the intrinsic muscles and temporal pattern differences for the extrinsic muscles are used as possible motor control strategies to successfully achieve the task across different postures.





161 - Activation Pattern of the Masticatory Muscles in Individuals With Craniomandibular Disorder

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Introduction: Craniomandibular Disorder (CMD) is characterized by several signs and symptoms, among which are pain and changes in the activation pattern of the masticatory muscles. Thus, the objective of this study was to evaluate the activation pattern of the masticatory muscles in individuals with myogenic CMD with pain.

Methods: Forty female volunteers participated in this study: twenty myogenic CMD individuals with pain, aged 19 to 33, (23,04 ± 3,5 years) and 20 clinically normal individuals, without pain, aged 19 to 31 (23,3 ± 3 years). The EMG signals were recorded by a (1) signal conditioner module, with a 100 gain, second order analog filter, 10,6-509Hz high-pass Butterworth and (2) analog/digital motherboard with 12 bites of resolution of dynamic band and sampling frequency of 1KHz (I model CAD 12/46 of Lynx Electronics Ltd.). Four active surface electrodes by Lynx Electronics Ltd. with two rectangular parallel pure silver bars (10x2 mm), with a fixed 10-mm distance between the inter-electrodes, 100 gain, 130 dB common mode rejection ratio (CMRR) and 10 GΩ. input impedance. For noise reduction, a rectangular stainless steel electrode was used reference. The EMG recording electrodes was guided by muscular function, having been placed on the center of the masseter and on the anterior portion of the temporal muscle. The EMG signal was captured during non-habitual masticatory activity, for 15 seconds. The muscular activation pattern of three masticatory cycles recorded between the fifth and the ninth recording seconds was obtained through the straightening and smoothing of the rough EMG signal with movable 250-ms windows and normalization by the EMG amplitude average of the straightened line. The construction of normalized linear envelopes was done by the MATLAB (Version 5.0 by The MathWorks Inc.)

Results and Discussion: The results of this study highlighted that individuals with CMD o the masseter muscle and the anterior portion of the temporal muscle, bilaterally, presented EMG activity in the phase of lowering the mandible - period indicated by the arrow– Fig. 1. Such pattern was not observed in the control group (fig. 2). According to LUND et al. (1991) pain in the oral facial region may influence the activation of agonist and antagonist muscles of a certain movement of the mandible.

Conclusion: Under the experimental conditions it is believed that the pain in one or more structures of the stomatognathic system may promote the change in the activation pattern of elevator muscles of the mandible during non habitual mastication.

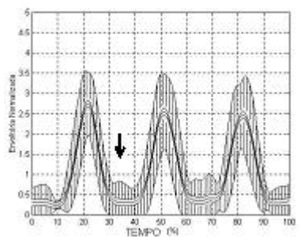

Figura 1. Linear envelope normalized by the average of the rectified EMG signal, recorded at the right masseter of the TMD

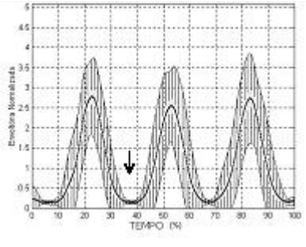

Figura 2. Linear envelop normalized by average of the rectified EMG signal, recorded at the right masseter of the control

group	group.

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168 - Can Complexity Analysis Evaluate the Severity of Parkinson Disease?

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Introduction: Tremor denotes an involuntary oscillation of parts of the body. One of main symptoms for patients with Parkinson's disease (PD) is tremor. Parkinsonian tremor spans a large range of different dynamical behaviors and exhibits a nonlinear oscillation. Traditional spectral and nonspectral methods are unable to quantify the dynamical, nonlinear process. Therefore, the present study is designed to evaluate the complexity of Parkinsonian tremor by using complexity analysis based on chaos theory. One purpose of the investigations is to distinguish the severity of PD patients according to the complexity of Parkinsonian tremor.

Methods: Thirty PD patients were studied. They were classified into three Hoeh-Yahr stages. Stage 2, 3, and 4 denote mild, moderate, and severe levels. The number of each stage was ten patients. All of the PD patients were under treatment taking anti-parkinsonian agents. Control subjects were 12 healthy young persons (N20) and 10 healthy old persons (N60). Finger tremor in PD group and normal group was measured under a condition maintaining the index finger in a horizontal position. The finger tremor was derived from a lightweight piezoelectric element accelerometer with a sampling rate of 250Hz. Ten thousand points data of the time series of finger tremor were used in complexity analysis. Correlation dimension, largest Lyapunov exponent and Shannon entropy were calculated from those data.

Results: Results were shown in Table 1. Correlation dimension was finite and non-integer value in both PD group and normal group. Correlation dimensions for stage3 and stage4 in PD group were significantly smaller than that in normal group ($p<0.01$). But there was no significantly difference between stage3 and Stage4. Correlation dimension more decreased when the symptom of PD patients became more serious. On the other hand, The largest Lyapunov exponent for stage 4 and Shannon entropy for stage3 and stage4 in PD group were significantly larger than those of normal group ($p<0.05$). There was no significantly difference between stage3 and stage4 in Shannon entropy. Both values more increased when the symptom of PD patients became more serious.

Discussion: Correlation dimensions in PD group and normal group were finite and non-integer. The leargest Lyapunov exponents in both groups were positive values. From these results, it was considered that the dynamics of tremor time series in both groups could be regarded as nonlinear deterministic, chaos process. Correlation dimension represents the degree of freedom of the underlying system, which is participating in the occurrence of finger tremor. Largest Lyapunov exponent is the rate at which the trajectory of tremor time series diverges. And Shannon entropy is the quantity describing the amount of disorder in the underlying system. Largest Lyapunov exponent and Shannon entropy mean the instability of trajectory for tremor time series. In other words, when the degree of PD symptom became serious, it became clear that the degree of freedom for the underlying system decreased and the instability of trajectory for tremor time series increased. In conclusion, complex analysis was considered to be a useful analysis technique to evaluate the severity of PD patients.

Table 1.

	Correlation dimension	Lyapunov exponent	Entropy
Normal20 (N20)	7.25 ± 0.61	2.31 ± 2.64	4.96 ± 1.26
Normal60 (N60)	7.56 ± 0.39	2.93 ± 1.57	5.59 ± 0.95
Stage2	6.67 ± 0.77	1.72 ± 2.13	5.11 ± 0.96
Stage3	5.55 ± 0.95 ‡	5.90 ± 4.41	6.49 ± 0.78 †
Stage4	5.46 ± 0.72 ‡	9.13 ± 7.43 †	6.41 ± 1.11 †

(mean ± SD), †p<0.05, ‡p<0.01 for comparison between PD and N20.

172 - Correlations Between Quadriceps Contraction Steadiness In Isometric and Dynamic Functional Movements

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With advancing age, there is an increased risk of falls, particularly in those over the age of 70 years (Tinetti & Speechley, 1989). However, the cause of these falls is not known when pathology and medication are accounted for. Recently it has been observed that the ability to perform a steady force muscle contraction can be reduced in the elderly (Tracy & Enoka, 2001) and this could contribute to the increased falls risk. To date steadiness has been assessed only during isometric and isokinetic contractions in laboratory situations while that during functional movements has not yet been investigated. The aim of this study was to measure steadiness during both isometric quadriceps contractions and during functional movements of the knee and investigate any relationship between them in elderly people with and without a history of falling and young subjects.

Bilateral measurements were taken in three groups: 1) 37 young subjects (aged 29 ± 1.1 years (mean ± SEM), 22 female), 2) 45 older people with no history of falls (aged 75.8 ± 0.62 years, 30 female) and 3) 27 older people with a history of falling (aged 71.2 ± 4.6 years, 22 female). Isometric steadiness was assessed at 10, 25 and 50% of maximum voluntary contraction force (MVC) and expressed as coefficient of variation (CoV) of the force signal. Functional steadiness was assessed using motion analysis (CODA MPX, Charnwood Dynamics, UK) during stepping up and down, standing up and sitting. Steadiness was defined as the standard deviation (SD) of the angular acceleration of the knee joint.

Isometric steadiness was similar in all three groups. During functional movements the younger subjects were most steady (P=0.04-0.001). The elderly fallers were less steady than age matched non-fallers during stepping up and down (P=0.04). There were no significant correlations between the isometric and functional tests in the younger group. Significant correlations for the older groups are shown below.

There appears to be no consistent relationship between the ability to hold a steady force isometric quadriceps contraction and the smoothness of functional knee movements. However, during stepping, significant correlations were seen only in the elderly fallers who were also less steady than the elderly non-fallers. This highlights the importance of stepping performance in older fallers and identifies a test that may be sufficiently sensitive to identify those at particular risk of falling.

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175 - MUAP Rate in Chronic Pain Patients

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Introduction: Despite extensive research, little is known about deviations in motor control in people with chronic pain. Most studies have used bipolar surface Electromyograhpy (EMG) to investigate motor control, resulting in a rather global view of muscle activation patterns. Recently, we proposed a new measure, motor unit action potential (MUAP) Rate (MR), to study motor control in a more detailed way (1). The objective of the present study is to assess differences in motor control between chronic pain patients and healthy controls.

Methods: EMG of the dominant upper trapezius during computer work tasks in a control group (n=13) and a patient group (n=10) was recorded. The protocol consisted of a dots task (in which the subjects had to place marks within circles on a paper with a fixed pace), a type task, an edit task, a mouse task and a stress task (STROOP test). EMG was measured with an 8-channel linear electrode array. MR was calculated by counting the number of MUAPs per second with a wavelet-transform based detection algorithm. RMS was calculated per second. Average values (across seconds) of MR and RMS are presented.

Results: In Figure 1, at the left side, RMS is shown. A two-way ANOVA revealed a statistically significant dependency for task only ($F = 10.7$, $p < 0.000$). At the right side MR is shown. A two-way ANOVA revealed a statistically significant dependency for task ($F = 6.67$, $p < 0.02$) and group ($F=3.92$, $p < 0.05$).

Conclusion: The higher MR implies that the activity during an imposed task is higher in patients than in controls, although the biomechanical demands are the same. As can be seen from Figure 1, this difference is not as much reflected in RMS. Apparently, MR is more sensitive than RMS to differences in motor control.

References

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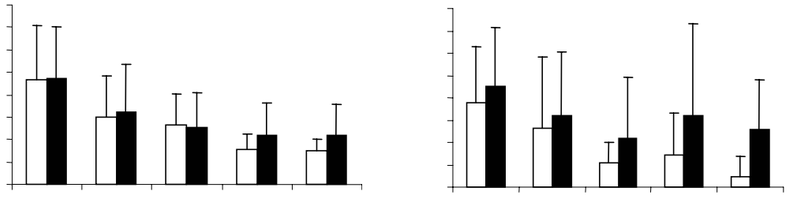

Figure 1 Mean RMS (left) and MR (right) for control group (white) and patient group (black) for all tasks.

176 - Delayed-Onset Muscle Soreness and Short And Long Latency Stretch Reflexes In Erector Spinae

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Introduction: Delayed-onset muscle soreness (DOMS) has been shown to influence the short (SL) and long latency (LL) muscle reflex response. However, most studies have looked at severe muscle soreness in leg muscles, while no studies have investigated the effect of moderate DOMS on SL and LL reflexes in erector spinae (ES). If moderate DOMS affects the reflex response of the back muscles, it could potentially disturb the fine motor control system normally protecting the spine during e.g. sudden loadings. The aim of the study was thus to determine the effect of moderate DOMS on the SL and LL stretch reflex response of the ES muscle.

Methods: Eight healthy controls and nine floor ball players experiencing moderate DOMS in the ES muscle after their first training session in the season participated in the study two and seven days after the training session.

SL reflexes were elicited by tapping the right ES at L3/L4 level. Surface EMG was measured bilaterally with the electrodes placed 2.5 cm below and beyond the tapping site. The EMG signals were pre-amplified and sampled with a frequency of 3000 Hz. Tapping depth and duration were 5 mm and 3-4 ms, respectively. In the analysis, the EMG response to 50 taps was averaged. Subjects were standing upright during tapping producing a steady background EMG activity. LL reflexes – "functional stretch reflexes" - were elicited exposing the participants to 11 sudden trunk loadings (STL). The STL was generated via a load (60 N) that momentarily was applied to the upper part of the trunk. The trunk movement was measured by a potentiometer measuring the movements of the wire connecting the participant and the load. The severity of DOMS was characterized on each experimental day using pressure algometry. A continuously increasing pressure was applied to the muscle belly at the L3/L4 level until the participant experienced pain rather than pressure. The magnitude of the pressure was used as a measure of soreness. Range of motion (ROM) was tested using the fingertip-floor test during maximal trunk flexion, and maximal isometric muscle strength (MVC) was tested during back extension.

Results: ROM decreased ($P<0.001$) and muscle soreness increased ($P=0.07$) on day two in the DOMS group compared to day seven. Furthermore, MVC decreased on day two compared to day seven ($P<0.01$). No changes were observed in the control group. No DOMS induced changes were observed in the SL and LL stretch reflex response neither in the latencies nor in stop time and stop distance of the trunk during sudden loading of the trunk in the two groups (Table 1).

Conclusion: Despite significant changes in muscle performance and muscle soreness moderate DOMS apparently had no influence on short and long latency stretch reflex responses.

Table 1. SL and LL reflex characteristics (Mean and SD)

	Short latency (ms)		Long latency (ms)		Stop time (ms)		Stop distance (cm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DOMS day 2	12.5	± 1.0	71.7	± 9.1	312	± 45	4.3	± 0.9
day 7	11.0	± 1.7	75.0	± 11.0	310	± 46	4.4	± 0.8
Control day 2	12.3	± 2.3	72.4	± 9.1	290	± 49	3.7	± 1.4
day 7	12.0	± 2.9	71.5	± 10.8	285	± 52	3.6	± 1.2

179 - Short Latency Stretch Reflexes in Human Erector Spinae Muscles

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Introduction: Few studies have investigated the characteristics of stretch reflexes in the erector spinae muscle. Dimitrijevic (1980), Tani (1997), Zedka (1999) using different manual-/automatic techniques reported short latency responses of the tapped low-back erector muscle in the range 12-19 ms. However, the dynamical characteristics of the tapping methods were different, and it is likely that the results have been influenced by the duration of the taps. The aim of the present study was to obtain latency measures characterizing the stretch reflex of the low back muscles independent of the actual dynamical characteristics of the tapping system.

Methods: An electromechanical tapping system was constructed, which consisted of a prodder and a position sensor fixed to the armature of a solenoid. The velocity of the prodder could be varied corresponding to a tapping duration from 3.5 to 20 ms for a depth of 5 mm. Signals from the position sensor, a prodder-contact and surface EMG were recorded. Subjects (7) were placed in a neutral standing position with their pelvis fixed. During the trials – including 50 tapping events in 1½ minute - the subjects produced a steady background EMG activity.

Results: A linear relationship was found between duration of the taps and the EMG onset (Figure 1 & 2). The latency of a 'zero-duration' tap, which corresponds to the real stretch reflex latency without influence of the actual tap duration, was found to be 7.4±1.4ms.

Conclusion: By utilizing a method, which compensates for mechanical delay of the tapping perturbation, it has been shown that the short latency stretch reflex in the erector spinae muscles is considerable faster that previous reported.

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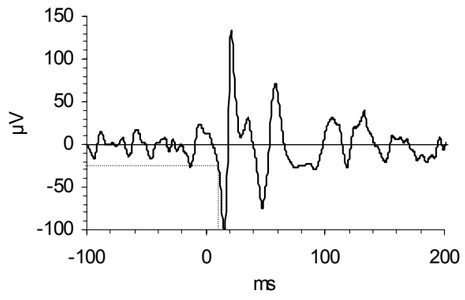

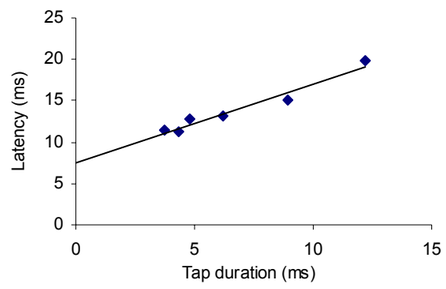

180 - Muscle Force Frequency Response of Human Tibialis Anterior

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The aim of this study was to estimate the frequency response of a human muscle carrying out the analysis of the force signal recorded during electrical stimulation of the tibialis anterior (TA). To this purpose, the stimulation pattern provided a sinusoidal variation in the number of recruited motor units by varying the amplitude of the stimuli. Eight subjects (age: 23-50 years, 5 males, 3 females) volunteered for the study. The leg was fixed in an ergometer expressly designed for isometric contraction of the ankle flexors. To detect force the foot was strapped to a wooden plate connected to a load cell. A large anode was placed on the gastrocnemius muscle while a small negative electrode was fixed by an adhesive tape to the most proximal motor point of the TA. The maximum stimulus amplitude was the one eliciting the maximal EMG response (M-wave). During a continuous 30 Hz stimulation, the largest range of changes in the stimuli amplitude (SA), providing a sinusoidal force variation with harmonic distortion <1%, was identified. The testing frequency for SA range definition was 0.4 Hz. A sequence of 14 frequencies (0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0 Hz) was administered. In each subject: a) the average harmonic distortion across the 14 frequencies was always below 1%; b) it was possible to model the force dynamic response by a critically damped II order system with two real coincident poles and a pure time delay. For the 8 subjects the Bode plots for gain attenuation and phase shift, reporting the amplitude reduction and phase shift with respect to the input sine, were calculated for each tested frequency. The double poles position and the time delay ranges were 2.01 - 3.0 Hz and 16 – 32 ms, respectively. To the authors' knowledge this is the first frequency response obtained from an in-vivo human muscle. The possibility to obtain, by means of the muscle input/output transfer function, data regarding the in-vivo mechanics of the muscle-tendon unit may represent a novel tool to investigate the functional features of different muscle groups, in subjects with different physical fitness or the influence of specific neuromuscular diseases on neuro-mechanical performance.

191 - Effects of Lower Median Nerve Block on Precision Grip

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Introduction: The median nerve provides sensation in the palmar areas of the thumb, index, middle, and radial half of the ring fingers. It also innervates the thenar muscles and the radial two lumbricals. Compression of the median nerve in the carpal tunnel results in decreased tactile sensitivity in the median nerve distribution [1, 2] and inefficient grip force coordination [3, 4]. The purpose of this study was to investigate the effects of median nerve block on fine motor control during precision grip by the thumb and the index finger.

Methods: Bupivacaine was injected into the carpal tunnels of 7 subjects to block their median nerves. The subjects were instructed to use the thumb and the index finger to grip an instrumented handle, lift it up, and hold it in the air as stable as possible for 60 seconds both before and after nerve blocking. The weight of the handle was alternated between 435g and 341g. The preload and load phases were calculated as the time periods between the onsets of grip force and load force, and between the onset of load force and the time instant when the load force just equalled the handle weight, respectively. The safety margin was the difference between the actual grip force and the minimal grip force to keep the handle from dropping. Coefficient of variation (CV) of the grip force was the ratio of the standard deviation to the mean, multiplied by 100%.

Results: Lower median nerve block significantly prolonged the length of the preload phase from about 200 ms to over 400 ms ($P < .05$). The average length of the load phase was also increased by over 100 ms after nerve block. However, the difference was not statistically significant ($P > .05$). The average safety margin was about 3.0 N before nerve block and was significantly increased to approximately 5.0 N after nerve block ($P < .05$). The average CV of the grip force was significantly increased from about 13% to 18% ($P < .05$). The weight of the handle did not significantly affect any of the above parameters.

Conclusion: After median nerve block, the precision grip by the thumb and the index finger was degraded in terms of prolonged preload phase and inefficient modulation of grip force. Impairment of the sensory and motor function induced by median nerve block could contribute to the degradation of the precision control of grip. Since the precision grip task required sub-maximal effort, it is likely that sensory function plays a more important role in the fine motor control of the digits than motor function. The current methods and findings could be utilized for functional evaluation of peripheral neuropathy.

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208 - Muscle Reaction Classification of Low Back Pain

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Introduction: It has been well documented that low-back pain (LBP) patients have slower muscle reaction times to perturbation than healthy controls. These muscle reactions appear to be reflexive and not voluntary in nature, and as a result, might be useful for objectively classifying LBP. The goal of the study was to develop an objective and accurate method for classifying LBP using a sudden load-release protocol.

Methods: Subjects were divided into two groups: learning group (20 patients and 20 controls), and holdout group (15 patients and 12 controls). Subjects exerted isometric trunk force against a cable in four different directions. Following cable release, the trunk was suddenly displaced eliciting a muscle reflex response. Reaction times for muscles switching-on and shutting-off were determined using electromyogram signals from 8 trunk muscles. Independent T tests were performed on the learning group to determine which reaction parameters were to be entered into logistical regression analysis to produce a classification model. The holdout group was used to validate this classification model.

Results: Using three parameters, the model was able to correctly classify 83 % of the learning group, and 81 % of the holdout group.

Conclusion: Using reaction parameters appears to be an accurate and objective method for classifying LBP.

222 - Synergistic Muscle Activation and Optimal Power Output In Lat Pulldown Exercise

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Introduction: Optimal power output is generally ensured through greater power absorption by faster pre-stretch in the eccentric phase together with subsequent power production in the concentric phase. Among the factors to be responsible for (e.g., stored elastic energy), however, active states of muscles across the segments presumably have a greater impact on such optimization in multi-joint movements. Thus, in the present study, amplitude and timing of EMG activities from two synergistic muscles during lat pulldown exercise were examined as a function of pre-stretch conditions.

Methods: Five male subjects performed lat pulldown exercise by repetition using a load of 30% 1RM. Prior to a quick pulldown motion in the concentric phase, two different pre-stretch conditions were treated in the eccentric phase: either (a) slower or (b) faster pre-stretch (SPS or FPS, respectively). Throughout the movement, surface EMG activities from latissimus dorsi (LD) and biceps brachii (BB) were sampled at 1,000 Hz. These signals were smoothed, full-wave rectified, and then integrated over the fixed interval of 50 ms. A digital video camera at 60 Hz captured the entire motion for determining kinematic profiles.

Results: Representative integrated EMGs are presented in Fig. 1. Patterns and trends were relatively consistent across the subjects. With SPS, most of the LD and BB activities occurred during the concentric phase. However, FPS resulted in a stronger LD activity around the movement reversal, while in a weaker BB activity with only few temporal changes. Therefore, the pulldown motion by FPS began with a stronger LD activity followed by a weaker BB activity. In contrast, the pulldown motion by SPS began with a stronger BB activity followed by a weaker LD activity. In lat pulldown bar kinematics, FPS had greater peak acceleration at the movement reversal, whereas SPS had smaller peak acceleration during the concentric phase. Indeed, FPS yielded shorter time-to-peak velocity in the concentric phase.

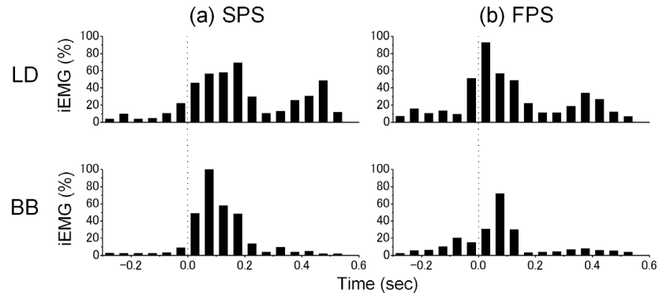

Fig. 1: Representative integrated EMGs during lat pulldown exercise

Discussion: The most significant finding was a change in synergistic muscle activation patterns as a function of pre-stretch conditions. In FPS, quicker deceleration of the upward movement undoubtedly caused a stronger LD activity prior to the movement reversal. This power absorption in the eccentric phase appeared to produce quicker acceleration, and thus shorter time-to-peak velocity in the concentric phase. While such effective use of power absorption with a stronger LD activity, the neuromuscular control system perhaps neglected redundancy in the concentric phase, resulting a weaker BB activity. This synergistic muscle activation pattern by FPS suggests a proximal-to-distal sequence of multi-joint movement, and therefore reasonable and favorable to optimal power output.

240 - Coherence Analysis Between Electroencephalogram and Electromyogram During Self-Sustained Contraction in Humans

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Introduction: Self-sustained contraction (SSC) is the involuntary activation of 'Plateau Potentials' which is an intrinsic property of spinal motor neurons. As this phenomenon occurs without brain involvement, it can be assumed that there is no coherence between electroencephalogram (EEG) and electromyogram (EMG) during SSC by autonomous neuronal activity in spinal cord. On the other hand, EEG during voluntary contraction exhibits coherence with EMG at around 10 Hz and 15-30Hz (Rosenberg et al. 1998). This research investigated on whether the sustained muscle contraction after vibratory tendon stimulation was produced by cortical output.

Methods: We studied 9 healthy subjects by recording the EMG from their right lateral head of gastrocnemius muscle (LG) and soleus (Sol), and EEG from the parietal region (Cz) under 3 different experiments: 1) during weak isometric contraction (5 min), 2) during and after the vibratory stimulation (120 sec, amplitude 10 mm, 100 Hz) to the ipsilateral Achilles' tendon, 3) during voluntary isometric contraction producing a similar EMG measured in experiment 2. Experiment 1 was used to evaluate the suitability of the subject, by verifying whether Cz corresponds to the leg area of the motor cortex. Coherence of the data collected from Experiments 2 and 3 were calculated and compared for differences in coherence peaks and frequency bands.

Results: In Experiment 1 three subjects showed significant coherence in the frequency range of 15-30 Hz at 4 % of maximal voluntary contraction (MVC) in the sitting position. In Experiment 2, when the vibration was applied to the tendon, the stimuli produced tonic vibration reflex (TVR). After the vibration was removed, SSC was observed although the subjects maintained relaxed. During both TVR and SSC, coherence was observed in approximately the same frequency band in both or either muscles of three subjects. As a representative result in one of the subjects, coherence peaks of the SSC (0.07) and TVR (0.08) were found at 27.3 Hz when both exhibited the similar %MVC. In two subjects, strength of peak reduced for SSC, compared with both isometric contraction and SSC.

Conclusion: In this study, coherence was used to investigate interaction between motor cortex and spinal motor neuron pool as it is thought that TVR relies on a transcortical reflex pathway in the lower limb. Also, as it is said that the proprioceptive input from primary spindle afferents increases cortical excitability, the lasting discharge resulted from facilitated motor cortex may partially contribute to SSC. This also implies that the SSC may, at least in part, be produced by the signal from the motor cortex. Although we found that involuntary activity may depend on motor command from the cerebral cortex, our results do not dismiss the suggestion that SSC may be produced by plateau potentials.

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246 - The Emergence of Neuromuscular Adaptation to Changing Cadence in Children – The Role of Aging and Experience

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Introduction: Accommodating changing task requirements is an important step in general skill acquisition. To achieve a goal successfully, the neuromuscular activity must be regulated in a synergy that can be scaled with the task. For example, skilled adult cyclists demonstrate spatially earlier muscle onsets with increases in pedalling speed (Neptune & Herzog, 2000). We used a similar pedalling task to probe age-related changes and training impacts in task adaptation. Two studies were designed. In Study A, the purpose was to test the hypothesis that neuromuscular pattern changes show an age-related change in organization associated with the task – younger children showing less of a cadence-dependent response. Pedalling on a stationary bicycle was chosen as the task, because it can be scaled to different body sizes, allowing performance kinematics to be held constant. In Study B, the purpose was to exam the developmental hypothesis that training can strengthen the neuromuscular synergy in children – a test of developmental readiness. To limit changes due to growth and maturation a training protocol was carried out over a short timeframe (3 weeks).

Methods: Study A – 33 healthy children (4 -10 yrs) and 8 adult cyclists (30 ± 7 yrs) performed pedalling at 5 cadences (40, 60, 80, 100, and 120 rpm). Electromyographic (EMG) data were collected from 4 lower extremity muscles, rectus femoris (RF), biceps femoris (BF), gastrocnemius (GAS) and soleus (SOL) muscles. The coefficient of determination $r2 \geq 0.5$ between muscle onset (in terms of crank angle) and cadence was interpreted to mean that the muscle onsets were shifting as a function of cadence. To test for age effects, a Chi-squared test was applied to compare the percentage of subjects with an $r2 \geq 0.5$ within each age group (4 – 6 yrs, 7 – 10 yrs, and adults). Study B – 9 healthy children (4 – 10 yrs) participated in a 3-week pedalling training protocol. Pedalling tests as described in Study A were given before and after training. EMG data were also collected and analyzed as in Study A. To test for training effects, pre-training and post-training r2 values (between muscle onsets and cadences) were compared by RM ANOVA.

Results: The result of Study A supports the hypothesis of significant age-related differences in the neuromuscular patterns across all muscles ($p < .05$). Motor experience which accumulates in daily activities (e.g. walking and running) may be inferred as a fundamental factor leading to this age-related change. Developmental readiness was revealed in Study B. Results of this study revealed a training effect on the onsets of the BF muscle which became more highly correlated with cadence (r2 values increased significantly ($p < .05$)). **Conclusion:** The adaptability of children's neuromuscular systems to cadences emerges with age and experience. In Study A, when the task was scaled to eliminate physical diversity due to growth, a significant age-related trend was still observed. This age-related difference may be primarily the result of general experience from daily activities. In Study B, the experience provided by training induced an adjustment in BF muscle. Training had a limited but positive effect on neuromuscular modification. The observation of such training effects helps to identify developmental periods of susceptibility to intervention. Future work is directed as changing training intensity to achieve a more global change in the neuromuscular pattern.

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274 - Principal Components Analysis Applied to Anticipatory Postural Adjustments in Parkinsonian Patients

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Introduction: Step initiation is a complex motor task that requires anticipatory postural adjustments (APA) to move the center of body mass laterally over the stance leg and forward, obtained by an impulsive force which must be appropriately scaled for initial stance conditions. In the present study we investigated the main features of the impulsive force time-series, by means of principal components analysis [Ramsay JO, Silverman BW. Functional data analysis. Springer-Verlag NY, 1997], that allows the analysis of the entire time-series, without an a priori parameterization of the curves. Our purpose was to identify differences in APA in patients with Parkinson's Disease (PD), compared to control subjects (CTRL), and the effects of different treatments and initial stance conditions.

Methods: Twelve subjects with PD and 18 elderly CTRL were included in the study. Subjects were instructed to take a self-paced step, starting on a force platform, from a narrow stance (NS, i.e. feet close together) and from a wide stance (WS, i.e. feet shoulder-width apart). Subjects with PD (recruited 6 months after surgery for deep brain stimulation –dbs-) were tested in four different conditions depending on combinations of dbs and levodopa (dopa) medication (i.e.: off; dbs; dopa; dbs+dopa). Principal components (PC) analysis was applied to the trajectory over time of the vertical force under the stepping foot (FV) during the anticipatory phase just prior to taking the foot off the ground, considering separately data from NS and WS. In the space identified by the most relevant PCs, a linear Bayes classifier was designed to distinguish subjects with PD and CTRL.

Results: Over 99% of the variance, both for NS and WS data set, was explained by the first 4 PCs, which were used to design the Bayes classifiers. Projections of the 4-dim spaces, spanned by the first 4 PCs, are represented in FIG.1. PD subjects and CTRL are well separated in these planes, as the Bayes classifiers show, with a misclassification error equal to 11.3% in NS and to 9.4% in WS. It is noteworthy that the misclassified trials of PD subjects are almost exclusively associated with treated conditions (see legends of FIG 1), suggesting that the anti-PD treatments may improve the APA.

Conclusion: Our results confirm that PD subjects and CTRL have different behaviours during step initiation [Burleigh-Jacobs A. et al., Mov Disord, 1997] and this difference increases in WS (lower misclassification error). The misclassification error may be interpreted as due to the beneficial effect of treatments for some patients. This emphasizes the efficacy of the treatments, but also the variation in individual responses to treatments.

294 - Non-Linear Analysis of the Surface Electromyographic Signal in Parkinsonian Patients

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Introduction: The effectiveness of recurrent quantification analysis (RQA) in the study of surface electromyographic signal (sEMG) has been demonstrated in normal subjects and it has also been foreseen for studying neuro-muscular diseases (1). The Parkinson's patient (PD) presents some peculiar sEMG features that can be summarized as follows: high sEMG amplitude at rest; burst-like discharges coupled with tremor at a frequency of about 4-7 per second (2). The resting tremor of Parkinson's disease is present in 70-80% of cases. It is worsened by stress, and it is generally reported to decrease/disappear with action. However, it is not yet clear if the output from the "tremor generators" is still present during voluntary contraction either during the states "on" and "off" therapy. In the present study we used the RQA to test the hypothesis that a significant amount of deterministic structures is still present in the sEMG of PD patients also during voluntary sub-maximal contractions. We also compared results thus obtained with those gained with sEMG analysis in the frequency domain.

MATERIAL AND Methods: Six PD patients volunteered for the study. Myoelectric signals were recorded from the first dorsal interosseus muscle (FDI) by means of surface electrodes. The abduction force of the FDI was measured by means of a piezo-electric force transducer. The maximal voluntary force (MVC) of the FDI was measured. After a convenient recovery, the following protocol was adopted: 10 seconds at rest, 20 seconds at 50% MVC, 10 seconds at rest. This protocol was repeated three times with a 5 minutes interval between attempts. Myoelectric signals were amplified by means of a portable electromyograph (SATEM-VD10) and A/D sampled at 2048 samples per second. Surface EMG signals were filtered with a digital low pass Butterworth filter (order: 15; Cut-off frequency: 350Hz; Pass-band ripple: 1; Attenuation factor: 90). Non-linear analysis of sEMG data was performed using the RQA algorithm (1) on epochs of 1s length overlapped by 0.5 s. We choose the parameter % of determinism (%DET) to quantify sEMG deterministic content. Besides, sEMG data have been analysed in the frequency domain and the median frequency (MDF) of sEMG power spectrum was chosen.

RESULTS: Parkinsonian sEMG signal at rest was characterised by bursts of activity at a frequency of 5 s-1. Correlation of sEMG bursts with tremor was very high with a lag between sEMG and mechanical activity of about 50 ms. Frequency analysis of sEMG at rest failed to show the decay typical of myoelectric fatigue. RQA analysis revealed %DET values at rest between 60% (off-therapy) and 45% (on-therapy). During attempted voluntary contraction at 50% MVC, %DET oscillated between 50% (off-therapy) and 40% (on-therapy). It is to note that being voluntary muscle activation pathologically intermittent in these patients, during the "pauses" between activity phases the involuntary bursts prevailed and %DET raised again.%. This latter aspect was not sensed by frequency domain analysis. During the rest phase following voluntary exercise, %DET was, on average, higher than during the pre-exercise rest phase.

DISCUSSION/CONCLUSION: At rest the sEMG pattern we observed is that typically reported for these patients. RQA analysis showed its high deterministic structure. Results of the analysis of PD during voluntary contraction confirm the presence of a background activity of oscillating circuit(s) also when the pharmacological effect of

therapy was present (“on” therapy state). In conclusion, RQA technique is a useful tool for the study of the sEMG even in pathological conditions.

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304 - Preservation of Grip Aperture Scaling to Object Size in the Impaired Hand of Adults with Hemiparesis

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Introduction. In patients with hemiparesis, trunk movement is used to assist both arm transport and hand orientation for grasping when distal deficits are present. Despite these deficits, patients use the same range of grip apertures as healthy subjects when grasping a 35 mm diameter cylinder with the whole hand. However, this study did not evaluate the ability of patients to scale grip size according to object size and the effect of differents types of prehension on this ability (i.e. whole hand grasping versus precision grip).

Method. Twelve patients with chronic hemiparesis and 12 neurologically healthy subjects participated in this study. Patients had sustained a stroke 16 ± 12 mos previously and had mild to severe arm/hand paresis. Subjects were required to reach and grasp cylindrical objects with two different diameters: medium (33 mm) and large (55 mm) with whole hand or finger tip grasp. The object was placed in the workspace within the reach of the arm. A series of 10 trials was done for each condition. Twelve infrared emitting diodes were placed on bony landmarks of the hand, arm and trunk and kinematic data were recorded by an optical analysis system (Optotrak) at 120 Hz.

Results. In both groups, grip aperture sizes varied with cylinder diameter ($p < 0.001$) and type of grasping ($p < 0.001$). Despite a prolongation in movement time (MT) and in duration of the deceleration phase in the stroke compared to the healthy group, changes in object size had no effect on movement time (MT). In both groups the time to maximal grip aperture, expressed as a percentage of MT, occured latter for larger cylinder. The type of grasping have no effect on temporal parameters of reaching and grasping. The amount of trunk anterior displacement was larger when subjects, in both groups, grasped the cylinder with the whole hand compared with to fingertip prehension.

Conclusion. Patients with different degrees of hand paresis retain the ability to scale the timing and amplitude of grip aperture with cylinder size independently of the type of grasp.

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311 - Balance Maintenance Strategies While Standing During Bilateral Achilles Tendon Vibration And Support Surface Perturbations

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Introduction: Support surface perturbations trigger balance reactions that depend on the accuracy of somatosensory, visual and vestibular inputs. Tendon vibration activates primarily the muscle stretch receptors, and is thus useful to study the sensori-motor interactions needed for upright balance control. We have shown previously that vibration affects postural control and balance 1, persisting even after vibration stops 2. This research was conducted to examine how bilateral Achilles tendon vibration (ATV) affects the muscular and kinematic strategies used during quiet and perturbed stance, as well as the duration of these effects.

Methods: Twelve young and healthy subjects stood on two force plates with vision occluded. They were submitted to 30 s periods of bilateral ATV (frequency: 80 Hz; amplitude: 1-1.5 mm) and asked to maintain their balance at all times. Random perturbations of the support surface in the toes-up (TU) or toes-down (TD) directions were given either before, during, 5s or 25 s after ATV. Body kinematics in 3D was acquired at 120 Hz using a 6-camera Vicon motion system tracking reflective markers positioned over anatomical landmarks. Ground reaction forces were captured using 2 AMTI force plates embedded in the moveable support surface. EMG from 8 right-sided trunk and lower limb muscles was recorded using a telemetric Telemyo900 system, bandpass filtered (10-500 Hz) and sampled at 1080 Hz along with the ground reaction forces.

Results: ATV applied during quiet standing resulted in an increased postural sway and a backward shift of the mean center of pressure (CoP) and center of mass (CoM) positions. These shifts are explained by trunk extension (up to 10°) caused by increased activation of the Erector spinae (ES) muscle ($p<0.05$), as well as a greater knee flexion (up to 16°). Increased dorsiflexion during ATV was observed in half of the subjects, whereas the other half presented a greater plantarflexion. A two-fold increase in Soleus (Sol) activity during ATV contributed to the subjects' backwards shift, whereas the greater Tibialis anterior (TA) activity was sometimes observed to counteract this backwards shift. Two opposing trends were observed when subjects were given TU or TD perturbations during ATV. CoP and CoM peak-to-peak excursions were either increased (54% of the trials) or decreased (46%), and the change was determined by the magnitude of backwards leaning prior to the perturbation. A stepping strategy occurred mainly when TU perturbations were given during ATV in subjects standing in a position at the limits of stability (significant trunk extension and ankle plantarflexion). Muscles onset latencies and amplitudes in response to surface perturbations were delayed during ATV with Sol, TA and ES activation onset occurring 20 - 40 ms later than without ATV. Postural responses were still affected 5 s after ATV, but were back to their initial levels by 25 s after ATV.

Discussion: Modification of lower limbs proprioceptive information by bilateral ATV results in increased postural sway and alterations of the postural responses triggered by support surface perturbations, as shown by the changes in kinematic and muscular responses during quiet and perturbed standing. These results suggest that local alterations of proprioceptive information can have widespread effects on the maintenance of whole body equilibrium.

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322 - Lower Body Analysis of Muscle Recruitment in Visually Impaired and Sighted Matches

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Introduction: The purpose of this study was to identify the ability for visually impaired individuals to recruit muscle at different speeds, related to sighted matches.

Methods: Fifteen individuals matched by sex, age, and height with a visual impairment and fifteen individuals without a visual impairment were tested on a Cybex Norm Isokinetic (CSMII, Norwood, MA) system. During Cybex testing EMG data was collected on the medial/lateral quadriceps and medial/lateral hamstring. Participants then were tested at angular velocities of 90, 180 and 300 deg/sec. These speeds reflect a continuum from strength to power to endurance. Participants performed a maximal effort for contraction of the quadriceps (knee extension) followed by a maximal effort of the hamstrings (knee flexion) for 6 continuous repetitions at 90 deg/sec, and 180 deg/sec, followed by 20 repetitions at 300 deg/sec. The EMG data was analyzed using a BioPac Acknowledge III software. The median frequency (MDF) of the root mean square (rmsEMG) as a measure of muscular activity and the wave form was normalized using a maximal voluntary contraction (Basmajin & DeLuca, 1985). Between group differences were analyzed using three separate 2 X 4 MANOVAS. Each MANOVA represented all four sites with the differences pertaining to the speed at which they were collected (90 deg/sec, 180 deg/sec, & 300 deg/sec). Means and standard deviations were calculated on all data. **Results:** No significant differences were found between groups for the EMG among the dependent variables on any of the three speeds ($p < .05$). Table 1 contains EMG means and standard deviations for each muscle at each Cybex speed. Even though no significant differences ($p > .05$) were indicated between groups, it is of interest to note that at 180 deg/sec. Hotelling's Trace = .379 ($F(4,25) = 4.00$, $p = .08$) and the partial eta squared = .28 which indicates a large effect in muscle recruitment between visually impaired and sighted participants (Cohen, 1977; Huck, 2000).

Table 1: rmsEMG Group Comparisons

	Site			
	MQ	LQ	MH	LH
90 deg/sec.				
Visually Impaired	98.4 +/- 29.5	105.8 +/- 25.8	91.8 +/- 32.3	88.3 +/- 38.2
Sighted	109.4 +/- 22.8	105.6 +/- 22.9	99.5 +/- 34.7	91.0 +/- 29.7
180 deg/sec.				
Visually Impaired	89.4 +/- 24.0	96.6 +/- 37.2	93.4 +/- 33.9	84.5 +/- 27.7
Sighted	109.1 +/- 23.4	93.6 +/- 26.9	102.7 +/- 31.5	90.5 +/- 36.2
300 deg/sec.				
Visually Impaired	87.3 +/- 30.5	93.6 +/- 41.2	88.9 +/- 32.9	91.5 +/- 26.3
Sighted	92.1 +/- 25.6	88.4 +/- 29.7	98.5 +/- 28.1	105.0 +/- 39.2

Discussion: Ability to recruit muscle does not seem to contribute to mobility concerns in Visually Impaired individuals, however, in addition to there being a multivariate effect approaching significance, it is also important to note that on 9 out of the 12 measures of muscle recruitment, the sighted group was more efficient based on the mean values in Table 1. Future studies need to address components of force produced and motion analysis to determine where improvements can be made to alleviate the mobility concerns within the population.

328 - Muscle Activation Is Different When the Same Muscle Acts As an Agonist or Antagonist During Voluntary Movement

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During movement, the intrinsic muscle force-velocity property decreases the net force for the shortening muscle and increases it for the lengthening muscle. We present a quantitative analysis of the effect of this muscle property on activation and force output of the same muscle acting as the agonist (shortening muscle) and antagonist (lengthening muscle) in fast and medium speed goal-oriented movements. The biceps activation and force output were compared when this muscle was the agonist in a series of elbow flexions and when it was the antagonist in a series of elbow extensions. The same analysis was done for the lateral, long, and medial heads of the triceps muscle. We found that when the muscle(s) acted as the agonist the muscle EMG was about 2 times larger and the contractile impulse was up to 3 times larger than when the same muscle(s) acted as the antagonist in movements with similar kinematics. This large effect of the muscle force-velocity property strongly suggests that in order to generate movements with a commonly observed bell-shaped velocity profile the neural controller must account for intrinsic muscle properties.

335 - Reflex Modulation of Spinal Motoneurones by Single Low Threshold Cutaneous Mechanoreceptors in the Glabrous Skin of the Human Foot

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Introduction Sensory feedback is an important element in fine motor control of the human body. It has previously been demonstrated that the input from some single cutaneous low-threshold mechanoreceptors in the glabrous skin of the hand exert a spinally mediated reflex facilitation of ongoing EMG in muscles acting on the digits [1,2]. We have now extended this work to examine the same spinal circuitry in the lower limb of human subjects.

Methods We recorded the activity of 54 single low threshold cutaneous mechanoreceptors located in the glabrous skin on the plantar surface of the foot and three additional afferents arising in the foot. Data were recorded during 31 experiments on 18 subjects (13 female, 5 male), aged 19-36. To record afferent activity an insulated tungsten microelectrode was inserted percutaneously into the tibial nerve at the level of the popliteal fossa as awake subjects lay prone. Surface EMG was recorded from muscles acting about the ankle, namely medial and lateral gastrocnemii, soleus and tibialis anterior while subjects performed weak voluntary contractions of less than 10% of maximal voluntary effort. Spike triggered averaging was used to reveal any EMG events time locked to the afferent discharge.

Results Reflex modulation of ongoing EMG was noted for all classes of low threshold cutaneous mechanoreceptors in the foot, specifically 17 of 21 FA I, 2 of 5 FA II, 2 of 18 SA I, 4 of 10 SA II and one deep Ruffini-like ending. Additionally one ectopically active (presumed cutaneous) afferent demonstrated modulation of the motoneurone pool of muscles acting around the ankle, while one joint afferent showed no such synaptic coupling. The latencies of the observed reflex responses suggest a spinally mediated, oligosynaptic pathway. Although surface EMG electrodes were used, the activity of 13 single motor units could be discriminated. Preliminary analysis of the firing pattern showed eight of these units demonstrated reflex modulation associated with the input of two FA I and three SA I afferents.

Discussion These results emphasize the important role of single cutaneous low threshold mechanoreceptors located in the glabrous skin of the sole of foot in providing sensory mediated reflex modulation of both single motor units and a larger portion of the motoneurone pool during ongoing EMG in muscles acting about the ankle. Unlike the hand where SA I receptors showed no evidence of synaptic coupling, the reflex activity observed for SA I afferents in the foot in this study suggests a different role for this receptor class in the two extremities. Furthermore, the amplitude of the observed modulation is smaller for reflexes associated with mechanoreceptors in the foot than in the hand, particularly for the FA I afferents. These data suggest that the spinal reflex pathway we have observed in the lower limb may help maintain balance and provide ongoing control of human posture and locomotion.

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360 - Postural Strategies to Maintain Balance During Lateral Walking After Stroke

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Introduction: Balance and mobility dysfunctions are common in individuals with stroke, who often exhibit asymmetric weight-bearing. Trunk stabilization and control of the center of mass (COM) are important components in the maintenance of stable upright posture especially during locomotion. Sideways falls are more prevalent in the elderly, indicating that the control of mediolateral (ML) stability during stepping can be impaired by aging (Maki et al., Clin Geriatr Med 1996;12:635-58). We hypothesize that anteroposterior (AP) stability is an important control variable during lateral walking and the control is impaired following a stroke.

Methods: Ten individuals with stroke and 4 healthy subjects of similar age participated in this study. Subjects walked sideways towards the paretic and non-paretic (or right and left) side along a 3.5m path. Subjects were instructed to gaze straight ahead at a red line suspended at eye level 57cm in front of and parallel to the path. The red line was used to prevent subjects from turning the head and fixating on an end point in the direction of progression. 3-D head and body positions were recorded at 120 Hz with a 6-camera Vicon 512 system. Displacements of the whole body COM, the feet, and upper body angles of the head, trunk, and pelvis in the AP, ML, and vertical directions were computed offline, along with temporal distance factors, including the durations of the gait cycle and single and double limb support, as well as the step length and step height.

Results: The ranges of COM displacements in the AP and vertical directions were 40-50% and 25-50% larger, respectively, in stroke individuals, as compared to healthy subjects. The difference was larger when walking towards the paretic side. Healthy subjects displaced their body COM 30% more than stroke subjects in the ML direction, which was the axis of progression. COM displacements in the ML direction were smaller in stroke individuals when walking towards the paretic side, which were associated with smaller step lengths in both the leading (paretic) and trailing limbs. The horizontal COM trajectories relative to foot positions were similar between stroke and healthy subjects. Head, trunk, and pelvis rotations were in phase during lateral walking in both stroke and healthy subjects. Stroke individuals exhibited 30% greater maximal trunk rotation compared to healthy subjects, with 35% greater rotation towards the paretic compared to the non-paretic direction. In healthy subject, initial body orientation was rotated towards the direction of progression, with an opposite rotation occurring during stepping with the leading limb, followed by a resetting towards the initial orientation during stepping with the trailing limb. Stroke individuals displayed similar patterns but with a rotational bias toward the paretic side. Stroke subjects spent more time in double support and less time in single leg support and swing than controls. The duration of double limb support was 50% of the total duration of swing and single leg support in healthy subjects. In contrast, stroke individuals spent approximately equal proportions of time in double limb support as in swing and single leg support. Step lengths were smaller and step duration was longer in stroke subjects compared to healthy controls. Stroke subjects side-stepped 50% slower than healthy subjects, especially when progressing toward the non-paretic direction. The vertical distance was always greater in the leading limb as compared to the trailing limb in both groups. Stroke subjects took higher steps with the leading limb in the paretic direction.

Discussion: This study confirms our hypothesis that AP stability is maintained in healthy subjects while challenged in stroke individuals. AP stability during lateral walking, as shown by minimal AP excursions in healthy subjects, is affected by stroke, similar to ML stability in forward walking. Shorter periods in single limb support and asymmetric temporal distance factors suggest an avoidance of weight-bearing on the paretic limb during lateral walking.

366 - Extensor and Flexor Muscle Contribution to Active Trunk Stiffness

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Introduction: Biomechanical stiffness of active trunk muscles contributes to neuromuscular control of spinal stability. However, existing data regarding the contribution of flexor versus extensor muscle groups to active trunk stiffness is limited1,2. The purpose of this study was to quantify the role of trunk extensor and flexor muscle groups on active trunk stiffness.

Methods: Eighteen subjects participated in the study. A harness and cable system attached the subject to a servomotor (Pacific Scientific, Rockford, IL) such that cable tension applied external loads at the T10 level of the trunk. The motor was programmed to provide three levels of isotonic load, 100 N, 135 N, and 170 N while the subjects stood upright with their pelvis and legs strapped to a rigid support. Superimposed on the preload were force perturbations of ± 30 N applied in a pseudo-random stochastic fashion with a flat bandwidth from 0-50 Hz. The applied forces were measured by a force transducer attached to the motor sampled at 1000 Hz (Omega, Stamford, CT). The small amplitude dynamic trunk movement was recorded using IRED motion analyses at 2000 Hz. Three pseudorandom perturbation trials of ten seconds were performed at each load level presented in random order. The protocol was performed with the isotonic loads applied to invoke both flexor and extensor muscle groups for a total of eighteen trials. Using standard deconvolution techniques and 2nd order parametric analyses trunk stiffness, damping and inertia were calculated from the transfer function describing the relation between input force and output trunk movement.

Results: Results show that the trunk behaves as an underdamped 2nd order system usually exhibiting one oscillation before returning to an upright posture during both an impulse inducing extensor and flexor muscle group activation (Figure 1). Preliminary results from five of the subjects demonstrate that trunk stiffness was significantly ($p<.05$) higher during activation of extensor muscle groups than flexor muscle groups. Trunk stiffness increased significantly ($p<.01$) with load level. Furthermore, there was a significant ($p<.05$) interaction between trunk flexor/extensor muscle group and load level (Figure 2).

Conclusion: Interaction between trunk flexor/extensor muscle group and load level suggest load affects extensor muscles more than flexor muscles. Stability analyses must consider the fact that trunk flexor and extensor muscles functions demonstrate significantly different biomechanics. Future studies must investigate the neuromechanical cause of this difference.

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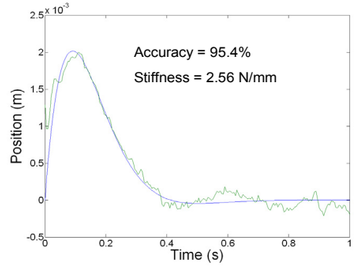

Figure 1. Impulse Response and stiffness

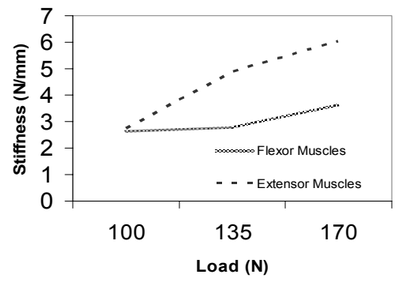

Figure 2.Extensor muscles had higher stiffness values than flexor muscles

392 - In Vivo Load Sharing Among the Three Heads of Human Triceps Surae During Isometric and Submaximal Plantar Flexion

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Introduction: Although ankle plantar flexion (PF) is performed with simultaneous contractions of the three heads of the triceps surae, it is often not clear how the load is shared among them under normal and pathological conditions at different joint positions. We hypothesized that: the absolute moment generated by each head of the triceps surae increases with the total ankle PF moment; the relative contribution and its dependence on the total ankle PF moment are different for different heads of the triceps surae; and the relative contribution of each head would be changed at different ankle positions.

Methods: Six ankles of 4 subjects were tested at 15 degree of dorsiflexion (DF), neutral, 15 and 30 degrees of PF positions with the knee immobilized at 60 degree of flexion. Electrical stimulations with a wide range of intensities were used to activate each triceps surae head selectively while the compound muscle action potentials (M-waves) and ankle PF moment were measured. The relationship between the ankle PF moment generated by an individual triceps surae head and the corresponding M-waves over various contraction levels was established for each triceps surae head at each ankle position. This relationship was used to calibrate the corresponding EMG signal and determine load sharing among triceps surae heads during submaximal isometric voluntary ankle PF.

Results: The soleus contributed more than the medial gastrocnemius (MG) or lateral gastrocnemius (LG) to ankle PF moment ($P =< 0.038$). As the ankle PF moment increased, the relative contribution of the soleus decreased ($P=0.044$) while the relative contribution of the LG increased ($P=0.028$). There was no significant change in the relative contribution of the MG ($P=0.912$). The absolute moment generated by each triceps surae head always increased with the total ankle PF moment ($P =< 0.043$) except for the MG ($p=0.148$). The LG showed increased contribution with increasing PF in contrast to the soleus, which contributed less at PF positions than at neutral or DF position but no statistical significance was demonstrated for either observation.

Conclusion: Our in vivo approach determined subject- and condition-specific load sharing among individual heads of the triceps surae and showed that the central nervous system utilized the uniarticular soleus in submaximal isometric ankle PF with the knee at a considerably flexed position. The preferred utilization of each head was changed in relation with the demand of the ankle PF moment and/or different ankle positions.

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401 - Surface EMG Activity of the Paraspinals and Hamstrings during Manual Force Application

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Introduction: Manual therapy is used clinically to improve joint and soft tissue mobility, however, the effectiveness of the techniques are poorly documented. To date, a few studies have used the method of psychophysics to measure individuals' perception of force production (1,2,3). Another approach was by Thelkeld (4), who analyzed external and internal forces on patient's connective tissue by measuring vertical ground reaction forces of 2 physical therapists during thoracic mobilization. The recruitment of physical therapists' postural muscles when the hands are used to apply manual force has not been investigated directly. The purposes of this study were to: 1) detect activation patterns of two anti-gravity postural muscles during manual application; and 2) quantify the differences in level of muscle activity measured during application of a range of forces to simulated soft tissue.

Methods: Ten physical therapists with at least 5 years of clinical experience were tested. The recruitment of the paraspinals and hamstrings was determined by recording the surface electromyographic (sEMG) activity of the muscles during 4 levels of manually applied force over 3 trials. Manual force was applied, bilaterally with the thumbs and elbows maintained in extension, to simulated human soft tissue. A Piezo-force transducer was mounted on a dry femur to directly measure manually applied force (kg). The root mean square (RMS) value of the sEMG data was calculated and sub maximal activity was normalized against the muscle activity measured during maximal force exertion.

Results: A repeated measure ANOVA was used to determine the main effect of force level and muscle group on the measured normalized sEMG. Across force levels the amplitude of the hamstrings did not significantly differ. Baseline measurements, static maintenance of posture without application of force, of the hamstrings were equivalent to RMS values across all force levels. However, there was a statistically significant difference ($p<0.05$) in paraspinal recruitment across force levels. During low levels of force and baseline the muscle was active but at high levels and maximal force exertion the muscle was quiescent.

Conclusion: In this study, we detected characteristic muscle patterns associated with different levels of force application. Across various force levels the hamstrings were a constant contributor to trunk stability. The observed decrease in activity of the paraspinals during high force exertion levels may be due to compensatory recruitment of anterior abdominal muscles to maintain trunk stability. Determining the muscle strategies of therapists can help in educating trainees and ensuring beneficial and efficient care.

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406 - Non-Invasive Assessment of Recruitment of the Abdominal Muscles in People with Low Back Pain: Ultrasound Measurement of Muscle Activity

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Introduction: Changes in recruitment of the deep trunk muscles, particularly transversus abdominis (TrA) have been reported in people with low back pain (LBP) [2,3]. However, clinical evaluation of the coordination of these muscles is problematic due to their depth. Recent attempts have focused on the use of ultrasound imaging of muscles [1], however, it has not been established whether ultrasound measurement can provide a meaningful measure of motor control in LBP. This study aimed to compare the recruitment of the abdominal muscles (measured as a change in thickness with ultrasound imaging) between people with and without LBP, and to compare the measurements made from the ultrasound imaging with electromyographic (EMG) recordings.

Methods: Twenty volunteer subjects (10 with a history of LBP and 10 controls) participated in this experiment. There were no differences in demographics between groups. EMG recordings were made using intramuscular fine-wire electrodes inserted into TrA, obliquus internus abdominis (OI), and obliquus externus abdominis (OE). Ultrasound images were recorded from the abdominal muscles during an isometric limb movement task. Ultrasound images of TrA, OI, and OE were recorded on the lateral abdominal wall and the muscle thickness of all muscles was measured at three sites and expressed as a proportion change from resting thickness.

Results: In contrast to the control subjects, people with LBP had a smaller increase in thickness of TrA. There was no difference in the change in OI or OE thickness between groups. The findings of EMG data were consistent with a lesser increase in EMG activity of TrA in the LBP group. Again there was no difference in the superficial muscles.

Conclusion: These data suggested that ultrasonography, as measured by the proposed protocol, provides a valid measure of motor control of the deep muscles and may provide a viable non-invasive clinical tool for assessment of LBP patients.

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417 - Assessment of Muscle Fiber Conduction Velocity During Explosive Contractions in Humans

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Introduction: estimation of conduction velocity (CV) is feasible during fast dynamic contractions with the use of advanced detection systems and algorithms for surface EMG signal processing [1]. Local estimates of CV can be obtained in short time windows, thus allowing characterization of muscle functions during short muscle activations. In this work we analysed explosive contractions in which the muscles were active for intervals of time of the order of 200-300 ms. The main objectives of the study were 1) to investigate motor unit (MU) recruitment strategies during short explosive contractions by CV estimates, and 2) to compare the CV trends with explosive force with the trends of mean instantaneous frequency computed from time-frequency representations.

Methods: four linear adhesive arrays of 4 electrodes (10 mm inter-electrode distance) were used to detect surface EMG signals from the vastus lateralis and medialis muscles of both thighs of 12 healthy subjects. The subjects performed two isometric contractions at linearly increasing force, from 0% to 100% of the maximum. A multipurpose ergometer dynamometer, consisting of a seat mounted on rails tilted at 20°, was used for the explosive contractions. The device incorporated two footboards equipped with force sensors, against which the subject pushed during explosive leg extensions, thrusting backwards with the maximum possible speed. A goniometer measured the knee joint angle and the leg extension speed. Six explosive contractions were performed with a two-minute rest in between. CV was estimated from partially overlapping Gaussian windows (with 30 ms standard deviation), centred at seven instants of time in the interval of muscle activation. The seven instants corresponded to increasing force levels from 17.5% to 100% of the maximal explosive force. The Choi-Williams time-frequency transform was applied to the signals to obtain an estimate of the instantaneous mean frequency at the time instants considered for CV estimation.

Results: CV values estimated during the reference isometric ramp were significantly correlated with those of the explosive contractions (linear regression analysis over all subjects and muscles, R = 0.75). Moreover, CV estimates computed at the beginning of the explosive contractions (instantaneous limb velocity almost null) was significantly correlated with CV estimates obtained at peak force (R = 0.81). In the explosive contractions, a three-way ANOVA (factors: muscle, side, and force) of CV was significant for the muscle and force. CV significantly increased with force. The average CV values (± SD, over the two muscles), at the seven force levels, were 4.34 ± 0.46, 4.38 ± 0.48, 4.50 ± 0.47, 4.54 ± 0.45, 4.71 ± 0.53, 4.80 ± 0.49, and 4.97 ± 0.45 m/s. Although there was no statistical difference between CV values at maximum force in the isometric and explosive contractions, instantaneous mean frequency was significantly lower in the explosive than in the isometric contractions. Moreover, instantaneous mean frequency did not depend on the force level in the explosive tasks.

Discussion: the main conclusions were 1) the technique for CV calculation in dynamic conditions proposed in [1] can be applied to the assessment of short (200-300 ms), explosive contractions, 2) this method allows the analysis of MU recruitment in dynamic conditions, and 3) instantaneous mean frequency does not provide reliable information on MU recruitment in dynamic tasks.

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433 - Force-EMG Relationship in Isometric and Dynamic Ballistic Contractions

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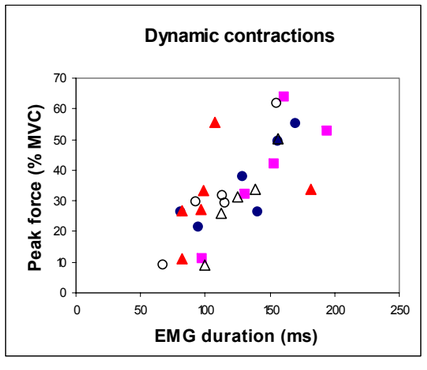
Introduction: It is well established that motor unit recruitment and rate coding are both important for grading force output. However, in ballistic contractions, all motor units are recruited at force levels as low as 20 % of the maximum voluntary contraction (MVC). In this situation, the duration of electrical activation is short (less than 100 ms), allowing only a few action potentials of each motor unit. It has been shown that in ballistic contractions, the number of action potentials in motor units increases as force increases. One would then expect peak force to be closely related to duration of the electrical activity. This hypothesis was tested in the present study. In addition, we examined if the relation between EMG (amplitude and duration) and force differed between dynamic and isometric contractions.

Methods: Five healthy subjects volunteered to perform 8 or 9 series of abductions with the first dorsal interosseus (FDI) muscle of the right hand. Three contractions were isometric attempting a peak force of 10%, 35 % and 65 % MVC. Three contractions were isotonic, moving the FDI about 15 mm measured at the proximal interphalangeal joint, with peak force about 10, 35 % and 65 % MVC. Two or three additional series were performed with shortening distances varying between 10 and 25 mm, at peak force about 35 % MVC. Each series lasted 45 s, and contractions were generated every 1.5 s. The subjects were required to contract as fast as possible to reach the targeted force and immediately relax. With modest training this was readily acomplished. Subjects received visual feedback of force output and distance moved. We recorded the FDI's force output and surface EMG for each contraction using Labview software on a personal computer.

Results: Force rise time varied between 50 and 100 ms, with the shortest times seen for isometric contractions. There was a close relationship between EMG duration and peak force or force-time integral for both isometric and isotonic contractions. These relationships were almost equal among individuals (each with different symbols in fig) , and no clear differences were seen between the relationships for dynamic and isometric contractions. Neither peak force nor force-time integral were associated with rmsEMG during dynamic contractions, whereas some associations were observed for the isometric contractions.



Conclusion: The direct relationship between EMG duration and peak force suggests that the length of the activation period is an important regulator of force in voluntary ballistic contractions and needs to be considered in analyses of rate encoding. This appears to be true for both isometric contractions and those that involve movement. Recruitment seems to play a negligible role based on the fact that rmsEMG does not change.
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435 - Dynamic Trunk Kinematic Stiffness

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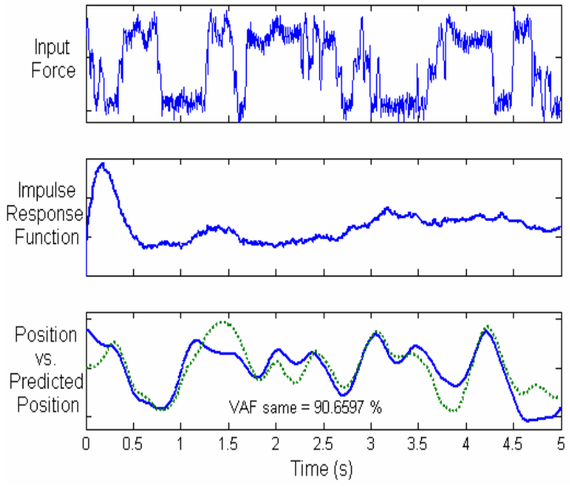
Introduction: Spinal stability and risk of low-back pain (LBP) are related to active stiffness of the trunk musculature1. Factors contributing to LBP risk include exertion level, fatigue and gender2. The goal of this study was to quantify trunk stiffness during extension exertions and examine the role of exertion level, fatigue, and gender on stiffness.

Methods: Healthy adult subjects (9 males, 7 females) wore a harness with a cable attached to a servomotor such that isotonic external flexion loads of 70 N, 105 N, and 135 N were applied at the T10 level of the trunk. The legs and pelvis were securely strapped against a rigid structure and subjects were asked to stand upright against the loads. A pseudo-random stochastic force sequence (bandwidth 0-50 Hz, amplitude ± 30 N) was superimposed on the preload and measured (1000 Hz) by a force transducer. These force perturbations caused small amplitude dynamic trunk movements recorded using IRED motion analysis at 200 Hz. Three pseudorandom perturbation trials of ten seconds were performed at each preload level before and after a fatigue protocol. The fatigue protocol required subjects to perform dynamic trunk extension exertions (10/min, 15 min duration) with isometric MVE extension exertions recorded each minute to document fatigue. To quantify trunk stiffness from the pseudorandom perturbations a transfer function describing the relation between input force and output trunk movement3 was calculated for each preload and fatigue condition. 2nd order parametric analyses were used to estimate trunk stiffness, damping and inertia.

Results: The IRF and 2nd order model accounted for 90.8% of the data variance indicating the trunk can be accurately represented as an underdamped 2nd order system (Figure 1). Mean trunk stiffness was 2.89 ± 1.04 N/mm. ANOVA revealed a significant ($p<.01$) increase in stiffness with trunk extension exertion, greater ($p<.01$) trunk stiffness for females than males (Figure 2), but no significant change in stiffness associated with fatigue.

Conclusion: This series of studies was the first to apply pseudorandom perturbations and dynamic systems analyses to quantify trunk stiffness. The dynamic response included components of passive and active intrinsic muscle stiffness, and reflex stiffness. Increase in stiffness with exertion agrees with published data whereas the influence of fatigue remains disputed in the literature. Gender differences in active stiffness have been observed in the knee and ankle, but have been attributed to anthropometric differences. Ongoing work is focussing on the role of dynamic stiffness for the control of spinal stability.



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442 - Measurement of Muscular Effort: Effects of Movement Frequency and Load

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Introduction: The concept of effort as it relates to the biomechanics and motor control of human movement is not clearly defined. Although a number of investigators have asked individuals to report the effort they experience while performing different tasks, there has been little research in which effort ratings have been used to investigate the mechanics and control of movement. One exception is a study by Burgess et al. (1995) in which participants gave effort ratings for isometrically generated torques; effort was found to be positively related to the produced torque. More recently, Rosenbaum and Gregory (2002) developed a method for measuring movement-related effort during isotonic movements; it was found that effort was proportional to angular velocity. The purpose of this study is to determine the effects of movement frequency and load on the sense of effort during single-joint isotonic movements.

Methods: Eight healthy adults (24.5±4.6 yrs, 173.8±6.5 cm, 73.9±15.8 kg) participated in this experiment. All participants were asked to perform elbow flexion/extension movements in the horizontal plane using their dominant arm while moving at three frequencies (1, 2, and 3 Hz) and holding three loads (0.33, 0.67, and 1.0 kg). The participants were required to produce movements that corresponded to effort levels of 1, 3, 5, 7, or 9 on a modified Borg CR-10 scale. The forty-five conditions (five efforts x three frequencies x three loads) were tested in random order. Angular position of the elbow joint was measured by using a motion capture system; angular displacement, velocity, and acceleration for each movement cycle were calculated from the position-time series data. A three-way ANOVA was used to assess the effects of effort, frequency, and load on angular displacement, velocity, and acceleration.

Results: As the effort level increased from 1-9 across movement frequency and load conditions, there were significant increases in mean angular displacement (MAD) from 6.5±3.9-49.0±23.8°, peak angular velocity (PAV) from 34.8±19.2-253.3±85.1°/s, and peak angular acceleration (PAA) from 468.8±364.2-3,268.8±1,693.3°/s^2. There were significant decreases in MAD (from 39.2±26.3-15.8±11.8°) and increases in PAA (from 1010.2±906.0-2,320.5±1,733.7°/s^2) as movement frequency increased from 1-3 Hz across effort level and load conditions; PAV did not vary across the three movement frequencies. In addition, MAD, PAV, and PAA were found to be the largest in the 0.33 kg load condition (27.7±22.4°, 146.6±105.9°/s, and 1,896.2±1,628.3°/s^2, respectively) and smallest in the 1.0 kg load condition (23.9±19.9°, 122.1±85.7°/s, and 1,558.3±1,317.9°/s^2, respectively). There were no differences between the 0.33 and 0.67 kg or 0.67 and 1.0 kg load conditions across effort level and movement frequency. Also, correlations between angular displacement, velocity, and acceleration and effort level across movement frequency and load conditions were performed. While the correlations between effort level and MAD, PAV, and PAA were all significant, movement-related effort was found to be most strongly correlated with PAV.

Discussion: The results of this study confirm the finding of Rosenbaum and Gregory (2002) that effort has the strongest relationship with PAV in regards to kinematic variables. Also, it was discovered that movement frequency has a greater influence on movement-related effort than load. This is surprising, given the widely-held assumption that muscular effort is most directly related to joint torque (Andrews, 1981). Even though the increases in load resulted in larger elbow flexion/extension joint torques than the increases in movement frequency, these larger joint torques did not occur in conjunction with a greater influence on sense of effort. The results of this study demonstrate that there is a complex interrelationship between the biomechanical, physiological, and psychological factors that affect muscular effort, and that further investigation of the biomechanical measures of muscular effort is required.

453 - Analysis of the Relationship Between Impulse and Propulsive Force In Hemiparetic Individuals During Treadmill Gait

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Introduction : The mobility function loss, specially locomotion dysfunctions, is one of the first and most characteristic symptoms of a wide variety of neurological dysfunction's, including the Encephalic Vascular Accident. For this reason, the gait pattern study of such patients seeking to identify their main loss in a more detailed way, has been widely used. It has been demonstrated that an important factor for the motion inefficiency of hemiparetic patients after EVA is their inability to generate propulsive force during foot push off from the ground in the terminal support phase and pre swing of the gait cycle. On the other hand, few studies have been made about the influence of this propulsive force application for a determined period of time (impulse) in the gait efficiency of these patients. In order to better understand this relationship, this studies goal is to analyze the impulse and propulsion force variables, through the vertical component of the ground reaction force during gait in hemiparetic patients.

Methods: The Control Group was formed by 10 healthy participants of both sexes with 53+ 7 years old mean age, 170 + 6 cm mean height and 794 + 71 Newtons mean weight. The Hemiparetic Group was formed by 10 patients with 59 + 9 years old mean age, 167 + 10 cm mean height and 784 + 69 Newtons mean weight, with post EVA hemiparesis clinical condition. A Trotec instrumented treadmill from Gait Analysis Gaitway System was used to perform the study, composed of two Kistler piezoelectric force platforms. An anti fall security system for treadmill gait was also used. T-Student Independent Test was used for data analysis, as well as linear regression analysis in order to get the correlation between the analysed parameters.

Results: It was established that the propulsive force magnitude in the Hemiparetic Group, for the affected inferior member as well as for the healthy member, was significantly less ($p<0.01$) when compared to the values obtained for the Control Group, confirming the initial hypothesis. On the other hand, it was established that, against what was expected, the impulse magnitude for the Hemiparetic Group was higher ($p<0.05$), for the affected member as well as the healthy member, when compared to the Control Group. Besides that, the linear regression analysis made it clear that for the Hemiparetic Group the propulsive force and impulse variables do not show correlation between them, different from the Control Group result, where a positive correlation between the variables ($p<0.01$) was found. **Conclusion:** It was possible to establish that hemiparetic individuals really show a capacity reduction to generate the needed propulsive force during foot push off from the ground. This fact does not directly imply reduction in the impulse generated by these patients during gait. This behavior is due to the fact that the impulse variable corresponds to the integral of the curve of the ground reaction force in the time domain, that`s why the greater influence for the increase of impulse magnitude in the hemiparetic patients is due to the greater period during which such individuals keep the foot`s contact with the ground.

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495 - The Role of the Primary Motor Cortex During Skill Acquisition in a Two Degree-Of-Freedom Movement Task

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Motor skill acquired through practice can be partially eliminated during the five hours immediately following practice through the application of repetitive transcranial stimulation (rTMS) over the primary motor cortex. The extent to which such disruptions influence skilled performance is also dependent upon the complexity of the coordination task. The purpose of this experiment was to determine whether skill acquired in a discrete, aiming task could be degraded by disrupting the behaviour of the primary motor cortex, and whether the resulting performance regression was dependent upon the complexity of the coordination task. Eight subjects initially performed 25 aiming movements to each of three target arm positions. The movements required combinations of flexion and supination of the radio-humeral joint. Following these trials, a train of sub threshold (90% AMT) rTMS was applied at 5Hz over area of the primary motor cortex associated with activation of the biceps brachii. A second series of trials was undertaken by participants following the stimulation. RTMS was again applied, followed by 50 trials of each movement. 25 further trials of each movement were completed five hours after the third practice block, and were immediately preceded by rTMS. Eight control subjects were subjected to an identical schedule of task practice, with sham rTMS administered between practice periods. Substantial reductions in target acquisition time were observed during the initial practice period for each group (e.g. Flx: Pre-0.88s, Post-0.51s). Performance levels were maintained in the subsequent sessions following the application of rTMS, despite reductions in the magnitude of motor potentials evoked from the biceps brachii (mean reduction: 25.3%). These results suggest that disruption of the primary motor cortex does not influence the retention of acquired skill in this type of discete visuo-motor task.

Motor Units

075 - Differential Control of Low-Threshold Motoneurons In Human Masseter From Ipsilateral and Contralateral Motor Cortex

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Introduction: Movements of the jaw during chewing and speech require the bilateral coordination of the trigeminally innervated masticatory muscles which elevate and depress the mandible. The pairs of muscles on each side are often activated in unison, however the jaw-closing muscles such as masseter can be controlled relatively independently when the situation demands. Voluntary control of the masticatory muscles is provided by the motor cortex and corticobulbar projection to the trigeminal motor nuclei. Transcranial magnetic stimulation (TMS) combined with surface electromyography (EMG) has shown that motor cortex of both hemispheres provides short-latency excitation to the trigeminal motor nuclei on each side. It is unclear how this bilateral innervation contributes to selective activation of muscles on one side. To provide more detailed information we have studied the responses of single motor units in human masseter to TMS applied to either hemisphere to determine a) the existence and distribution of corticomotoneural projections, and b) whether single motor units receive uniform or differential inputs from the two hemispheres.

Methods: Corticobulbar inputs to single masseter motoneurons from the contra- and ipsilateral motor cortex were examined using focal transcranial magnetic stimulation (TMS) with a figure-eight stimulating coil. Single motor unit activity was detected with fine-wire electrodes inserted into the masseter muscle of six subjects. Subjects maintained steady tonic discharge of a motor unit while TMS was applied (<0.2 s^{-1}). In separate blocks of ~50 trials, the same motor unit was tested with ipsilateral or contralateral TMS and a range of stimulus intensities.

Results: Thirty motor units were tested with contralateral TMS, and 87% showed a short-latency excitation in the peristimulus time histogram (PSTH) at 7.0 ± 0.3 (SE) ms. The response was a single peak of 1.5 ± 0.2 ms duration. Increased TMS intensity produced a higher response probability (n=13, paired t-test, $p<0.05$) but did not affect response latency. Of the remaining motor units tested with contralateral TMS, 7% did not respond at intensities tested, and 7% had reduced firing probability without any preceding excitation. Sixteen of these motor units were also tested with ipsilateral TMS and four (25%) showed short-latency excitation at 6.7 ± 0.6 ms, with a duration of 1.5 ± 0.3 ms. Latency and duration of excitatory peaks for these four motor units did not differ significantly with ipsilateral *vs*. contralateral TMS (paired t-tests, $p>0.05$). 56% of motor units tested with ipsilateral TMS responded with a reduced firing probability without a preceding excitation, and 19% did not respond.

Conclusions: The short onset latency and brief duration of the excitatory response in masseter motoneurons following TMS is consistent with monosynaptic excitation *via* a single D- or I_1-wave volley elicited by the stimulus. Corticomotoneuronal projections are therefore confirmed for masseter, however the distribution is not uniform from each hemisphere. Most low threshold motoneurons receive direct corticomotoneuronal input from the contralateral hemisphere only. This organization of cortical inputs to masseter motor nuclei would contribute to the ability to activate the masseter muscles independently on each side, particularly at low bite forces.

124 - The Effect of Varying Levels of Contractile Force on Intramuscular and Surface-Detected Motor Unit Potential Size and Firing Rate

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Introduction: Quantitative electromyographic (EMG) techniques are used to obtain information related to the motor units (MU) of a particular muscle or muscle group. Often, examinations utilizing these techniques are performed at low levels of voluntary contractile force and as a result are biased to the lowest threshold MUs.

Purpose: The purpose of the current study was to examine the effect of varying levels of voluntary contractile force on size related parameters and firing rates of intramuscular (IM) and surface-detected motor unit potentials (MUPs).

Methods: Decomposition-enhanced spike-triggered averaging (DE-STA) was applied to the first dorsal interosseous muscle (FDI) of 10 healthy control subjects aged 22-50 years (29 ± 9). Maximal voluntary contractions (MVC) were performed and both force (N) and the maximal voltage of the root mean square (RMS) of the surface-detected EMG signal were measured. IM and surface-detected EMG signals were then collected simultaneously during 30-second voluntary isometric contractions performed at threshold, 10, 20, 30, 40 and 50 percent of MVC. Decomposition algorithms were used to identify the IM MUPs and their individual firing times. These firing times were used as triggers to extract the surface-detected MUPs (S-MUPs) using STA.

Results: 1130 MUs were collected from a total of 218 contractions. Mean IM MUP peak-to-peak voltage was 566.6 ± 566.5 μV (71.2 – 7398.2 μV) while mean S-MUP negative-peak amplitude was 154.2 ± 136.7 μV (4.5 – 1239.6 μV). The mean MU firing rate was 13.8 ± 3.6 Hz (5.9 – 37.7 Hz). Statistical analysis revealed significant differences for firing rates and MU size (IM and surface-detected) across all levels of voluntary contraction.

Conclusions: The results of this study support the size principle of motor unit recruitment as both IM and surface-detected MUP sizes increased as a function of contractile force. Additionally, the results suggest a necessity to examine varying levels of voluntary contractile force when performing quantitative EMG examinations in order to sample from the entire pool of MUs supplying a given muscle or muscle group.

153 - Age-related Changes in Human Motor Unit Properties

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With mature aging in mammals and humans, there seems to be a preferential loss of type II (fast-twitch) motor units (MUs) resulting in muscles composed of a greater relative percentage of type I (slow-twitch) motor units. However, whether this age-related remodelling of motor units is found in a variety of limb muscles, and the functional consequences of this process have not been studied extensively. In separate experiments, we compared the changes in steady-state motor unit firing rates at various levels of voluntary effort, including maximal effort (MVC), in four limb muscles (tibialis anterior, vastus medialis, biceps brachii, triceps brachii) in two groups (n=6-13 per group) of men separated by ~60 years of age. We hypothesized that at a given percentage of MVC force, the average MU firing rates in muscles of the old men would be lower than for the young adult men, especially at the higher (>50% MVC) force levels. Using tungsten microelectrodes, a population sampling method was used to record the steady-state firing rates from several hundred motor unit trains from each of the four muscles during brief (5-10s), repeated non-fatiguing isometric contractions. To acquire a large sample from as many active units as possible from each muscle, and at four separate force levels from 10% to MVC, two separate electrodes were manipulated in each muscle during the contractions. Spike shape recognition software (SPIKE2) was used to help determine individual MU trains and to calculate interpulse interval firing rates. In all muscles, and in both groups, as force level increased average MU firing rates increased. At MVC, the mean firing rates of the vastus medialis MUs were not different between the young and old men (26.4 vs 25.5 Hz). The mean MVC rates for the other three muscles in the young men ranged between ~36Hz and ~43Hz, but unlike vastus medialis their rates were lower with age by ~36% for biceps brachii, ~27% for triceps brachii, and ~25% for the tibialis anterior. The contractile properties of the whole muscles also showed inconsistent changes with age. The longer twitch duration often seen in muscles from aged subjects was found to be ~21% longer for tibialis anterior, only 10% longer for vastus medialis, and not different for triceps or biceps brachii muscles. These results indicate that not all muscles have similar age-related changes in MU properties, and that the matched relationship between MU firing rate and muscle contractile speed is affected differently with age in different limb muscles.

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167 - Contractile Property of Muscle Fibers During Repetitive Electrical Stimulation in Humans

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Introduction: We have previously reported that the spike interval of motor units gradually elongated during the initial period (initial elongation phase; mean duration of 3.5 min) of voluntary isometric contraction at a low constant force level (below 10% maximal voluntary contraction (MVC)) 2). Though the developed muscle force was a constant, the motor unit decreased its firing rate 1, 2). As a first step toward understanding of the force response of a motor unit in the decreasing firing rate phase, we investigated the force development of muscle fibers (fascicle) under electrical stimulation at a constant low frequency.

Methods: Experiments were performed on m. vastus medialis in three volunteers. In a sitting posture, the knee angle of the subject was set at 90 degrees by strapping the ankle joint with a belt which was connected to the force transducer. Muscle fibers were stimulated transcutaneously at the motor end-plate zone for 3 min. The electrical stimulation was a square pulse of 0.5 ms duration at the maximal intensity which did not feel pain. We employed three stimulation frequencies, 10, 6.7 and 5 Hz (stimulation interval, 100, 150 and 200ms). Additionally, to investigate the twitch response, we stimulated the fascicle every 5 s for 3 min. Evoked electrical response (M-wave) was recorded from the fascicle distal from the stimulation position by bipolar surface electrode. The evoked force and M-wave were recorded on a digital audiocassette tape using a PCM data recorder.

RESULTS: Twitch response of tested fascicles was constant throughout the experiment. In the tested fascicles, time to peak force of twitch response was 75-90 ms. Evoked force of the fascicles increased depending upon the stimulation frequency, but the evoked force did not fuse completely. During low frequency repetitive stimulations, the peak force changed complexly, with initial transient increment (initial peak), abrupt decrement, and gradual increase (second peak) followed by gradual decrease. Differences could be seen in the force response among the stimulation frequencies. The second peak appeared at 8-18 s during stimulation at 10 Hz (100ms) and at 20-30 s during stimulation at 6.7 and 5 Hz (150 and 200ms).

DISCUSSION/CONCLUSION: The force response in human muscle fascicle to low frequency stimulation was not a simple positive staircase but had a complicated configuration. The configuration was similar to the force response observed in the muscle of an anesthetized cat3). Our findings suggested that in human voluntary contraction motor unit discharge can not maintain constant force under a low constant firing rate, and change of spike interval may be necessary to maintaining the constant force.

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194 - Recruitment and Derecruitement of Motor Units in Biceps Brachii Muscle during Isovelocity Flexion Movement

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Introduction: Recently several investigators have examined motor units activities during movement [1]. In most of the previous studies, small angle range of at most 20 degree was utilized. It is necessary to monitor motor unit activities continuously over a sufficiently wide, in particular, for examining the behavior of recruitment and derecruitment. The purpose of this study is to investigate the motor unit activity of biceps brachii (caput breve) muscle during voluntary elbow flexion of 0 to 120 degree at constant velocity against the constant load torque.

Methods: Simultaneous recordings of eight channel surface myoelectric signals (EMGs) of biceps brachii muscle of seven subjects were measured in isovelocity elbow flexion against constant load torque. The velocity was 10, 15, 20 and 25 degree/s and the load torque was 5 -15 % of the torque obtained at the maximum voluntary contraction (MVC). Measurement was carried out five times under each condition. Individual motor units were identified with decomposition algorithm using the conventional template matching.

Results and Conclusion: Figure 1 shows a typical result of firing patterns of identified motor units. The elbow angle changed almost linearly with time at the average angular velocity 15 degree/s. The elbow torque became almost constant 15% MVC. Each bar represents one firing and firings of the same motor unit are aligned horizontally. In this case, we could found one recruitment of motor units ((i) in Fig.1) and one derecruitment ((ii) in Fig.1).

In the low-load (5, and 7 %MVC) experiment (total 30 experiments), 36 examples of recruitment and 22 examples of derecruitment were measured.

Refernces

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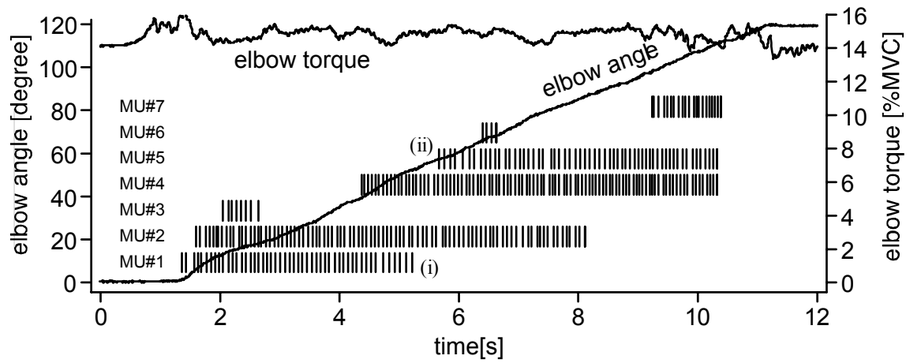

Figure 1 An example of time courses of the elbow angle and torque and activities of single motor units in isovelocity elbow flexion movement.

203 - Theoretical Interpretation of Motor Unit Coherence and Frequencygram

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Introduction: As indirect techniques for estimating pre-synaptic inputs to a motoneuron in human, two different methods, called motor unit coherence (Rosenberg et al. 1998) and Frequencygram (Turker et al. 1996), have been published. These methods have provided valuable frameworks on how motoneurons were driven by pre-synaptic inputs, although the theoretical explanation of these methods yet to be established. In order to clarify the theoretical process to estimate pre-synaptic 'analog' inputs from the 'digital (0 or 1)' spike train (output) using these methods, the present study investigated the encoding process of a single neuron by means of both human soleus motor unit activity in response to Achilles tendon tapping and Hodgkin-Huxley's mathematical model in response to rhythmic current injection. A special mention was made for the case that frequency of pre-synaptic input was much faster than that of the output spike train.

Methods and Results: In the physiological experiment, two recording soleus motor unit potentials were repetitively discharged with a mean frequency of 10.9 Hz in response to sinusoid homonymous tendon tapping with a constant frequency of 80.0 Hz with a slight voluntary contraction. The motor unit autospectra for each motor unit and their coherence showed a significant peak at 80.0 Hz, corresponding to that of tendon tapping. Frequencygram, a scatter plot of peri-stimulus instantaneous frequency, also showed a quasi-sinusoid trajectory with a frequency of 80.0 Hz, corresponding to that of tendon tapping, though it was skewed.

In the mathematical simulation using Hodgkin-Huxley equation, an imaginary neuron was repetitively discharged with a mean frequency of 110.0 Hz in response to sinusoid inward current injection with a constant frequency of 299.9 Hz. The autospectrum of its spike train showed a significant peak at 299.9 Hz, corresponding to that of the input current. Frequencygram also showed a quasi-sinusoid trajectory with a frequency of 299.9 Hz, corresponding to that of the input current, though it was skewed.

The notion of Discrete Fourier Transform for unevenly spaced time series data explained the common theoretical background for the estimates of spike train spectra and the process of Frequencygram, and it was also showed that the instantaneous frequency includes pre-synaptic information even if the discharge rate of the spike train is slower than that of the pre-synaptic signal.

Conclusion: The present study revealed that both empirically established techniques, motor unit coherence and Frequencygram, are based on the same mathematical theory for estimation of pre-synaptic signals from motor unit spike trains.

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225 - Synchronization Analysis Of Human Motor Units In Ankle Flexor/Extensor Using A New Wavelet-PCA Decomposition Technique

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Introduction: Motor unit (MU) synchronization has been studied for investigating synaptic connectivity. MU synchronization is a phenomenon when more than two MU fire synchrony. MU synchronization occurs more often than would be expected by chance. But comparison of MU synchronization in extensor muscle and flexor muscle has not been reported so far. It is important to identify each MU firing time for studying MU synchronization. Recorded electromyogram (EMG), however, generally contain action potentials (APs) of multiple MUs. Decomposition is a method that identifies individual MUs and their firing time from superimposed EMG signals by means of the characteristic differences of the motor unit action potential (MUAP) waveforms. Decomposition of needle EMG signals, using wavelet coefficients of MUAPs as features of their waveforms, is a recent technique. Several types of wavelet decomposition technique have been proposed so far. Wavelet transform is a typical time-frequency analysis. However, most of them only use several of all coefficients as features, selected by an operator or complex computations. To overcome the subjective criterion for feature selection, I propose another method using principal component analysis (PCA) of wavelet coefficients. And wavelet-PCA decomposition was applied for comparing ankle flexor/extensor synchronization.

Methods: A 24-year old male subject with no history of neuro-muscular diseases was recruited. Single MUAPs from the right tibialis anterior (TA) muscle and soleus (SOL) muscle were recorded using a disposable bi-polar needle electrode. The subject contracted the TA and SOL isometrically to allow the measurement of the MUAPs. The decomposition algorithm of single MUAPs consists of four processing steps: spike detection, wavelet transform, PCA, and clustering. Detected action potentials are processed using wavelet transform to extract its temporal frequency characteristics, and compress this information into few coefficients using PCA, and the coefficients were used for clustering. Superimposed waveforms (SWs), are decomposed by the firing time estimation.

Results: The proposed decomposition method could classify any types of MUAPs under about 5 %MVC (maximum voluntary contraction) almost perfectly. And new wavelet-PCA decomposition technique was demonstrated to be effective by comparing conventional wavelet method. For single APs, PCA is useful to gather whole frequency information effectively. About firing time estimation, this method could classify both SWs and single APs which were not classified before firing time estimation. As a result of synchronization analysis in both TA and SOL muscles using this new decomposition method, synchronization was observed. Strength of MU synchronization, expressed as peak length of cross-correlation histogram, was grater in TA than SOL.

Conclusion: the above result indicates a central origin, and supports the hypothesis that corticospinal projections are stronger in TA than SOL. This indicated that bipedal locomotion of human expand role of SOL as keeping posture and its corticospinal projection was changed.

239 - Relationship Between The Features Of Surface Motor Unit Action Potential And Its Source Position

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Introduction: Many detection systems have been proposed for the detection of the single motor unit (MU) activity from the surface of the skin. It was demonstrated that these detection systems had sufficiently high selectivity to separate single motor unit action potentials (MUAPs) from the interference surface electromyographic (SEMG) signal, even at relatively high force contraction levels. However, there are still no clear indications on the detection region and detected MUAP waveforms of those detection systems. The aim of this study is to investigate the detection region, and detected MUAP waveforms in the conventional one-dimensional (1-D) and previously proposed two-dimensional (2-D) detection systems.

Methods: MUs which had the same structure were located at intervals of 0.5 mm from the center of the detection systems in both transversal (perpendicular to the muscle fiber orientation) and depth directions, and each MUAP was computed based on the model proposed by Farina and Merletti [1]. The MU used in the simulation had a circular shape with a diameter of 4 mm and contained 250 fibers with a diameter of 50 μm. In this study, the detection region was defined as the region where MUAP which exceeded 5% of the maximum peak-to-peak amplitude was generated. The detected MUAPs were classified according to the number of phases and turns within the MUAP duration which was defined as the interval of time in which the MUAP exceeded 5 % of the peak-to-peak amplitude. The detection systems investigated in this study were the longitudinal double differential (LDD), transversal double differential (TDD), normal double differential (NDD), inverse binomial of order two (IB^2), one-ring, two-ring, and three-ring concentric (CR1, CR2, and CR3) systems.

Results: When the thickness of the skin and fat layers were both 1 mm, LDD, IB^2, and CR1 detected only one type of MUAP waveform. On the other hand TDD, NDD, CR2 and CR3 detected several types of MUAP waveforms according to the source (MU) position. The number of detected MUAP was 116 (LDD), 146 (TDD), 78 (NDD), 96 (IB^2), 82 (CR1), 67 (CR2), and 70 (CR3). The number of detected MUAP in 2-D systems, especially CR2 and CR3, was smaller than in 1-D systems. The width of the detection region in transversal direction was 10.5 mm (LDD), 14.5 mm (TDD), 5.5 mm (NDD), 7.0 mm (IB^2), 6.0 mm (CR1), 8.5 mm (CR2), and 9.0 mm (CR3). The depth of the detection region was 5.5 mm (LDD), 6.0 mm (TDD), 5.5 mm (NDD), 6.0 mm (IB^2) 5.5 mm (CR1), 5.0 (CR2), and 4.5 mm (CR3). The depth of the detection region was similar between 1-D and 2-D system. On the other hand, the width of the detection region of 1-D systems was more extended than in 2-D systems. The average detected MUAP duration was 9.9 ms (LDD), 15.6 ms (TDD), 11.0 ms (NDD), 11.5 ms (IB^2), 11.0ms (CR1), 7.5ms (CR2), and 6.6ms (CR3).

Conclusion: The above result indicates that CR2 and CR3 have the best MUAP decomposition ability, and NDD, IB^2, and CR1 (2-D systems) have better MUAP decomposition ability than LDD and TDD (1-D systems). The result also indicates that CR1 which has relatively high decomposition ability, and detects only one type of waveform, and has perfectly isotropic geometry is suitable for the clinical diagnosis.

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271 - The Effects of MUAP Duration on the Change of EMG Amplitude and EMG-Force Relation Caused By Motor Unit Synchrony

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Introduction: It is known that the occurrence of synchronous motor unit discharges, which has been reported to arise commonly during voluntary contractions in several different limb muscles, increases electromyogram (EMG) amplitude and decreases force steadiness [1]. In this study, we further explore the dependence of the change of EMG amplitude and EMG-force relation on MUAP duration of synchronized motor units, using a simulation approach.

Methods: Surface EMG and isometric force signals were simulated using existing motoneuron pool, muscle force, and surface EMG models, based primarily on reported properties of the first dorsal interosseus muscle in man [2]. Motor unit synchrony was simulated using different MUAP durations. First, 10% of the MUAPs discharged by reference motor unit were randomly selected, and then, for each selected MUAP of the reference motor unit, 10% of the other active motor units were randomly selected to have the timing of the nearest MUAP adjusted so that it was coincident with the reference MUAP. The time separation between the synchronized MUAPs had a Gaussian distribution with a mean of 0 ms and a standard deviation of 2ms. The process was repeated until each of the active motor units was selected as a reference unit [1].

Results: The simulation results indicate that motor unit synchrony has a substantial influence on the output of motor unit pool. The EMG amplitude increases as a result of synchronous discharges of different motor units within the pool, but the degree of the increase is determined by the MUAP duration of the synchronized motor units. As indicated in Table 1, the longer the MUAP duration, the larger the percentage of the increased EMG amplitude caused by motor unit synchrony. However, When the EMG amplitudes are normalized to their maximum levels, motor unit synchrony does not exert significant effects on the form of the EMG-force relation, provided that the synchrony level is similar at different excitation levels.

Discussion: For synchrony conditions, since there are many coincident firings, the increase in EMG amplitude is due to the reduction in positive and negative phase cancellation, the amount of which is influenced by the MUAP duration. To better understand the EMG-force relations, the MUAP duration changes and the possible increase of the synchrony with more excitation drive need to be further considered in the simulation.

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MUAP duration d (ms)	Increased EMG by motor unit synchrony		
	34%Excitation	67%Excitation	100%Excitation
5.47	-9.2%	-3.5%	-1.7%
10.94	10.5%	4.2%	7.6%
16.60	25.7%	28.8%	29.6%
21.88	49.7%	57.7%	58.4%
26.95	77.5%	80.4%	73.2%

301 - The Relationship Between Time and Frequency Domain Methods of Estimating Low Frequency Common Drive

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Introduction: The term common drive is traditionally used to indicate a common excitation to the motor neuron pool that results in concurrent low frequency fluctuations in the firing rates of motor units (MUs) from the same pool. Common drive is typically quantified by the values of peaks occurring near zero lag in normalized time domain cross-correlations between pairs of zero-mean signals representing the fluctuations in mean firing rates (De Luca et al. 1986). However, during voluntary activity in humans, MUs are exposed to a number of different modulating drives at various frequencies (Brown, 2000). The conventional method to determine the degree of common modulation, and the frequencies these occur at, is to calculate the coherence between individual pairs of MUs. A significant low frequency and beta-band association between motor unit firings in the 1-12Hz and 15-30Hz frequency ranges respectively has been demonstrated (Farmer et al. 1990). The drive responsible for the low frequency modulation detected with frequency domain coherence methods is thought to be the same drive that is quantified using the time domain common drive method. However the precise relationship between these two computational methods has not been explored.

Methods: A mathematical derivation is first presented to describe the theoretical relationship between the two (time and frequency domain) techniques. Subsequently, multiple recordings from concurrent activities of pairs of motor units are studied and linear regressions are performed between time domain common drive and frequency domain coherence estimates to assess their equivalence.

Results: The two methods are shown to be equivalent under the theoretical condition of a narrow-band point frequency. However practical situations deviate from this ideal condition. The degree of correlation between the two techniques varies with the length of the time domain moving average window. For window lengths of 200ms, 400ms and 800ms, the r2 regression statistics ($p<0.05$) are 0.56, 0.81 and 0.80 respectively.

Conclusions: The traditional time domain measure of common drive may be considered as the low frequency drive of a number of common modulating drives that are known to influence motor unit firings. This drive may be estimated in either the time domain or frequency domain (correlation or coherence respectively). Results from these two methods are well correlated. In general the time domain technique is preferred for short data segments and is better able to quantify the strength of a broad band drive into a single index. Alternatively, the frequency domain measures are more encompassing, providing a complete description of all oscillatory inputs and are better suited to quantifying narrow ranges of descending input into a single index. In general the physiological question at hand should dictate which technique is best suited.

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305 - A Novel Evaluation of Motor Unit Activity Based on Acceleration and Inhibition between Interpulse Intervals of Motor Unit Discharges

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Introduction: Motor unit (MU) is a quantitative unit of neuromuscular system to control muscular contraction. The investigations on MU activity will lead us to the clarification of its function. The studies on the variability between adjacent interpulse intervals (IPIs) of MU discharges have been already reported. The previous studies indicated that the variability in an IPI sequence is caused by various influences in the neuromuscular system, e.g. excitation of muscle spindle and inhibition of Golgi tendon organ, etc. However, any quantities of the variability have not yet been generally used as an index for clinical diagnosis because the no quantitative parameters have standard to define the neuromuscular activity itself. Tone-Entropy Analysis has been reported that cardio autonomic nervous system (CANS) activity could be measured absolutely by defining acceleration and inhibition between heartbeats, i.e. percentage index (PI). The analysis showed that, by the statistical properties of the PI distribution, i.e. tone and entropy, CANS activity in various physiological states could be evaluated on the Tone-Entropy space. The purpose of this study is to investigate the variability of IPI sequences during 5, 10, 15 and 20%MVC by calculating PIs of the IPI sequences and to discuss the possibility on the quantitative index of neuromuscular activity.

Methods: Eight male subjects participated this study after they had agreed to the informed consent on this study. The electrode box with 8 bipolar surface EMG (sEMG) channels was attached and fixed on the skin surface around the tibialis anterior muscle of the right leg. The EMG channels were vertically arrayed to the running direction of the muscle. The subjects were instructed to maintain isometric contraction at 5, 10, 15 and 20%MVC for 15 seconds. In each %MVC, 10 times trials were performed. The sEMG signals amplified at 80dB were recorded by sampling frequency 8192Hz. By means of EMG signal decomposition software based on a template matching method developed originally, MU discharge times have been identified from the sEMG signals. Neuromuscular system activity could be identified from the statistical properties of the PI distribution, i.e. tone and entropy, calculated from an IPI sequence. Tone and entropy of all the IPI sequences were evaluated on the tone-entropy space.

Results: In each %MVC level, the numbers of the IPI sequences derived were 197 in 5%MVC, 179 in 10%MVC, 153 in 15%MVC and 115 in 20%MVC. The means of the IPI sequences were decreased significantly with the increase of %MVC level (one-way ANOVA, $p<0.05$). It has been shown that, along a curvelinear path, tone in each %MVC was decreased [5%MVC: -.93+/-.44, 10%MVC: -.87+/-.36, 15%MVC: -.99+/-.55, 20%MVC: -1.26+/-.59 (mean+/-S.E.)] and entropy in each %MVC was also increased [5%MVC: 5.30+/-.27 bit, 10%MVC: 5.29+/-.29 bit, 15%MVC: 5.38+/-.33 bit, 20%MVC: 5.56+/-.29 bit] as %MVC level were increased. Also, means and S.D.s of IPI sequences were investigated with compared to previous reports. We could derive the similar tendency from the results as means of IPI sequences were decreased and S.D.s were decreased with the increase of %MVC and as the slope of mean-S.D. relationship became lower around lower %MVC and that was increased exponentially with the increase of %MVC.

Discussion: This study suggested a new evaluation of neuromuscular activity based on acceleration and inhibition between adjacent IPIs. On the tone-entropy space, the curvelinear path of MU activity was similarly formed with compared to the reports on CANS activity by Tone-Entropy Analysis. It was also indicated that this evaluation could make us measure physiological differences of neuromuscular system absolutely because the differences of tone and entropy between %MVC levels were shown.

306 - Motor Unit Coherence Is Influenced By Skilled Hand Muscle Use in Humans

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INTRODUCTION. The purpose of the study was to quantify the strength of motor-unit coherence from the left and right first dorsal interosseous muscles in untrained, skill-trained (musicians), and strength-trained (weightlifters) individuals who have had long-term specialized use of their hand muscles. The analysis was performed on data that was collected for a previous study, where significant differences were observed in the strength of motor unit synchronization with hand preference and training (Semmler & Nordstrom Exp Brain Res 119: 27-38, 1998).

METHODS. Motor unit activity was recorded with two fine-wire intramuscular electrodes in the first dorsal interosseous muscle during isometric contractions that caused the index finger to exert a small abduction force. The strength of motor-unit coherence was quantified from the left and right hands of 13 right-handed subjects, consisting of 5 untrained (113 motor unit pairs), 4 skill-trained (139 motor unit pairs) and 4 strength-trained (142 motor unit pairs) individuals.

RESULTS. The mean strength of motor-unit coherence was greater in the left compared with the right hand of untrained subjects, with the strongest differences observed from 15 – 30 Hz. No between-hand differences were evident in skill- or strength-trained subjects at any frequency (Figure 1). The largest differences between training groups existed in the left hand, where the trained subjects showed significantly less coherence than the untrained subjects at both low (1, 10 Hz) and high (25, 35, 50 Hz) frequencies. Furthermore, the left hand of skill-trained subjects showed significantly lower coherence compared with the left hand of strength-trained and untrained subjects at 5 Hz and 20 Hz.

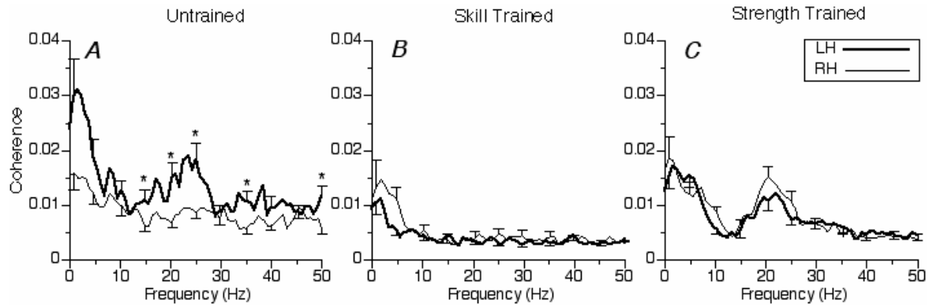

Figure 1. *Mean strength of coherence in left (thick line) and right (thin line) hands of untrained (A), skill-trained (B), and strength-trained (C) subjects. Standard error bars have been plotted every 5 Hz. * indicates significant difference between hands at P < 0.05 (ANOVA and Tukey post-hocs).*

DISCUSSION. These data suggest that there is reduced motor unit coherence during the simple isometric contraction in hands that are used to perform skilled tasks, which includes the dominant (skilled) hand in untrained subjects and both hands of skill-trained subjects (musicians). This is particularly evident at high frequencies (15-30 Hz), where shared inputs from corticospinal axons are believed to be a contributing factor in the observed common oscillation (see Farmer et al. J. Physiol. 470: 127-155, 1993).

316 - The Dynamic Sensitivity of Human Motoneurons

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Introduction. Human motor units (MUs) are known to fire more rapidly during increasing contractions than during decreasing contractions. We suggest that this asymmetry arises from the dynamic sensitivity of the motoneuron (MN), that is, from the MN's sensitivity to the rate of change as well as the instantaneous level of the synaptic drive. We investigated this hypothesis by analyzing MU firing patterns during non-constant-force contractions.

Methods. We recorded fine-wire EMG signals during isometric voluntary contractions of the medial gastrocnemius and tibialis anterior muscles in five normal subjects. The contractions consisted of an increasing phase, a plateau phase, and a decreasing phase. MU firing patterns were identified from the EMG signals using computer-aided decomposition, and instantaneous-firing-rate (IFR) profiles were computed. Each IFR profile was modeled as a weighted sum of the force profile (which was assumed to be similar in shape to the profile of the synaptic drive) and its first derivative. The dynamic sensitivity of each MN was characterized by its "corner frequency," proportional to the ratio of the weights.

Results. The IFR profiles differed considerably from the force profiles, but were fit fairly well by the weighted sums of force plus first derivative (see Fig. 1). The first-derivative terms were able to account for both the IFR differences between the increasing and decreasing phases, and the major IFR fluctuations, such as the rapid decrease that often occurred at the beginning of the plateau. The corner frequencies were typically about 0.1 Hz.

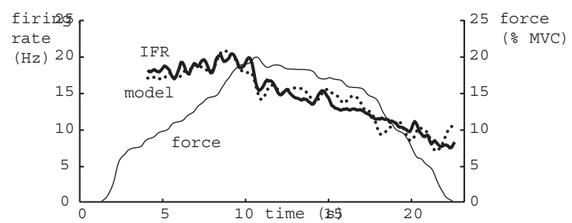

Figure 1. Results for one MU during a typical contraction.

Discussion. These results show that the asymmetry in MU firing rates during non-constant contractions can be explained by the MN's sensitivity to the rate of change of the synaptic drive. One reason for such dynamic sensitivity could be to pre-compensate for the sluggish mechanical response of muscle. The results suggest that human MNs are sensitive to much slower changes than cat MNs (0.1 Hz compared to 6 Hz reported in the cat). The reason for this is not clear. A secondary consequence of the MN's dynamic sensitivity is to exaggerate small fluctuations in synaptic input, converting them to relatively larger fluctuations in firing rate. This could be an important mechanism by which the common drive to the MN pool produces synchronous firing-rate fluctuations even during steady contractions.

317 - Coordination of Motor Units in Different Proximodistal Bands of a Series-Fibered Muscle

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Introduction. Muscle fibers in series-fibered muscles terminate intrafascicularly rather than extending from tendon to tendon. Effective force transmission in these muscles therefore requires coordination between motor units (MUs) in different proximodistal bands. We investigated whether this coordination involves synchronous activation of serially adjacent MUs or uniform recruitment in each band to produce a uniform net tension along the muscle.

Methods. Fine-wire EMG signals were recorded simultaneously from different locations along the proximodistal axis of the brachioradialis muscle in two normal subjects during voluntary isometric contractions. MU action potential (MUAP) trains were identified using computer-aided decomposition. The endplate locations were estimated from the MUAP onset/spike latencies, and the presence of a tendonous or intrafascicular termination was inferred from the presence or absence of a distinct terminal wave. Recruitment order was determined during a ramp contraction. Synchronization between MU pairs was measured by the size of the central peak of the firing cross-correlogram, using the common input strength (CIS) index.

Results. The results from one subject are shown in Fig. 1. The identified MUs fell into two distinct bands: 12 had proximal endplates and intrafascicular terminations, and 12 had distal endplates and tendonous terminations. The recruitment thresholds were distributed evenly between the two bands. The mean CIS value of all inter-band pairs was 0.05, indicating negligible synchronization. Results from the second subject were similar.

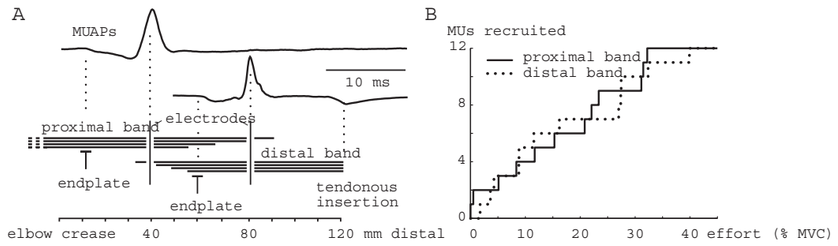

Figure 1. *Results from one subject. (A) MU architecture. (B) Recruitment.*

Discussion. These results support the hypothesis that MUs in different proximodistal bands of brachioradialis are coordinated by uniform recruitment, rather than synchronization. They suggest that the nervous system does not use any special mechanism to activate serially adjacent muscle fibers simultaneously. Instead, force transmission is accomplished by recruiting approximately equal numbers of MUs in each band to produce a uniform net tension along the muscle. This type of coordination would emerge naturally from the orderly recruitment properties of the motoneuron pool if the motoneurons supplying the different bands are distributed randomly throughout the pool.

319 - Decomposition of Surface EMG Signals Detected By Two-Dimensional Arrays of Electrodes

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Introduction: The decomposition of the surface electromyogram (EMG) into the constituent motor unit (MU) action potential trains is a complex issue whose solution has been addressed with a few methods [1]. Most methods are based on template matching techniques which suffer from a drop of performance in case of significant superposition of MU action potentials. Recent advances in the field of blind source separation enabled the development of surface EMG decomposition methods suitable for the identification of the complete MU firing patterns during low force contractions [1]. These methods require the availability of more signals than sources. This assumption is critical and can be met with high-density two-dimensional (2-D) surface EMG recordings. The aim of this study was to apply an inverse correlation matrix approach for decomposing surface EMG signals detected by 2-D arrays of electrodes in order to non-invasively investigate MU properties at low contraction levels.

Methods: Surface EMG signals were detected with a matrix of 61 electrodes arranged in five columns and 13 lines (without the four corner electrodes). The electrode pins (diameter 1.27 mm; RS 261-5070, Milan, Italy) are telescopic to adapt to the skin surface. Recordings were performed in single differential configuration during isometric, constant-force contractions of the dominant biceps brachii muscle. The matrix was connected to four 16-channel EMG amplifiers (LISiN; Prima Biomedical & Sport, Treviso, Italy). The EMG signals were amplified, band-pass filtered (3 dB bandwidth, 10 Hz-500 Hz), sampled at 2500 Hz, and converted to digital form by a 12 bit A/D converter. The four acquisition cards acquiring the signals from the matrix were driven by the same clock signal. Five healthy male subjects (age 27.8 ± 2.4 years, height 177.2 ± 4.5 cm, weight of 70.6 ± 4.9 kg) participated to the experiment. The contractions lasted 30 s and were performed at 5% and 10% of the maximum voluntary contraction (MVC) force. The method described in [1] was applied for the decomposition of the detected surface EMG signals. This method is not sensitive to MU action potential superposition.

RESULTS: On average (± SD) 5±1.0 and 7±1.6 MUs were identified during the contractions at 5% and 10% MVC, respectively. The sum of the energies of the identified MU action potentials was compared with the energy of the original signal. The ratio yielded 71±15%, proving that the largest components of the surface EMG signals under investigation were identified. The identified MUs had average firing rate of 11.2±1.9 pulses per second (pps) at 5% MVC and 14.1±2.1 pps at 10% MVC. The inter-pulse interval variability of the individual MU potential trains was 9.9±2.6 ms at 5% MVC and 12.4±3.6 ms at 10% MVC. Most of the identified MUs showed decreasing firing frequency over time (presumably due to fatigue). Finally, the shape of the MU action potentials as detected by the different electrodes of the array and obtained by an averaging technique triggered by the identified firing instants, were stable over time and indicated anatomical and physiological MU properties, such as location of innervation zones, length of the fibers, and muscle fiber conduction velocity.

CONCLUSION: The detection of surface EMG signals by the developed 2-D array of electrodes efficiently emphasized the differences in MU action potential shapes, while providing sufficient measurements to fully detect the firing pattern of the sources which mostly contributed to the signal. The proposed method has potential clinical applications for the non-invasive analysis of single MU properties.

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330 - Motor Unit Control in Vastus Lateralis Muscle During Fatigue

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Introduction: The force level of a voluntary muscle contraction is controlled through two mechanisms: recruitment of motor units and modulation of the firing rate of active motor units. The general belief is that a motor unit, once recruited, tends to remain active during a constant force contraction, although alterations in the recruitment of motor units during sustained contractions have been the subject of discussion for decades. This project was designed to systematically investigate changes to motor unit firing behavior during long-duration muscle activity.

Methods: We investigated the motor unit firing behavior of the vastus lateralis muscle during a sequence of isometric constant-torque contractions maintained at 20% of the maximum voluntary contraction (MVC) and repeated to exhaustion. Five healthy young men (21.4 ± 0.9 years) participated in this study. Electromyographic (EMG) signals were recorded via quadrifilar fine wire electrodes and subsequently decomposed into their constituent motor unit action potentials to obtain the motor unit firing times. In addition, we measured the whole-muscle mechanical properties during the fatigue protocol using electrical stimulation.

Results: The firing rate of motor units first decreased within the first 10% – 20% of the endurance time of the contractions and then increased. The firing rate increase was accompanied by an increase in the number of motor units recruited to reach a 50% MVC torque peak and to maintain the constant target torque. The elicited twitch and tetanic torque responses first increased and then decreased. The two processes followed the same time course and complemented each other.

Discussion: Our data suggest that when the vastus lateralis muscle is activated to maintain a constant torque output, its motoneuron pool receives a net excitatory drive that first decreases to compensate for the short-lived potentiation of the muscle force twitch and then increases to compensate for the diminution of the force twitch. However, the underlying inverse relationship between the firing rate and the recruitment threshold that has been reported for non-fatigued contractions is maintained. We, therefore, conclude that the CNS control of motor units remains invariant during fatigue in isometric isotonic contractions.

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353 - Can The Electrical Activity Of Individual Motor Units Be Monitored Using The Surface Electromyogram?

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Introduction: The motor unit action potential (MUAP), the waveform resulting from the spatial and temporal summation of the individual muscle fibre action potentials of a motor unit (MU), propagates with a speed referred to as the motor unit conduction velocity (MUCV). MUCV estimates can be used as an indication of the physiological or pathological state of the muscle fibre membranes. The standard method of MUCV estimation from the surface electromyogram (SEMG) results in a single, weighted-average estimate, which is of limited value. We have recently developed an alternative approach to MUCV estimation from SEMG: 'The MU Tracking Algorithm'.1,2 The results of applying this new technique to SEMG data collected during fatiguing contractions of the tibialis anterior (TA) of nine healthy subjects are presented.

Methods: The volunteers (6 male & 3 female), sat reclined on a bench with their left foot strapped into a rigid plate attached to a force transducer. A high-density surface electrode array (4x8 electrodes) was attached to the distal third of the TA. Subjects sustained isometric contractions of 30-40% MVC until exhaustion. Two normal-double differential SEMG signals are analysed (6 mm interelectrode, 12 mm intersignal distance). The data from each subject were analysed in 2 s epochs. The MU tracking algorithm operates by identifying peaks in the SEMG signal and assigning them to particular MUs based on their velocities, amplitudes and times of occurrence. MUCVs and MUAP amplitudes are determined from clusters of peaks with common velocities and amplitudes. These MU parameters are then tracked across time.

Results: On average, the activity of 13 MUs was observed in each of the subjects, with each MU active for a mean of 41% of the total contraction time. MU fatigue, recruitment and derecruitment patterns could be observed from the MUCV and MUAP amplitude traces obtained from each of the subjects.

Conclusion: The MU tracking algorithm enables the MUCVs and MUAP amplitudes of individual MUs to be monitored from SEMG signals, thus potentially enabling MU fatigue and recruitment behaviour to be studied. Such an analysis approach could prove useful for the non-invasive diagnosis and assessment of neuromuscular disorders.

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371 - The Second-Generation Precision Decomposition System for EMG Signals: An Overview

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Introduction: We have developed a new automatic system for decomposing the electromyographic (EMG) signal into the constituent action potentials corresponding to the firing of individual motor units. The system is an outgrowth of our previous rudimentary system, which over the past 20 years has enabled us to perform various novel investigations that have provided a variety of new insights into motor control. However, the old system suffered various limitations, which curtailed its usefulness as a research tool, and has never been useful as a clinical tool. The new Precision Decomposition II system is designed to overcome the restrictions of the previous system and render the technique useful in a clinical environment.

Methods: The development of the second-generation system is composed of 5 projects. The first and dominant project is the design and development of the new system, which has at its heart, knowledge-based algorithms for decomposing the EMG signals. The other four projects are hypotheses-based and address basic scientific questions and clinical applications that are intended to reveal the utility of the new system. Additionally, the experience and information obtained in these projects is used to test and improve the evolving design of the new system. Project 2 addresses the modifications, which occur in the firing of motor units as a function of aging. Project 3 addresses motor unit firing behavior in fatiguing contractions, which will be useful in ergonomics and in the rehabilitation of patients with peripheral nerve injury and spinal cord injury. Projects 4 and 5 are two clinical studies. Project 4 explores the use of quantified neuromotor activity for developing prognostic indicators for determining denervation and re-innervation of paralyzed laryngeal muscles. Project 5 investigates the firing characteristics of motoneurons in patients with manifestations of CNS disorders, such as cerebellar ataxia.

Results: The system is configured with a laptop computer linked to a panel PC. The latter contains custom data acquisition hardware and software; the prior contains the decomposition algorithms. The whole system weighs less than 4 kg. The EMG signal is detected with our existing needle electrodes that are connected to the system via a miniature signal-shaping and signal-quality alert unit. Software programs residing on each computer provide low-level hardware control and a user interface for seamless data collection, signal processing, and display. The decomposition algorithms have been completely rewritten using a newly developed knowledge-based artificial intelligence language blackboard platform known as IPUS. The new system has a dramatically enhanced performance: 1) the decomposition time for typical contractions decreased from dozens of hours to a few minutes, typically 2 to 4 for a 20 s contraction having an EMG signal containing 6 to 8 motor unit trains, 2) the automatic decomposition accuracy increased from 65% to 97% - with provisions for assisted editing to reach 100% accuracy, and 3) it is able to decompose signals from dynamic as well as static contractions. Four units have been built, two of which are in 'Beta test' at clinical sites. We have successfully decomposed signals of great complexity from normal subjects as well as patients suffering from cerebellar disorders and laryngeal muscle spasticity.

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373 - Clinical Evaluation of Laryngeal Muscle Dysfunction Using Advanced EMG Decomposition

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Introduction: Proper functioning of the larynx is essential for voice production, swallowing, and respiration. The larynx also inhibits aspiration (the passing of fluid into the trachea and lungs) and its associated complications (viz., infection, explosive coughing). Unilateral paresis and paralysis of the laryngeal nerves is a peril of thyroid, cardio-thoracic, pulmonary and neck surgery because of their proximity to the surgical field and the scope of the Xth cranial (Vagus) nerve. Surface electrical stimulation tests useful for other neuromuscular systems (e.g., facial nerve) are not helpful for laryngeal paralysis because the neural pathways are embedded rather than peripheral. Quality of life for patients with laryngeal muscle dysfunction is greatly improved by early diagnosis, prognosis and surgical management. We provide case examples of two patients for which the electromyographic (EMG) technique of Precision Decomposition II served to provide rapid clinical results to guide the preferred course of surgical care—in these instances, the decision for temporary and ameliorative surgical remedies rather than those that are enduring and irreversible.

Methods: Multi-channel electromyographic recordings were obtained from left and right thyroarytenoid muscle of awake, unsedated patients at the hospital bedside and clinical laboratory using a quadrifilar needle electrode and the Precision Decomposition II system. The portable hardware consists of two computers: A (panel) computer containing the EMG amplifiers and a second (notebook) computer containing the acquisition and decomposition software—with an Ethernet link connecting the two units. EMG and acoustic microphone data were recorded during repetitive sustained voiced /i/, high-pitch /i/ and Valsalva maneuver tasks. Immediately following clinical recordings, EMG data were decomposed into vector time-series representing up to 10 simultaneously-active laryngeal motoneurons.

Results: The firing rate ‘dot’ and ‘bar’ plots produced by the Precision Decomposition II system provide a physiologic picture of motoneuron recruitment and firing rate of the active motor units in the volume of muscle proximal to the electrode recording surface for the paretic vocal fold and the unaffected ‘normal’ vocal fold. In addition to classifying motor units with fibers still communicating with their respective motoneurons, the decomposition technique provides the additional benefit of sorting de-innervated fiber depolarizations (‘fibrillation’ potentials, positive sharp waves) from the signal ‘hash’, which serves to improve clinical analysis and guide the surgical management for these patients.

Discussion: In addition to the clinical benefits derived from morphological analyses facilitated by the Precision Decomposition II system, our longer-range study will examine hypotheses relating ‘signatures’ in motoneuron recruitment and firing rate of the effected muscle to prognostics of laryngeal nerve recovery, and explore signatures of synkinesis during recovery of neuromuscular function.

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375 - A Model of the Motoneuron Pool to Examine the Effect of Common Oscillatory Inputs on Motor Unit Firing Patterns

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Introduction: Correlated pattern of activity are commonly observed between motor units in the same, and concurrently active muscles. Two examples of such behaviour are short-term motor unit synchronization and common drive. Synchronization refers to an increased tendency of motor units to fire within a few milliseconds of one another, while common drive refers to in-phase fluctuations in the mean firing rates of simultaneously active motor units at approximated 1-2 Hz. Motor unit synchronisation is believed to result from branched common inputs from descending fibres. The origin of common drive is less well known, but it is thought to be indicative of a common excitatory input to the motoneuron pool. The functional significance, if any, of both phenomena also remains unclear.

Methods: A model of the motoneuron pool and muscle force output was developed to examine how common oscillatory inputs to the motoneuron pool can effect patterns of correlated motor unit firing and force stability. The model was based on the first dorsal interosseous muscle and was comprised of 100 motoneurons. Individual motoneurons were simulated using a single compartment threshold crossing model described by Powers (Powers 1993). Motor unit twitch force was modelled as a critically damped, second-order system, (Fuglevand, Winter et al. 1993). Each motoneuron received three inputs: an activation current that dictated the level of activation of the muscle and was common to all motoneurons; an independent random membrane noise component; and a common oscillatory input that was applied to all motoneurons. The common oscillatory input signal was generated by band-pass filtering a Gaussian white noise signal about the center frequency of interest with a 2 Hz bandwidth. As the simulated contraction progressed, the amplitude of the activation current was adjusted such that the force output of the model followed a pre-determined target force level. Motor unit synchronization, common drive and the coefficient of variation of the force output were examined as the amplitude and frequency of the common modulatory input were varied systematically from 0-60 Hz.

Results: The amount of common drive, motor unit synchronization and the coefficient of variation of the force increased with the amplitude of the common input, and varied with the its frequency. Common drive was highest for input signals less than 5 Hz. The coefficient of variation of the force output also reached a maximum value at approximately 2 Hz. Oscillatory inputs above 5-10 Hz had little effect on either common drive or force stability. In contrast, motor unit synchronization was relatively insensitive to common input signals in this low-frequency range and reached a maximum in the region of the mean motor unit firing rates. The simulation results suggest that common low frequency oscillations in motor unit firing rates and muscle force, and short-term synchronization of motor units result from separate sources of oscillatory activity. Furthermore, the amount of synchronization between motor unit firings depends both on the amplitude and frequency of the common input signal and on the firing rates of the individual motor units.

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378 - Second Generation Precision Decomposition: Solutions

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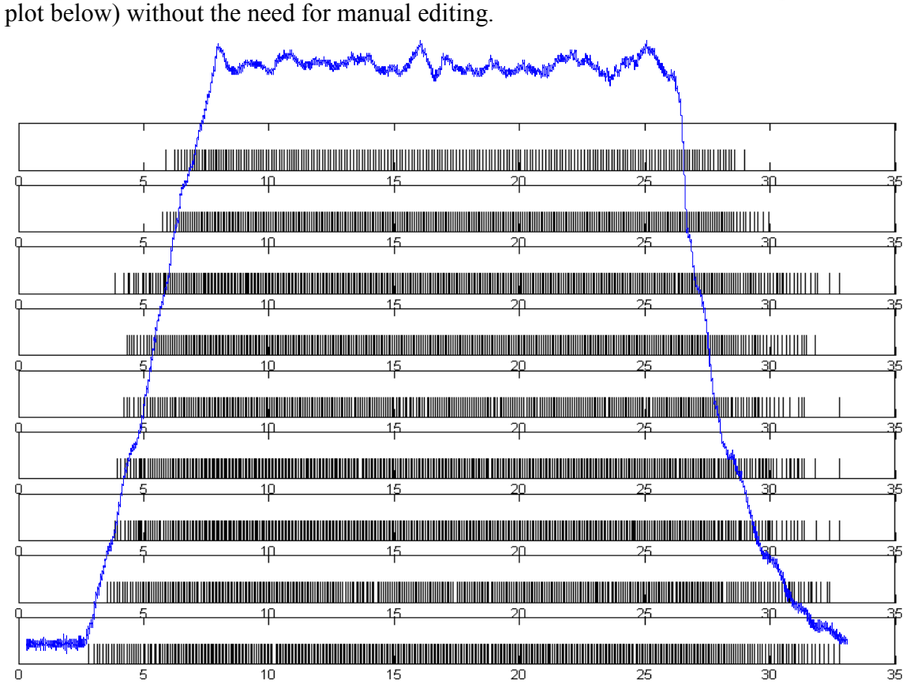
Introduction: The original Precision Decomposition system (PD I) developed by the NeuroMuscular Research Center at Boston University has led to significant physiological findings. However, decomposition results from this system require significant amounts of manual editing (often taking several days to complete) to produce useful results. In order to address the limitations of the original system, we have developed a second generation knowledge-based system, Precision Decomposition II (PD II), whose accuracy is well above 90% without the need for manual editing.

Methods: Precision Decomposition II was designed to better address the four basic decomposition challenges: pulse superposition, pulse evolution, dynamic range of pulse amplitudes, and similarities of pulse shapes. To address these challenges, our new system employs the *Integrated Processing and Understanding of Signals* (IPUS) framework [1] from artificial intelligence. This permits the use of stored *prior* information in an organized and systematic manner to guide the detection and subsequent correction of initial decomposition errors.

Results: Experiments on real EMG data indicate that our new system has significant speed as well as accuracy advantages over previous generations of precision decomposition programs. For example, on a complex EMG data file with nine significant motor units, PD II was an order of magnitude faster than PD I while providing an accuracy of approximately 94% (see continuous force profile and estimated MU firing times indicated by vertical bars in the plot below) without the need for manual editing.



Time [s]

References:

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379 - Second Generation Precision Decomposition: Challenges

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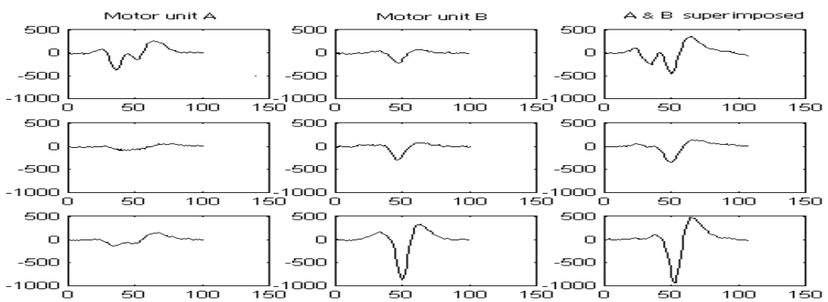
Introduction: In the late 1970's and through the 1980's, the Neuro-Muscular Research Center (NMRC) at Boston University developed an automated multi-channel EMG decomposition system [1] referred to as Precision Decomposition I (PD I). The application of PD I to experimental EMG data has led to significant physiological findings. However, decomposition results from this system require significant amounts of manual editing (often taking several days to complete) in order to obtain accuracy rates well over 95%. Alternative approaches by other investigators have also produced accuracy rates in the 60-70% range and require significant amounts of manual editing before producing usable results for physiological interpretation. The desire to remove the need for such extensive manual post-editing of EMG decomposition results has motivated the study reported here.

Methods: We carried out an experimental performance analysis of PD I in order to identify the major challenges that must be addressed in order to produce the desired degree of accuracy. For this analysis, the software for PD I was re-written using state-of-the-art software engineering methods to ensure its reliability and extensibility for future revisions. With the new software, PD I became compatible with today's hardware platforms with their faster speeds and larger memories. Having ruled out software and hardware limitations as possible sources of performance limitation, we focused on PD I challenges posed by the intrinsic nature of the EMG data to be decomposed.

Results: A major source of error in PD I was found to be the system's inability to adequately resolve *superpositions* (see illustration below) of motor-unit action potentials (MUAPs), particularly when there was a substantial *dynamic range* of MUAP amplitudes in the data. Another factor was the system's inability to adequately track the *temporal evolution* of MUAP shapes, particularly in situations involving different motor units with *similar* MUAP *shapes*.



To address these challenges, we developed a knowledge-based analysis strategy that was then incorporated into PD II.

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388 - Changes in Thenar Motor Unit Electromyographic Activity and Force with Repeated Activation

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Introduction: Few human studies have examined the changes in electromyographic activity (EMG) and force that occur at the single motor unit level in response to repeated activation. In this study our aim was to describe the changes in thenar unit EMG that occur in response to force potentiation and fatigue.

Methods: Thenar motor unit EMG and force were recorded in 10 able-bodied control subjects in response to stimulation of motor axons within the median nerve. EMG was recorded from the proximal and distal muscle surfaces. Abduction and flexion forces were measured as described previously (Westling et al. J Neurophysiol 64: 1331-1338, 1990). Twitches were recorded before and after a series of pulse trains delivered at frequencies between 5 and 100 Hz. Fatigue was induced by 2 minutes of intermittent stimulation at 40 Hz.

Results: The peak-to-peak amplitude of the initial proximal and distal EMG was of similar magnitude but opposite in polarity, suggesting that the end plates were near the middle of the muscles. After stimulation at 5-100 Hz, the mean (± SE) increases in EMG amplitude were small relative to the twitch force potentiation (5 ± 2 % versus 72 ± 15 %, n=24 units). Units with larger EMG amplitudes produced force in an abduction direction. These units also tended to have stronger tetanic forces and were more fatigable. The mean decline in force after 2 minutes of stimulation (21 ± 3 %) was accompanied by increases in the mean EMG amplitude and area (15 ±3 % and 15 ± 3 %, respectively).

Conclusion: These data suggest that changes in thenar motor unit EMG with activity are not good predictors of the changes in force.

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390 - Excitatory and Inhibitory Responses of Single Motor Units to Trans Cranial Magnetic Stimulation: A Comparative Study in Healthy Subjects and Patients with Motoneurone Diseases

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Transcranial magnetic stimulation (TMS) is commonly used as a diagnostic tool to assess the functional integrity of the excitatory cortico-motoneuronal pathway in neurological disorders. It is, however, well established that stimulating the cortico-spinal axons induces on the motoneurones not only excitatory post-synaptic potentials but also inhibitory ones. The contribution of these inhibitory processes in the pathological alterations of TMS- induced motoneurone responses is questioned. In the case of Lateral Amyotrophic Sclerosis (ALS), a disease characterized by the degeneration of both populations of cortico-spinal neurons and spinal motoneurones, the hypothesis has been put forward that a deficit in inhibition might contribute to the apparent “hyper-excitability” to TMS stimulation reported in the early stages of the disease. Such “hyper-excitability”, however, might also be explained by a greater convergence of cortico-spinal axons on surviving motoneurones, in the same way as the surviving motoneurones form abnormally large motor units by sprouting. In this case, “hyper-excitability” might also be expected to occur in spinal motoneurone diseases.

The present study aimed at reassessing the ”hyper-excitability” and inhibitory phenomena in ALS in comparison with Kennedy Disease which affects the spinal motoneurones only, Primary Lateral Sclerosis (PLS) which affects the cortico-spinal neurons and healthy subjects. A new approach focussing on the changes in the inter-spike interval has been developed in order to dissociate the concurrent inhibitory and excitatory effects induced by TMS (resting threshold intensity)

Results: In healthy subjects, as previously reported, TMS was found to induce systematically a mixture of early excitatory and inhibitory effects affecting the triggering of the first spike after the stimulation (either advanced or delayed). depending on the stimulation timing in the inter-spike interval. TMS was also found to affect the triggering of the second spike after the stimulation, with a prominent inhibitory effect.

In patients, the peristimulus inter-spike interval analysis has revealed no convincing evidence of ‘hyper-excitability” in the 11 cases of ALS and 3 cases of Kennedy disease tested. In ALS subjects, the early excitatory effect was globally reduced whereas the early and late inhibitory effects were enhanced. In the Kennedy disease, no changes were detected in the early excitatory effects, whereas the early and late inhibitory effects were also significantly enhanced. In the 2 PLS patients tested, the peristimulus inter spike interval analysis revealed the presence of late excitatory effects which were widely spread over 3 to 4 inter-spike intervals after the stimulation with a complete loss of the early excitatory and inhibitory effects present in healthy subjects.

Discussion: Contrasting with the current idea of a deficit in inhibition in ALS, the present data suggest an enhancement of the inhibitory processes which is also observed in Kennedy patients. These changes may be taken to reflect a dysfunction related to the loss of spinal motoneurons common to both diseases. The late excitatory effects induced by TMS in PLS, suggest the involvement of some slow and diffuse excitatory networks under cortical control which may play a role in the voluntary control of motoneurones in these patients.

405 - How is Force Maintained when Motor Unit Firing Rate is Decreased During Experimental Pain? Investigation of Synergist Muscles

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Introduction: Pain has potent effects on motor control. A frequent finding is that activity of agonist muscles is reduced during pain 4. This is generally explained in terms of the “pain adaptation” model 2 in order to reduce the velocity and displacement of the movement. Recent data indicate that when a contraction is performed with constant force there is a reduction in motor unit firing rate in the agonist muscle when pain is induced by injection of hypertonic saline 1,3. Although this is consistent with the pain-adaptation model it is difficult to explain how the force can be maintained. One possibility is that activity of synergist muscles is increased to maintain force. This study investigated this possibility

Methods: Recordings of electromyographic activity (EMG) of soleus (SO) and medical gastrocnemius (MG) were made with fine-wire electrodes in 12 subjects. Subjects sat with the right foot strapped to a force transducer. With low force, subjects plantarflexed the right ankle until single motor unit action potentials (MUAP) were observed and force level was recorded. Subjects were given feedback of force and were instructed to plantarflex to the reference force level for 5 20-s contractions (separate by 100 s) before pain, 3 20-s contractions (separated by 100 s) during pain induced by injection of 5% hypertonic saline (1.5 ml) into lateral gastrocnemius (LG), and 2 20-s contractions after pain. Pain was recorded continuously on a visual analog scale (VAS). MUAPs were sorted on the basis of morphology and were analysed if recordings of an individual unit could be identified in trials before, during and after pain. Trials were rejected if force varied more than 5% from the reference level.

Results: Subjects reported a peak pain of 5.4 (3.8). Ten single motor units in MG and 10 in SO were identified. Firing rates are presented in Table 1. Although force was maintained, motor unit firing rate was reduced by 12 (1) % for SO and 11 (1) % for MG ($P<0.05$). Recordings from LG in one subject confirmed that motor unit firing was also reduced in the painful muscle. Motor unit firing rate returned to baseline levels when pain resolved.

Table 1: Motor unit firing rate (Hz).

	Baseline	Pain	Post-pain
SO	6.4 (0.7)	5.6 (0.7)	6.3 (0.8)
MG	7.0 (1.4)	6.2 (1.1)	6.9 (1.4)

Conclusion: The results of this study indicate that motor unit firing rate of synergist muscles is reduced in association with the painful agonist muscle during constant low force contractions. Thus, changes in firing rate of synergist muscles cannot explain the maintenance of force output. Other adaptations must be responsible.

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415 - Human Inspiratory Muscles: Insights from Motor Unit Recordings

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Despite their critical importance for survival, there have been relatively few studies of the behaviour of motor units in the human respiratory muscles. Respiratory motoneurones receive both volitional and ponto-medullary drives and they must be rhythmically activated throughout life. Volitional drives are of several types: those which are primarily directed to alter respiratory flows and pressures (e.g. for talking), those which alter truncal and limb position, and those concerned with postural stability. In addition, ponto-medullary outputs are driven by more than purely ventilatory demands. Little is known about how these drives are integrated within single inspiratory muscles and across the various obligatory inspiratory muscles. The diaphragm is the principal muscle generating inspiratory volumes and it is subject to precise voluntary control. In one study we used intramuscular recordings of the simultaneous activity of several motor units in the costal diaphragm to examine how these units responded to a range of voluntary inspiratory volume ramps and to quiet breathing. We derived an index to assess the reliability of their recruitment (i.e. a shuffle index). This study revealed that at each recording site there were some units whose recruitment pattern consistently deviated across the series of tasks. Recruitment times could vary by some seconds. The study suggests that the recruitment order of a group of phrenic motoneurones can be systematically altered in some situations. This may reflect the influence of the combined descending drives that the motoneurones receive (Butler et al. 1999; J Physiol 505: 907-920. In more recent studies we have recorded single motor unit activity in different sessions from several muscles which act on the chest wall to determine how the inspiratory drive is sculpted at the different motoneurone pools (e.g. De Troyer et al. 2003; J Physiol 546: 943-954). These studies indicate that the output of populations of scalene and diaphragm motor units begins a little earlier than for other muscles with an inspiratory action (Saboisky et al. 2004; Proc ANS 15: 45). The diaphragm and third dorsal external intercostal muscle had higher initial firing rates and reached a higher rate during inspiration than other muscles. Some muscles showed a high level of tonic firing with superimposed inspiratory modulation. These studies indicate that so-called respiratory muscles may not receive uniform drives during respiratory and voluntary tasks.

419 - Low-Threshold Motor Unit Twitch Force and Conduction Velocity Following Sub-Maximal Fatiguing Contractions

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Introduction: the aim of this study was to jointly investigate single motor unit (MU) twitch force and conduction velocity (CV) following fatiguing contractions in order to assess fatigue-related changes in membrane and contractile properties of single MUs.

Methods: eleven healthy male subjects (age, mean ± SD: 25.8±5.7 years) took part in the study. Surface EMG signals were detected from the tibialis anterior muscle of the dominant leg by a linear adhesive array of 8 electrodes (5 mm inter-electrode distance) located between the most distal innervation zone and the distal tendon region. Intramuscular signals were recorded by means of four wire electrodes made of Teflon coated stainless steel (A-M Systems, Carlsborg, WA, USA), inserted proximal to the surface array [1]. The subject sat in a reclined position with his foot strapped to a foot plate (90° ankle joint angle) with a torque transducer (sensitivity 10 V/mNm). After 10-min rest following the maximal voluntary contraction (MVC) torque measure, the subject was asked to modulate the force during ankle flexion to control a single MU activity (feedback MU) by visual and auditory feedback on the intramuscular EMG signals. After training with the feedback, the selected MU was activated at the minimum firing rate for three contractions lasting 3 min and separated by 10 s rest (contractions C1-C3). Five minute after the three contractions, the subject exerted an isometric contraction at 40% MVC until endurance (visual force feedback was provided) (endurance test). When the force level decreased to less than 35% MVC for 5 s, the subject relaxed and, after 10 s, activated again the feedback MU for five 3 min long contractions separated by 10 s rest (contractions C4-C8). Intramuscular recordings were decomposed into the constituent MU action potentials, which were used to average the surface EMG signals (for CV estimation) and the force signal (for twitch assessment). Only firings separated by at least 150 ms between each other were used for the twitch averaging. Average CV was also computed during the endurance test.

Results: the endurance time was on average (±SE) 231±30 s. During the endurance test, average CV decreased over time until 50%-75% of the endurance time, then increased, probably due to progressive recruitment of higher thresholds MUs. Average CV at 50% (3.79±0.57 m/s) and 75% (3.75±0.61 m/s) endurance time was significantly lower than at the beginning of the contraction (4.36±0.56 m/s) (one-way ANOVA: $F = 2.40$, $P < 0.05$; post-hoc Student-Newman-Keuls, SNK: $P < 0.05$). For the feedback MU, neither the average firing rate (6.7±0.1 pulses per second) nor the inter-pulse interval variability (33.3±6.3 %) depended on the contraction (C1-C8). The recruitment threshold significantly increased (by 11.5±4.5 %) in the C4 contraction with respect to contractions C1-C3 and C5-C8 (one-way ANOVA: $F = 2.33$, $P < 0.05$, SNK: $P < 0.05$). The twitch rising time was unchanged in the eight contractions (C1-C8) (74.4±3.5 ms). On the contrary, the peak twitch force significantly increased (by 93±29%) in the contraction C4 compared to C1-C3 and C5-C8 (ANOVA: $F = 2.46$, $P < 0.05$; SNK, test: $P < 0.05$). CV of the feedback MU significantly decreased (by 6.3±1.8 %) after the fatiguing contraction (ANOVA: $F = 2.08$, $P < 0.05$, SNK: $P < 0.05$).

Conclusion: after a fatiguing contraction until endurance, low-threshold MU twitch force almost doubled, with a concomitant increase in recruitment threshold. CV slightly decreased with fatigue. Peak twitch, recruitment threshold, and CV returned to control values within 3-4 min. This result shows that a decreasing trend of CV may be associated to an increased twitch force of low-threshold MUs.

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420 - Muscle Fiber Membrane Properties of Sub-Threshold Motor Units Vary During Sustained Contractions

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Introduction: during sustained activation, the muscle fiber membrane properties change. In particular, muscle fiber conduction velocity (CV) decreases over time. These modifications are due to the repetitive activation of the muscle fibers and to the modifications of the extracellular environment. The present study aimed at testing the hypothesis that the membrane properties of muscle fibers may vary even without any activation of these fibers.

Methods: ten healthy male subjects (age, mean ±SD: 26.3±2.1 yr) participated in the study, which was approved by the Regional Ethics Committee. The hand of the subject was fixed in a specifically designed ergometer. Surface EMG signals were detected with a two-dimensional electrode array (61 electrodes, 1 mm diameter, arranged in 13 rows and 5 columns, without the four corner electrodes; 3.5 mm interelectrode distance) from the abductor pollicis brevis muscle. EMG signals were amplified, filtered (10-500Hz), sampled at 1650 samples/s, and digitized (12 bit A/D converter). Single motor unit (MU) activity was controlled using a visual feedback on the surface EMG signal, as proposed by Farina et al. [1]. The subjects had approximately 20 min to practise with the EMG visual feedback. The goal of the training phase was to identify (in a force range between 10% and 20% MVC) a MU (feedback MU) clearly distinguishable from the others and learn to control its recruitment/derecruitment. After the training phase, ischemia was induced with an inflated cuff applied to the forearm (180mmHg pressure). After five minute rest in ischemic conditions, three successive contractions were performed. In the first contraction, the subject modulated the force level in order to maintain the feedback MU active for 10 s. In the second contraction the subject maintained the force level slightly below the recruitment threshold of the feedback MU for 180 s. Thus, in the second contraction the feedback MU was not active. The third contraction was as the first one. The signals recorded during the first and third contractions were decomposed to extract the action potentials of the feedback MU. CV was estimated from the identified action potentials. Global CV was estimated during the second contraction (1 s long epochs). On the same subjects, in another experimental session, single MU CV was assessed at 5 and 13 min of ischemic condition without the sustained contraction of 180 s.

RESULTS: all subjects were able to control the force level to activate or deactivate the feedback MU. The force level at which the feedback MU was recruited in the first and third contraction was (±SE, N=10) 18.8±5.1 % and 12.0±2.1 % of the maximal force, respectively. The average firing rate of the feedback MU was not different in the first (14.0±3.0 pulses per second, pps) and third contraction (12.3±2.3 pps) (Student t-test for dependent samples, N = 10 subjects). CV initial values (3.61±0.75 m/s, 3.45±0.65 m/s, and 3.35±0.47 m/s, in the three contractions respectively) were significantly different among contractions (1-way ANOVA; $F = 4.30$; $P < 0.05$). The post-hoc SNK test showed a significant difference between the third contraction and the other two ($P < 0.05$). The percent decrease of global CV during the second contraction (-10.70±2.05%) was not significantly different from the percent decrease of the feedback MU CV between the first and the third contraction (-7.20±3.10%). Without the sustained contraction (second experimental session) CV of single MUs did not significantly change due to ischemia. Thus, MU CV was not affected by the ischemic condition per se.

CONCLUSION: these results demonstrate 1) the possibility to control the activity of a single MU in ischemic conditions at contraction levels higher than 10% MVC with surface EMG feedback, and 2) that the membrane properties of not active muscle fibers may vary due to the activity of other muscle fibers. Thus, the accumulation of metabolites during a contraction has a primary role in the modifications of the membrane muscle fiber properties.

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Muscle Fatigue

012 - Correlation Between Fatigability of the Sternocleidomastoid and Anterior Scalene Muscles and Duration of Symptoms In Chronic Neck Pain Patients

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Introduction: Previous studies have demonstrated greater myoelectric manifestations of superficial cervical flexor muscle fatigue [1, 2] and different motor unit pool recruitment [2] in patients with neck pain compared to healthy controls. Despite the evidence of greater fatigability of the superficial cervical flexor muscles in neck pain patients, the relationship between duration of neck pain and muscle fatigue has not been investigated. The purpose of this study was to investigate the correlation between duration of pain and myoelectric manifestations of sternocleidomastoid (SCM) and anterior scalene (AS) muscle fatigue in a group of patients with chronic neck pain.

Methods: Twenty chronic neck pain patients with a history of pain ranging between one and twenty five years (mean 6.15, SD 5.48 years) participated in this study. Myoelectric signals were recorded from the SCM and AS muscles from the side of greatest pain as patients performed sustained sub-maximal isometric cervical flexion contractions at 25% and 50% of the maximum voluntary contraction (MVC). The initial value and slope of the mean frequency (MNF), average rectified value (ARV) and conduction velocity (CV) of the EMG signal were calculated. Correlation analysis was applied to determine whether a relationship existed between the duration of neck pain and estimates of EMG variables.

Results: No significant correlation was found between duration of pain and estimates of the MNF, ARV and CV for either SCM or AS contracting at 25% and 50% MVC.

Conclusions: The length of history of neck pain does not appear to correlate with the extent of SCM and AS muscle fatigability in patients with chronic neck pain. As demonstrated by muscle biopsy studies, we suspect this may be due to initial transformations of muscle fibres from type I slow-twitch to type IIB fast-twitch fibres in the first two to three years of neck pain. Future studies are warranted to examine how early signs of cervical muscle fatigability are evident after the onset of neck pain as this will have implications for rehabilitation.

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059 - Protocol of Determination of Fatigue Index to Muscular Training in Patients with Duchene's Muscular Dystrophy

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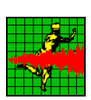
Introduction: Duchene's Muscular Dystrophy (DMD), a muscular disturbance caused by the hereditary muscular disease, is characterized by rapid progression muscular atrophy, mainly affecting proximal muscles, preferentially the hip and knee extensor muscles, resulting in a difficulty in standing up and in the later stages, gait loss, finally leading to severe respiratory problems. Thus, the aim of the physiotherapeutic rehabilitation is to provide a better quality of life, preventing the onset of such atrophies. The load and periodization of training to such rehabilitation, until nowadays, has been largely unknown, mostly because of the fatigue onset, a severe point to lesional commitment of the muscular fibers. The present study had as objective to determine, by a surface electromyography (EMG), a fatigue index which can be used as a parameter of the training periodization to be followed by physiotherapists.

Methods: The electromyographic data were collected in temporal and frequency domains using three pairs of bipolar differential active-type surface electrodes on the motor point of vastus mediallis, vastus laterallis and femoral muscles, where they were collected at 4 strength levels (100, 80, 60, and 40% of maximal voluntary contraction). The signal was pre-amplified in the differential electrode with a 10-times and afterward a 100-times gain in the signal conditioning module (totalizing a 1000 gain), besides a rejection common mode reason of 80dB.

Results: The results show an inclination angle to the linear regression line performed by the Pearson Test to median frequency of each collected strength level, that were crossed (abscissa axis) with the respective loads (ordinate axis), performing a new linear regression line, that, meeting the ordinate axis (load percentage), shows the fatigue index to the analyzed muscle.

Conclusion: Considering the obtained results of this study, we can conclude that the fatigue index proposed presents an extremely reliable and effective collection methodology to the load determination and period of therapeutic training of DMD patients.



063 - Electromyographic Parameters in Induced Fatigue by Prolonged Mastication in Temporomandibular Disorders Patients

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Introduction: Most of the investigations about EMG parameters utilized maximal clenching to induced fatigue in masticatory muscles. The purpose of this study was to evaluate the endurance time, pain and discomfort intensities, the RMS and median frequency (Fmed) in the induced fatigue by prolonged gum mastication in control and temporomandibular disorders (TMD) groups.

Methods: This study evaluated 8 healthy and 11 TMD patient women (mean age 27±6 years). Each gum (18x17x4mm, weight 245mg) was put on both sides of the dental arc. The metronome was set at 80 bpm indicated chewing rate. Endurance time corresponded to time ranging from beginning of mastication to subjective fatigue. Pain and discomfort intensities were evaluated by visual analogue scale (VAS) obtained before and after the prolonged gum mastication. Surface EMG was recorded from the anterior temporalis and masseter muscles using surface differential electrodes (silvers bars 10mm apart, 10mm long, 2mm wide, gain of 100x, input impedance of 10GΩ and CMRR of 130dB). The EMG signals were analogically amplified with gain of 50x, filtered (10-1500Hz band-pass) and sampled by 12 bits A/D covert board with a 2KHz frequency. The signals were digitally band-pass filtered (10-500Hz). The RMS and Fmed (PSD, FFT, 250 ms, 1024 points, Hanning window processing) were obtained from masticatory cycles in 250ms windows determined visually considering the most stable epoch. The maximal clenching RMS values were used to normalize masticatory cycles EMG amplitude. The first masticatory cycle Fmed values were used to normalize other masticatory cycles EMG frequency.

Results: There were no significant differences among the values of RMS and Fmed during the prolonged gum mastication ($p>0.05$, Friedman ANOVA). Endurance time was significantly shorter to TDM group ($p>0.05$, Mann-Whitney test). Pain and discomfort intensities were not different for control and TDM groups after the prolonged mastication ($p>0.05$, Mann-Whitney test).

Conclusion: There was no evidence of change related to prolonged gum mastication in the investigated electromyographic parameters, in these experimental conditions.

089 - Evaluation of the Force And Endurance of the Paravertebral Muscles In Man And Woman: A Comparative Study of the Different Dynamometric Tests.

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Introduction: Several studies using electromyographic (EMG) measures to evaluate the endurance and strength of para-vertebral muscles have reported contradictory results regarding potential differences between genders. The divergent conclusions of these investigations could be partly explained by the differences in their methods. The aims of this study were to describe and to compare, between males (n=15) and females (n=15), 3 methods of assessment of muscle strength and fatigue during forced trunk extension.

Methods: In the first method, the subjects were standing and asked to produce a trunk extension against a dynamometer fixed at the level of the fourth thoracic vertebra. In the second test, in a squat position, the subjects were asked to produce a trunk extension while pulling-up an handle fixed to the floor. In the third test, the subjects were lying in prone position, with the lower limbs fixed to a table and were asked to hold their unsupported trunk against gravity. Dynamometric and EMG measures were recorded bilaterally in four (4) back muscles (multifidus L5 level, iliocostalis lumbar L3 level, longissimus lumbar L1 level and longissimus thoracic T10 level). The EMG signal was assessed in order to obtain the median frequency (Md) of the power spectrum and also to obtain its amplitude using the root mean square (RMS). The variations in the Md and RMS parameters over time of contraction were respectively measured by the Md/time and RMS/time relations during 60 seconds of maintained isometric contractions at 50% of the maximal moment of back muscles.

Results: The results show that (1) there is no significant difference between genders in the endurance of the back muscles tested, (2) the test in the squat position reveals less sensitivity to fatigue when compared to the tests in the upright and prone positions and (3) both fatigue parameters, RMS/time and Md/time, showed an increase of fatigue in the multifidus muscle compared to other para-vertebral muscles.

Discussion: According to these results, the multifidus seems to be more sensitive to fatigue when compared to other back muscles during isometric extension of the trunk. The test in the squat position produces less fatigue in the muscles tested when compared to the other tests. Finally the lack of evidence of difference between genders in muscle fatigue for the 3 methods of assessment used and for the different muscles tested strongly suggests that the gender parameter should no more be taken into account in clinical investigation on muscles fatigue of back muscle.

Key search headings: back muscles, assessment, fatigue, EMG, dynamometric measures

112 - Does the Decrease of Mpf/Mf Reflect Localized Muscle Fatigue Specifically?

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Introduction: Decrease of Mean Power Frequency / Median Frequency (MPF/MF) of surface electromyographic (sEMG) signal was the unequivocal response to muscle fatigue induced by exercise. But what factors and how they caused this phenomenon are still remaining unclear. Studies had identified that sEMG signal was the co-action results of motor controlling information of central nerve system (CNS) and various physiological and chemical factors which would affect the muscle bio-electrical activities. If the changes of sEMG signal parameters are only the results of the peripheral chemical factors during muscle fatigue , then no any sEMG changes would be seen when the muscle is not fatigued, otherwise, muscle fatigue might not be the only factor that caused the changes of sEMG parameters. In order to testify this assumption, we arranged subjects to perform isometric contraction of BB(biceps bralii), and recorded the sEMG signal of BB and TB(triceps brachii) simultaneously. We assumed that if the changes of MPF/MF were fatigue specifically, there would be no changes in sEMG of TB when it is not fatigued.

Methods: 10 healthy volunteers of college students (age: 23.2±3.6 years, height: 172.9±4.9 cm, weight: 67.4±6.9 kg) participated in this study. They sat on a chair behind a table which the right elbow was put on, Keeping trunk upright and joint of thigh, knee, and heel at 90o. The right carpus of the subject was connected with a force transducer behind him through a fine wire. Subject then performed 3 maximal voluntary contractions of right elbow joint extension. Using PCLAB bio-signal gathering and recording system recorded values of the MVCs. 5min after the last MVC of elbow extensor, the subject's right carpus was pulled by a forward force of 20kg horizontally for 60sec. The angle of right elbow joint must be kept at 90o by isometric contractions of right biceps brachii (BB).As soon as it reached the 60th sec, subject performed a MVC of right elbow extension promptly. sEMG signal were collected from right BB and right triceps brachii (TB) .MPF, MF ,AEMG and Lempel-Ziv complexity (C(n)) of sEMG signals were calculated and the slopes were analyzed with linear regression methods.

Results: The Lempel-Ziv complexity and MPF, MF of the sEMG signals in BB all decreased regularly and linearly with the continuation of elbow flexion, and AEMG increased regularly and linearly. At the same time, except that there were no remarkable changes in AEMG, other sEMG parameters in TB showed the same developing trends. while the values of MVC of elbow extension before and after elbow flexion were same(14.0±3.2kg and 14.6±2.6kg respectively ,t=1.097, p=0.299).

Discussion: Our study found that MVC of elbow extension after fatiguing elbow flexion was not decreased compared with that of before exercise load, while the decreases of MPF, MF, and Lempel-Ziv complexity in TB were significantly greater than those in BB. These results indicated that changes of sEMG frequency-domain indices were not the specific reflection of muscle fatigue. The motor-controlling strategy of the CNS might be the important mechanism accounted for the changes of the sEMG signal parameters.

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121 - Effect of Weak Magnetic Stimulation for the Strained Peripheral Muscle

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Introduction: Recently, magnetic stimulation is being used as a new technique for nerve functional diagnosis as a replacement of electric stimulation in the clinical field. However, the focality or function of magnetic stimulation has not yet improved. Nevertheless, magnetic stimulation has been positively applied in the rehabilitation field. The authors have previously studied the effect of pulsed magnetic stimulation on recovery from fatigue. In this paper, the recovery effect of pulsed magnetic stimulation on peripheral muscle fatigue on the forearm was quantitatively examined. As a result, performing pulsed magnetic stimulation for strained muscle proved an improvement in movement performance.

Methods: Subjects were nine healthy volunteers aged average 22.6±0.7 years old. All of them had no previous history of neurological illness and no special physical strength training. All subjects provided informed consent for the study. In this study, an object of measurement was flexor digitorum superficialis and subject was lying on one's back during experiment. Fatigue was performed by grasping a hand dynamometer with 30% isometric maximum voluntary contraction(MVC) during 30 seconds. This task was repeated 10 times at intervals of 180 seconds. After 30% MVC, magnetic stimulation was performed 20 times at interval of 5 seconds. We measured an exhibiting muscle strength, which was observed by strain gauge attached to the hand dynamometer, and integral electromiogram (iEMG). The recovery effect of magnetic stimulation for muscle fatigue was estimated by the ratio of iEMG to muscle strength.

Discussion : During experiment, muscle strength of each subject was constant. In control (non-magnetic stimulation), iEMG increased rapidly from set4 stage. On the other hand, iEMG in exposure did not change by set7, but from set8 it slightly increased. Increase of iEMG showed that electrical activity of muscle activated for exhibiting 30% MVC. Fig.1 showed that mobilizing state of peripheral muscle changed for exhibiting the same muscle strength. During experiment, contraction of muscle was not observed. It can be considered that there is effect of induced current for the strained muscle. We assumed that the induced eddy current in the forearm elevated H+ density in a muscle and pH value returned to its original state. As a result, weak pulsed magnetic stimulation accelerated a recovery of muscle fatigue.

Conclusion: These results suggested that the strained muscle is mitigated by weak pulsed magnetic stimulation, which could not generate muscle contraction

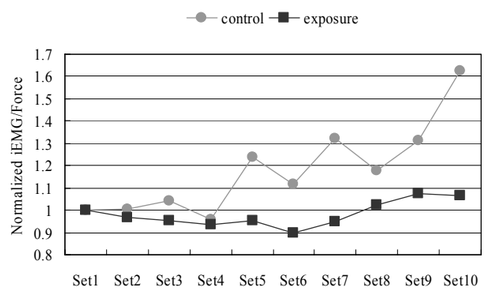

Fig.1 iEMG/muscle strength

127 - Fatigue Assessment Using Discrete Wavelet Transforms for High Intensity Exercises (Wingate Test)

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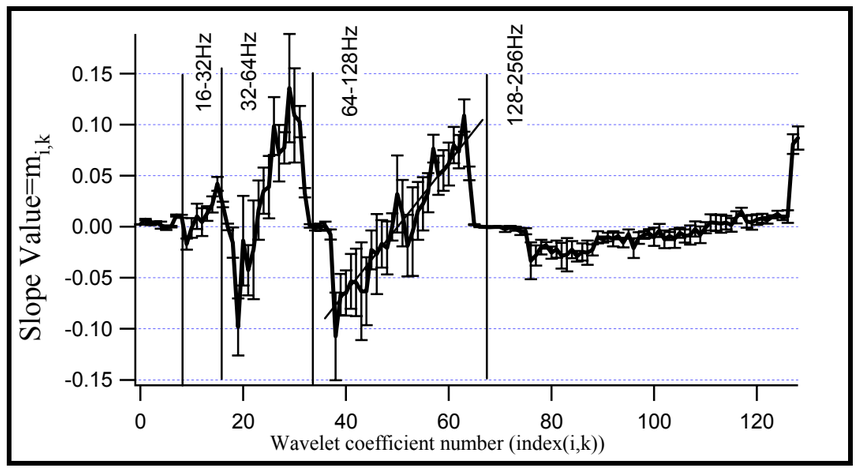
Introduction: Muscle fatigue research has tradicionally used low angular velocity movements under dynamics conditions. Here we assess dynamic fatigue under maximun anaerobic power, a situation where EMG signals are highly nonstationary. The time course of the variation of the relative power of discrete wavelet coefficients is used to measure fatigue.

Methods: Surface EMGs from the vastus lateralis muscle were collected during the execution of a Wingate test (N=9 subjects) lasting 30 s aprox. The beginning and end of each contraction were automatically calculated, and visually checked, to extract from the original signal a sequence of bursts, of 256 points, $\{b_p^s/p=1,...,n_s\}$ for each subject s. Using Time-Frequency techniques (IGOR from wavemetrics.com) each burst was transformed using Daubechies of order 6 to generate the sequences ($c_{i,k}^{p,s}$) where $c_{i,k}^{p,s}$ = the *(i,k)* wavelet coeficient for the burst p and subject s. Then for each $c_{i,k}^{p,s}$ we calculated its relative variation by normalizing by the total energy in each burst producing the sequences ($d_{i,k}^{p,s}= c_{i,k}^{p,s}/|$energy of (b_p^s)). Next we investigated, for each subject, the variation of $d_{i,k}^{p,s}$ with respect to p by calculating $z_{i,k}^s$ = regression coefficient of $\{d_{i,k}^{p,s}/p=1,...,n_s\}$ for subject s. Finally we averaged across subjects by calculating $m_{i,k=}$ average$\{z_{i,k}^s/s=1,..9\}$. We summarized this data by expressing, for each index *(i,k)* the average variation $m_{i,k}$ (Figure1).



Results: The figure show that the average contribution of all energy bands changes during the performance of each burst. For example, wavelet coeficient 38, equivalent to the frequency band (64-128 Hz) operating at 48 ms after the onset of each burst declines its energy contribution to the burst, while the coefficient 60 (the same band but at 218 ms after onset) increases its contribution.

Discussion: First, by analizing the time course of the relative contributions of each wavelet coefficient during a EMG contraction we have developed a technique to assess the degree of non-stationarity of a EMG signal. More importantly we shown that for each frequency band, its contribution during the execution of each burst varies. This result is different from the research involving low angular velocity movements. An explanation could be caused by the distinct metabolisms participating in each situation.

143 - Localized Muscular Fatigue: The Limiting Factor for Lifting

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Introduction: The composition of the workforce has changed dramatically over the past several years, yet work requirements have rarely been modified to accommodate gender differences1 in the rate of muscular fatigue2. The purposes of this study were: 1) to develop a protocol for inducing localized muscular fatigue for determining the limiting neuromuscular factor during repetitive lifting in both men and women, and 2) quantify gender differences in fatigue accumulation and recovery rate of lower (vastus lateralis) body musculature after repeated bouts of sustained isometric muscular contractions.

Methods: Seven healthy males (age 25.2 ± 2.6 yrs.; BMI: 25.6 ± 1.9) and seven healthy females (age 24.0 ± 2.7 yrs.; BMI: 20.9 ± 2.2) underwent bilateral localized fatigue of the quadriceps femoris muscle group, quantified using evoked contractile characteristics and spectral analysis of EMG signals from the vastus lateralis muscle, along with changes in MVC. Using a custom-made isometric knee extensor myograph, ten 30-second isometric contractions at 50% of the previously determined MVC with 30 seconds of rest between contractions were performed. Immediately following the last sub-maximal contraction, a 5-second MVC was performed. Afterwards, the participants remained in the myograph for 45 minutes in order to monitor recovery; performing a 5-second MVC every 15 minutes, with single twitches evoked every 5 minutes. All EMG, force, and electrical stimulus data were recorded simultaneously.

Results: Statistical significance was accepted at $P < 0.05$. The group had a significant reduction in right (24.1%) and left (19.3%) leg extension MVC immediately following the fatigue protocol, throughout the recovery period, and both the negative slope for median frequency (MF) and positive slope for root mean square (RMS) were significantly different than zero with a significant decline in the amplitude of the potentiated twitches during the sub-maximal contractions. Males had a significantly greater drop in the right leg MVC (17.5%) immediately following the sub-maximal contractions, throughout the recovery period, and were less capable of maintaining the required level of force production during the sub-maximal contractions. Effect sizes ranged from 0.3 to 0.7. There were no significant group differences with respect to EMG measures or voluntary activation.

Conclusion: The fatigue protocol employed resulted in a significant reduction in voluntary and evoked force. The relative changes in MVC between males and females suggest that males may be at greater risk of a fatigue-induced injury when lifting with tired legs. However, it is difficult to isolate which factors are contributing to the gender differences given the sample size. Work is currently underway to increase statistical power and determine the fatigability and recovery of other muscle groups considered to be important for performing lifting tasks, and their effects on lifting performance.

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146 - Effect of Short Period of Unweighting On Muscle Tissue Oxygenation and EMG Activity Profiles during Exercise in Human Calf

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Introduction: There are unknown issues about the relevance of a muscular activity level and oxygen dynamics in muscles, and also about effect of muscle unweighting on the relevance. Besides, muscle contractile alterations induced by unweighting depend on the muscle fiber types. Near-infrared spectroscopy (NIRS) has provided insights into the dynamics of oxidative metabolism during exercise. Thus, the present study was carried out to examine the effect of short period of unweighting on the tissue oxygenation and EMG profiles in human calf synergistic muscles.

Methods: Five healthy but sedentary male adults (age: 21.6 ± 1.3 yrs, height: 175.0 ± 9.7 cm, body weight: 64.3 ± 6.1 kg) who did not participate in any regular exercise program took part in this study. All subjects performed 5 sets of 10 repetitions of dynamic calf-raising exercise at frequency of 15 times per minutes with 1-min intervals, before and after the 20-day bed rest period. During the calf-raise exercise, the tissue oxygenation (TOI), the tissue hemoglobin index (THI), changes in oxy/deoxy- Hb/Mb contents (Δ[oxy-Hb/Mb] and Δ[deoxy-Hb/Mb]) were monitored in both medial head of gastrocnemius muscle (Gas-M) and soleus muscle (Sol) using a NIRS (NIRO-300, Hamamatsu Photonics, Japan). Simultaneously signals of surface electromyography were recorded using portable two-channel EMG system (The Bagnoli-2 EMG System, DelSys, USA). The average amplitude (AMP) was calculated from the signals.

Results: The TOI decreased gradually during 10-bout calf-raise exercise and recovered at the resting level during the recovery phase and observed the similar trend during 5-set of exercise. The change in TOI of Gas-M tended to extend its magnitude as compared with that of Sol ($F=8.77$, $p<0.01$) and it was accompanied by the slight decrease in THI. The THI obtained in Sol tended to increase slightly. The AMP of EMG signal obtained from Gas-M and Sol increased from the beginning to the end of the 10-bout contractions. The AMP in both muscles neither increased through the 5-set calf-raise nor altered by unweighting. All these trends of TOI, THI and AMP did not affected by unweighting.

Discussion: The AMP indicated that the target muscles were not fatigued obviously during the exercise test, and was not affected by unweighting during exercise with sub-maximal load. The tissue oxygenation during exercise indicated different trend depending on the muscle characteristics. The Sol, which is dominated slow-twitch and oxidative muscle fibers, would maintain (or increase) oxygen supply even during exercise. Thereby, TOI in Sol might not show obvious decrease during exercise. On the other hand, Gas-M, which is mixed muscle fiber types, would decrease relative tissue oxygen level concomitant with lower oxygen supply. However, the short period of unweighting might not induce significant alteration in tissue oxygenation profile in lower limb synergistic muscle. Further study is necessary in detail to clarify the tissue oxygen dynamics during exercise and effect of unweighting (bed rest).

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150 - Efforts Can Stop as a Direct Consequence of Postural Muscle Exhaustion

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Introduction: The purpose of this study was to explore whether manual efforts can stop as a direct consequence of trunk and/or lower limbs, that is postural muscles exhaustion. To this end, in addition to the push force, the primum movens and postural muscle electromyograms (EMGs) were considered, during submaximal isometric push efforts sustained until exhaustion [1].

Methods: Subjects were asked to sit upright on an adjustable seat, the upper limbs stretched out horizontally, and the hands gripping a bar. Five right-handed subjects were asked to maintain a sub-maximal (75%) bimanual push effort till exhaustion. Five representative muscles were considered: i) the primum movens (Serratus Anterior: SA), which moves the scapula in a forward movement of the shoulder and arm producing push effort; and ii) four postural muscles, that is: Trapezius Superior (TS), Erectores Spinae (ES), Rectus Abdominis (RA), Rectus Femoris (RF). In addition to push force Fx, Root Mean Square (RMS) and Mean Power Frequency (MPF) were monitored over two-second intervals, from the push onset to its end.

Results: The results showed that the 75% MVC push force (50.8±10.2N) was sustained for 180 to 360 s, depending on the subject, after the onset of the effort. This duration corresponded to 30% of the effort total duration. Then, Fx began to fall. The decrease lasted until complete exhaustion, and the period was referred to as the "exhaustion period". Complete exhaustion occurred 720 to 1020 s after the onset of the effort. At this time, Fx ranged between 40 and 50% of the 75% MVC reference value. During this period, the fatiguing process did not induce the same EMG changes in the various muscles. Indeed, in SA, the RMS and MPF decreased significantly. The postural muscles yielded two different EMG features. On the one hand, RA and RF displayed a very significant RMS increase, while their MPFs showed a very significant decrease. On the other hand, TS displayed a significant RMS decrease and ES a highly significant one, while the MPF decrease was highly significant in TS, and was not observed in ES.

Discussion: The question is where the fatigue process is developing to such an extent as to cause complete exhaustion to occur so rapidly. The push primum movens, SA, might be considered to carry on the fatigue process, as the MPF decline is less rapid than force decrease, which would exclude fatigue recovery. However, the RMS decline is proportional to the Fx one. As the force exerted by SA, is largely submaximal, an increase in its RMS might be expected in order to oppose the fatigue development process. But this is not the case. Therefore, the results cannot support the hypothesis that effort ceases because SA contractile capacity is exhausted. At exhaustion, RMS values are increased in RA and RF, as compared to their value at the endurance time and even more at the onset of the constant push effort: motor unit recruitment (and firing frequency) can be supposed to increase continuously when push force decreases, in agreement with Stephens and Taylor [2]. Moreover, as their MPFs are declining drastically (more than 50%), it can be considered that these EMG features are the expression of severe muscle fatigue. In other words, exhaustion is very likely to occur in these postural muscles. On the contrary, TS and ES, the other two postural muscles, do not appear to behave in the same way as RA and RF.

It is suggested that the effort stops as a consequence of postural muscle exhaustion. These muscles make a major contribution to global efforts, in that they allow compliance with biomechanical requirements, in particular in preserving the distance between the Centre of Pressure and the Centre of Gravity, which must be proportional to the external force.

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152 - Fatigue-Related Changes in the Relative Activation of the Muscles Forming the Quadriceps Femoris with the Hip Flexed Versus Extended

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Introduction: The force produced by a muscle depends, amongst other factors, on its length. Therefore, the relative contribution of the rectus femoris muscle (RF; biarticular) to knee extension force could vary depending on hip angle. In contrast, hip angle would not influence the force produced by the vastus medialis (VM) and vastus lateralis (VL) (both monoarticular) muscles. The purpose of this study was to assess the relative level of activity of the RF compared with that of the VM and VL during a fatiguing contraction performed with the hip in a flexed compared with an extended position.

Methods: Twelve healthy adults (6 women, 6 men; 19-36 years) volunteered for the study. Subjects were seated either upright (hip at 90^o) or with the seat back reclined to horizontal (hip at 180^o) and knee extension force was measured with a transducer placed in front of the leg, just above the malleoli. Surface EMG electrodes were taped to the skin overlying the RF, VM, VL and hamstrings, in a direction parallel to the muscle fibers, between the respective motor point and the distal tendon. The main experimental task consisted of a fatiguing contraction, performed at both hip angles on two different occasions (at least one week apart). The fatigue task was a continuous isometric contraction at 50% of the maximum knee extension force, sustained until exhaustion. The variables of interest were fatigue-related changes in the Root Mean Square amplitude and the median frequency of the EMG signals for all 3 muscles.

RESULTS: EMG amplitude increased in all 3 muscles with fatigue. However, there was a greater relative increase in RF compared with VM and VL with the hip at 90^o, whereas this trend was reversed with the hip at 180^o ($p<0.05$). No such muscle by angle interaction was observed with the median frequency data ($p>0.05$).

DISCUSSION: These results suggest that hip angle influences the relative activation of the muscles forming the quadriceps femoris, with the RF showing a greater fatigue-related increase in activation compared with both vastii muscles with the hip at 90 degrees. This could reflect a greater mechanical advantage for the RF with the hip at 90^o compared with 180^o.

158 - SEMG as an Objective Tool to Assess the Responses of Car Passengers to Lateral Accelerations

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Introduction: Anecdotal reports from both car drivers and passengers have indicated problems with comfort during cornering. Previous works on automotive seat comfort have not taken into consideration the effect of lateral acceleration. Therefore, the purpose of this study was to objectively assess the muscular response of car passengers while cornering in order to compare different chassis-seat configurations.

Methods: Surface EMG signals were collected unilaterally (right-hand side) from the cervical erector spinae (CES), latissimus dorsi (LD), erector spinae (ES), external oblique (EO), vastus lateralis (VL) and tibialis anterior (TA) muscles of 13 subjects using Red Dot 2330 electrodes. Skin preparation and electrode placements were in accordance with SENIAM recommendations. Lateral acceleration was also recorded. Data were sampled at 2000 Hz with an anti-aliasing filter of 500 Hz. Two models of chassis and seat (A & B) were tested, giving four possible configurations (AA, AB, BA, BB: the first-mentioned letter refers to the chassis). Testing was performed on a track comprised of three right and four left corners. An approach velocity of 80 km/h was used for all corners. Two laps of the track were performed for each configuration, a combined time of 3 min 30 s. The configurations were tested in a random order 15 min apart. Owing to problems with the recording environment, data were retained for only seven subjects. Energy was calculated for each SEMG signal after exclusion of those spectral bands where electromagnetic interference was too large. The maximum energy for each corner was retained as the dependent variable with the corresponding acceleration as the independent variable. EMG data were normalized for each subject with respect to the BA configuration.

Results: Greater energy was observed for negative accelerations (left turn) as shown in figure 1 ($p < 0.05$). Muscle activation of levels of both VL and LD were significantly affected by the configuration tested ($p < 0.05$), and are shown in figure 2.

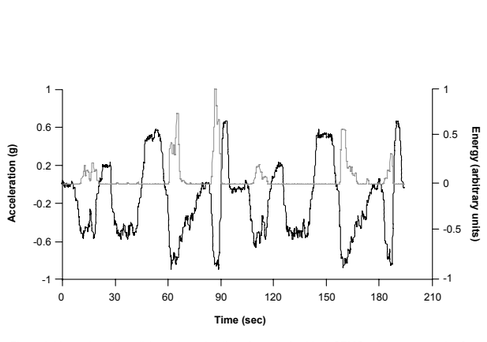

Figure 1. Vastus lateralis activity and acceleration of a typical subject. SEMG values are energies for band 2.

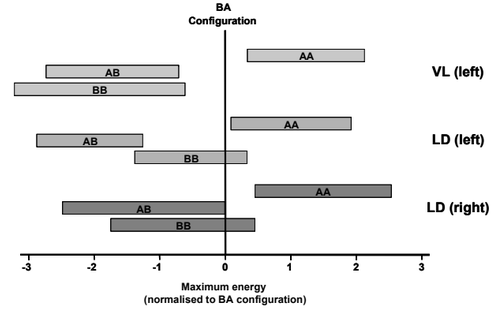

Figure 2. Muscle activity of VL and LD muscles. Values are 95% confidence intervals. The y axis confidence intervals. The y axis represents the BA configuration, which was used for normalisation

When configurations were ranked in terms of muscle activity for both VL and LD, seat A showed greater muscle activity than seat B. No differences were observed between chassis.

Discussion. The different levels of muscle activity observed between configurations could have an effect on comfort. If trials were to have lasted longer, configurations with greater muscle activity would be expected to induce fatigue earlier than configurations with lower activity. For instance, the greater VL activity for seat A could lead to thigh fatigue during long duration trials. SEMG can therefore be used to provide an objective measure of discomfort for car passengers subjected to lateral accelerations.

189 - Biomechanical Assessment of Gloves. A Study of the Sensitivity and Reliability of EMG Parameters Related to the Level of Activation and Fatigue of Different Forearm Muscles

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Introduction: Gloves are needed to protect workers from hand injuries but they also have adverse effects on task time, tactility, strength, dexterity and range of motion. The most popular method to assess the biomechanical effects of gloves is to measure the maximal grip strength. However, it appears better to assess gloves during submaximal tasks to better generalize the results to more functional or everyday tasks. The purpose of this study was to evaluate the relevance of a protocol based on EMG measures to assess the effect of gloves on the internal loading of forearm muscles during a submaximal handgrip task.

Methods: 15 males and 15 females performed isometric handgrip contractions of the dominant hand with the use of an handgrip dynamometer. Five maximal voluntary contractions (MVC) were performed (barehand) to get the maximal grip force and maximal EMG activation of each muscle (for EMG normalization). Then, three fatigue tests, consisting of a 60 s static handgrip effort at 35% MVC, were performed using a real-time visual feedback. The three experimental conditions, randomly assigned and separated by a 20 min rest period, were (1) barehand (control task), (2) with a moderately-stiff glove and (3) with a highly-stiff glove. Ten of these subjects performed the assessment twice, on separate days, to assess reliability. Surface electrodes were positioned on the flexor digitorum superficialis (FDS), flexor carpi radialis (FCR), extensor carpi radialis longus (ECR) and extensor digitorum (ED). From the EMG signals, series of 1 s windows of data, 80% overlapped, were processed to get the (1) RMS amplitude and (2) median frequency (MF) of the power spectrum. Linear regression was applied to the time-series of RMS and MF to get their intercept (RMS_i, MF_i) and slope values (RMS_{slp}, MF_{slp}), $NRMS_i$ (normalized to EMG_{max}) reflecting the level of muscle activation and MF_{slp} reflecting muscle fatigue.

Results: Only the EMG indices related to the relative activation of forearm muscles presented some potential to assess gloves, the EMG fatigue indices showing poor sensitivity and reliability results. The results from extensor muscles (ECR and ED) were more sensitive than flexor muscles to experimental conditions and were not influenced by gender. The $NRMS_i$ index corresponding to these muscles was the only EMG parameter able to detect differences between all experimental conditions. Bootstrap analyses revealed that only 6 to 8 subjects would be required to get a $NRMS_i$ (ECR and ED combined) estimate with a good precision (CV < 10%), which was not the case for MF_{slp} indices (> 30 subjects).

Conclusion: More research is needed to refine this EMG protocol. EMG fatigue indices are apparently not relevant to assess gloves, allowing us the removal of the fatigue task. To decrease the variability of EMG activation indices, several short handgrip contractions at 35% MVC would be of value to get an averaged and more stable estimation of muscle activation. This would be of interest to evaluate gloves performance, classify them and help glove manufacturer enhancing their products.

This project was funded by the Occupational Health and Safety Research Institute Robert-Sauvé (IRSST)

214 - Monitoring the Fatigue Process of Elbow Flexors in Sustained Maximal Contractions with Correlation Integrals

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Introduction: Innovative applications of non-linear time series analysis have recently been used to investigate physiological phenomena. For example, detecting epileptic seizure onset by monitoring the correlation integral (C) of the EEG signals has been demonstrated [1]. In this study we investigated the feasibility of using the correlation integral to monitor the localized muscle fatigue process in the biceps brachii.

Methods: Eight healthy young male participants (age range 21 to 28 yrs old) were tested. Each participant performed an isometric maximum voluntary contraction (MVC) until failure (decrease in net torque below 10% MVC) in elbow flexion (90° from neutral). The biceps SEMG activity and net elbow torque were measured using bipolar double differential surface electrodes (DELSYS) and a load cell (Futek), respectively, which were sampled at 5KHz using a data acquisition system (computer, LabVIEW, 16 bit A/D card). The data sets were divided into non-overlapping windows of 2048 sample points. For each window, we calculated the average torque and the correlation integral, which was calculated by first embedding the original time series $\{x_i\}$ to a higher dimensional space by forming a vector valued series $y_i = (x_i, x_{i+\tau}, ..., x_{i+(m-1)\tau})$ in $\Re^m$, for some lag time τ and for sufficiently large m. The correlation integral is then calculated as follows: $C(r) = \frac{2}{N(N-1)} \sum_{i<j\le N} \left(\Theta\left(r - \left|y_i - y_j\right|\right)\right)$, where $\Theta(x)=1$ if $x\ge 0$ and $\Theta(x)=0$ otherwise. Then C, at a specific r, is expressed in terms of time (Fig.1).

Results: A linear relationship between log(T) and log(C) (Fig.2) was observed with an average correlation coefficient of 0.75.

Conclusion: Our study suggests that the correlation integral can be used to study the localized fatigue process. Our results are also consistent with previous Recurrence Quantification Analysis (RQA) studies [2] in which the %determinism of the SEMG signal was found to increase with localized muscle fatigue.

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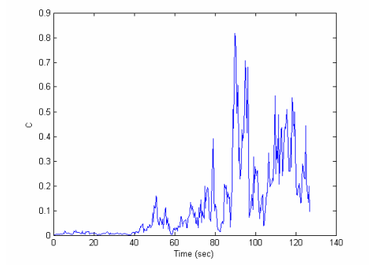

Figure 3 Correlation Integral Vs. Time

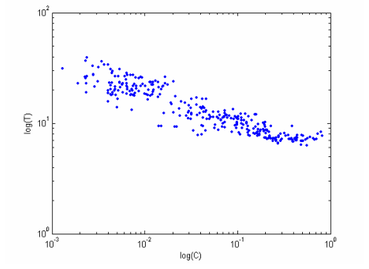

Figure 4 Log(T) Vs. Log(C)

217 - Changes in Voluntary Activation of the First Dorsal Interosseous Muscle with Low, Moderate and High Force Fatiguing Contractions

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Introduction: It is known that as a muscle exerts more force, the more rapidly the muscle will fatigue (force/fatigability relationship). A failure in voluntary activation (VA), or insufficient neural drive to the muscle, can contribute to the decline in maximum force during prolonged activity (central fatigue). However, it is still unclear to what extent central fatigue contributes to the force decline observed during contractions of different intensities. The purpose of this study was to compare the amount of central fatigue in the first dorsal interosseous muscle during and after fatigue tasks performed at low, moderate and high force levels.

Methods: Nine healthy adults performed four fatigue tasks on separate occasions. A given fatigue task consisted of sustaining one of four isometric index finger abduction force levels (30%, 45%, 60%, and 75% of maximum) until exhaustion. Trains of electrical stimulation were superimposed on maximal efforts performed before, during and after fatigue to assess the level of VA (interpolated twitch technique). Endurance time, the extent of VA (estimated from the relative amplitude of the extra force generated by the trains of electrical stimulation, above the voluntary force), maximum voluntary force, and resting twitch force were the main variables of interest. Repeated measures ANOVAs and paired t-tests were used to assess changes with fatigue and differences between the different tasks.

Results: Endurance time decreased as target force increased ($p<0.05$). Maximum voluntary force and resting twitch force were decreased after each fatigue task, and this was more pronounced for the tasks performed at low force levels ($p<0.05$). VA was equally high (~95%) before fatigue across the four different sessions. VA decreased significantly during and after the 30% task ($p<0.05$), but not for the other tasks.

Discussion: Central fatigue was present only for the fatigue task performed at the lowest force level. Therefore, it appears that for the first dorsal interosseous muscle, a decrease in VA can influence the shape of the force/fatigability relationship only for a range including relatively low forces.

218 - Using a Mathematical Model to Predict the Isometric Force-Intensity Relationship

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Introduction: Electrical stimulation of skeletal muscle can help patients with CNS damage to produce functional movements (FES)[1]. However, muscle fatigue limits the widespread clinical use of FES[1, 2]. To combat fatigue clinicians often increase stimulation frequency or intensity to maintain the required force output. Both, unfortunately, accelerate the rate and level of fatigue. Because stimulation factors such as the activation pattern, frequency and intensity affect the force production and fatigue of the muscle, it is important to identify the optimal combination of these three factors that produces the least fatigue for a targeted force. We have previously reported the development of a force- and fatigue-model system that accurately predicts muscle forces prior to, during, and post fatigue testing of human skeletal muscles with a wide range of frequencies and stimulation patterns[3, 4, 5]. This model aims to predict the changes in muscle forces when the stimulation intensity is modulated.

Methods: The current model was developed and tested on quadriceps femoris muscles (N=8) of healthy subjects at 4 different knee flexion angles (90^o, 65 ^{o}, 40 ^{o}, and 25 ^{o}) with stimulation trains of different patterns, pulse widths (100 ~ 500 μs), and frequencies (twitch ~ 80 Hz). All the testing trains were either 1 sec in duration or contained 50 pulses, whichever yielded the shorter train duration.

Results: The results showed that our model successfully predicted the forces produced when the muscle was activated with stimulation trains of a wide range of pulse widths, frequencies, and different pulse patterns. For more than 79% of the comparisons the experimental and predicted peak forces differed by ≤15%. For more than 90% of the comparisons, the predicted peak forces for each testing train matched the experimental peak forces with r^2 values above 0.9 for all intensities tested and at all four knee joint angles.

Conclusion: The success of the addition of an intensity component to our model system further supports the potential use of our mathematical models for the design of optimal stimulation patterns for individual users during functional electrical stimulation.

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227 - Neuromuscular Endurance in Ankle Muscles of Older Male In Relation To Level of Daily Physical Activity

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Introduction: Studies have demonstrated that ankle muscle weakness in elderly is associated with fall incidence. Currently, half of the elderly population of Japan do not perform habitual exercise training or vigorous physical activities. Therefore, we were interested in investigating whether a high level in daily physical activity (DPA) without exercise training improves ankle muscle function. The purpose of this study was to investigate relationships between DPA and the ankle muscle function in older males.

Methods: Nine healthy older male volunteers (73.7±2.53yrs, 1.64±0.06m, 64.5±8.7kg) participated in this study. After maximal voluntary isometric contraction (MVIC) of the dorsi- and planter-flexors, subjects were evaluated for neuromuscular endurance capacity. Each subjects generated force corresponding to 50%MVIC, then myoelectric (EMG) signals recorded from bi-polar surface electrodes on the tibialis anterior (TA) and soleus (SOL) muscles were band-pass filtered (5-1000Hz) and amplified for 60s. The EMG signals were digitized at a sampling rate of 1 KHz with 14-bit analogue-to-digital conversion. From six consecutive 10s integrated EMG (iEMG) value, the increase rate of iEMG (iEMG-slope) during the muscle contraction was calculated as index of neuromuscular muscle endurance capacity. The subjects were evaluated for DPA over a one-week period by pedometer. We examined relationships between DPA and muscle capacities, and also compared these muscle function parameters between in low (5,209±1,824 steps/d; n=3) and high PDA groups (10,624±760 steps/d; n=3).

Results: There were no significant relationships between DPA and MVIC of the ankle muscles. However, there was a significant correlation between DPA and iEMG-slope in the TA ($r=-0.71$, $p<0.05$), but not the SOL. iEMG-slope of TA in the high DPA group (0.14μV□s/min) was significantly lower ($t=2.86$, $p<0.05$) than that of the low DPA group (0.70μV□s/min). There were no significant differences in any other muscle function parameters between both groups.

Discussion: These results indicate that a high level of DPA is associated with greater neuromuscular endurance capacity of the TA of older males, which may be associated with reduced risk of fall in this cohorts.

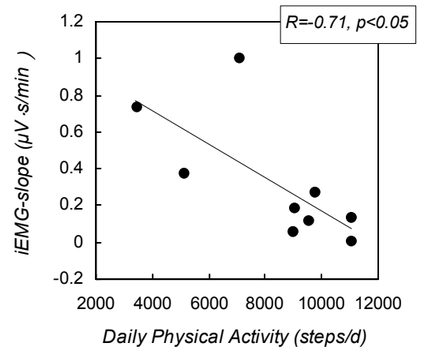

Fig 1.Relationships between daily Physical activity and iEMG-slope in tibialis anterior

326 - M-Wave Size is Influenced by the Range of Conduction Velocities and the Timing of Motor Unit Action Potentials

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Introduction: Reductions in the amplitude and area of the compound muscle action potential (M-wave) during a fatiguing contraction are often interpreted as indicating an impairment of neuromuscular propagation (1). In addition to variation in the number of motor units (MUs) that are activated by stimulation of the muscle nerve, however, the M-wave can be influenced by the temporal dispersion of the MU action potentials (2). The purpose of this study was to quantify the influence of MU conduction velocities (CVs) and activation times on the amplitude and area of simulated M-waves.

Methods: The study involved computer simulations that were based on models previously described by Fuglevand and colleagues (3), with the addition of a model of surface EMG that described each source as the generation, propagation, and extinction of an intracellular action potential along muscle fibers of finite length. Average fiber length was 40 mm and the end-plate and tendon endings had a spread of 5 mm. The volume conductor was described as a layered medium simulating the skin (1 mm), subcutaneous (1.5 mm), and muscle (radius 8.67 mm) tissues (4). The model produced MU action potentials consistent with the known physiological properties of a hand muscle. For each of the simulated conditions, 40 separate libraries of 120 MU action potentials were generated and the location of the MUs was varied randomly. Peak-to-peak amplitude and area of the M-wave were calculated by summing the MU action potentials in each library. A reference M-wave was obtained by assigning a CV distribution across the MU pool of 2.5 to 5.5 m/s, with a SD of 0.15 m/s for the CV of the muscle fibers in each MU. The parameters that were changed in the simulation included: 1) the range of MU CV values (3.5 - 4.5 m/s and 1.5 - 4.5 m/s); 2) the SD of CV for the muscle fibers in each MU (0 and 0.3 m/s); and 3) temporal dispersion in the activation times of the MUs (SD 1, 2, 3, and 4 ms). Results are reported as mean ± SD in arbitrary units (au).

Results: The reference M-wave amplitude was 454.4 ± 50.7 au and its area was 998.7 ± 75.5 au•ms. A reduction in the CV range (from 2.5 - 5.5 m/s to 3.5 - 4.5 m/s) increased M-wave amplitude (607.3 ± 42.0 au), whereas a decline in mean CV (CV range: 1.5 - 4.5 m/s) decreased the amplitude (398.9 ± 44.2 au). Variation in the SD of CV for muscle fibers within the MUs had little effect on amplitude: 460.3 ± 61.4 (SD 0 m/s) and 437.1 ± 53.6 (SD 0.3 m/s) au. An increase in the temporal dispersion in the MU activation times, simulating a variability among neuromuscular junction delays, caused a marked reduction in M-wave amplitude: 301.3 ± 54.2 au (1 ms), 191.9 ± 47.1 au (2 ms), 155.1 ± 37.8 au (3 ms), and 116.9 ± 21.7 au (4 ms). Relative to the reference M-wave, amplitude increased with a narrow range of CVs (+34%), but decreased with a 1-ms temporal dispersion in MU activation times (–34%) and a reduction in mean CV (-12%). The changes in M-wave area were less substantial than those for amplitude, but included an increase for the narrow range of CVs (+28%) and the decline in mean CV (+17%), and a decrease for the 1-ms temporal dispersion in MU activation times (-17%).

Conclusion: Because average CVs decline, and the CV range and dispersion of MU activation times change during sustained contractions, variations in M-wave size depend on more than the efficacy of neuromuscular propagation.

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354 - Analysis of Global Conduction Velocity Estimation from the SEMG

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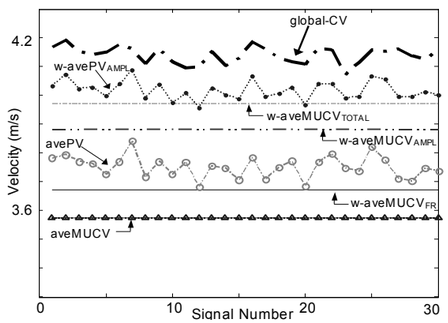
Introduction: The most common approach to conduction velocity (CV) estimation from the surface electromyogram (SEMG) is to determine a single estimate per data epoch 0.5 – 2 s in duration, referred to here as the global-CV estimate. However, as the SEMG typically comprises the electrical activity of a number of motor units (MUs), each with different motor unit conduction velocity (MUCV) values, a single estimate is inherently limited. Nonetheless, the global-CV estimate is commonly assumed to be an amplitude-weighted average of the MUCVs of all MUs within the electrode pick-up region[1]. This paper presents an analysis of the global-CV estimate using simulated SEMG data.

Methods: Three MUs, (with associated MUCVs, amplitudes & firing rates, Table 1) were used in these simulations. The relative phase shifts between the MU action potential trains were randomly varied to generate thirty independent SEMG signals. Average (ave) and weighted average (w-ave) MUCV values were determined from the simulation inputs. Individual peaks in the SEMGs were identified and peak velocities (PVs) and amplitudes determined, enabling average and weighted average PV values to be calculated. The weighed averages were derived using amplitudes (w-aveMUCVAMPL, w-avePVAMPL), firing rates (w-aveMUCVFR) and both amplitudes and firing rates (w-aveMUCVTOTAL). The global-CV was also estimated for each signal.

Results: Fig. 1 illustrates that, of all the averages and weighted averages, the amplitude-weighted average of the PVs is most closely associated with the global-CV estimate.

Figure *5* – Average and weighted average estimates. Note the four variables derived from the simulation inputs are constant for the thirty signals.



MU	MUCV (m/s)	|MUAP|	Firing Rate (Hz)
1	4.53	1.0	12 (0.90)
2	3.64	0.5	10 (0.86)
3	2.55	0.4	9 (0.82)

Table 1 - Parameters used in simulated SEMG signals. Each signal is 2 s in duration. MUAP amplitudes in arbitrary units. Mean (standard deviation) firing rates.

Conclusion: These results show that the global-CV is a close approximation of an amplitude-weighted average of the velocities of individual peaks in the signal (as opposed to MUAPs, as commonly assumed), illustrating its sensitivity to MU firing rates and interference.

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359 - An Ergonomic Evaluation of Physical Workload in Holding a Portable Device With and Without the Use of Strap Support: A Surface Electromyography Study Application

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Introduction: Due to significant advances in computer and communication technologies, recently hand held user interface devices are widely employed in various kinds of work places. It has been shown that the object characteristics (i.e., weight and its distribution, shape, and the availability of handling) may affect task performance. In a portable device, strap is one of the factors that might be influence biomechanical, physiological and psychological stress. The aim of the present study is to perform an ergonomic investigation of strap support in a specific hand held device (Graphic Order Terminal: GOT), and its effects on physical workloads, which was measured by electromyographic (EMG) recordings.

Methods: Six females participated as subjects. Experimental models of GOT (280×200×30 mm) in the four weights: 500, 750, 1000, and 1250 g, by a combination of two situations: with strap (W-strap) and without strap support (N-strap) were provided 8 experimental conditions. The procedure of test was designed repeated consecutively sessions for tasks of 2-hour duration in each test condition with a rest period of 45 s between sessions. Subjects were instructed to hold a GOT and asked to perform numerical calculations in each session. EMG activity of the four muscles: upper trapezius (TP), biceps brachii (BB), brachioradialis (BR), and flexor digitorum superficialis (FDS) on the left side of the body was measured. Signals from four channels in parallel, were transmitted telemetrically, A/D converted and stored on a PC. Mean power frequency (MPF) and integrated of EMG signals (iEMG) were analysed.

Results: The results of ANOVA showed significant main effect of strap on iEMG for BB. At W-strap, iEMG values of BB were approximately 2-3 times significantly lower than those at N-strap. There were significant interaction between strap and time for BB and BR. Two-way ANOVA revealed that for BR at N-strap condition, the effect of weight on both MPF and iEMG values were found near to significant. In the frequency analysis, for both BB and BR at the beginning of the test, at W-strap condition higher values of MPF was found than those at N-strap. This difference was highly significant. Regarding FDS, this study found significant interaction between the condition and strap for iEMG values. Results showed that for higher weight than 1000 g, iEMG values of FDS at W-strap were significantly lower than those at N-strap. After 30 min of the test, iEMG values of TP for W-strap was larger than those at N-strap, and increases of iEMG at W-strap was found significant.

Discussion: Past studies have shown that a manual handling of material performance is highly dependent on the method used to holding the load. Based on our results obtained from the experimental conditions studied, the factor of strap in portable device has been shown to be an important parameter in the design of manual holding tasks. One possible explanation for these results could in part be related to the biomechanical principles. It is well known in biomechanics that the effect of an external load on the human is very dependent on the location of the load relative to the body. Due to using strap support, different rate of physical loads were occurred on the muscles compared to the test at N-strap, which cause to changes in the level of force. This can be potentially influenced on EMG characteristics from a given muscle that exhibit different values at two conditions. In conclusion, the findings of the present study may be used by designer to more effectively choose an alternative in maximizing efficiency and minimizes muscular load activity in tasks that entail holding an object.

361 - An On-line Fatigue Monitor During Electrically Elicited Contractions

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Introduction: As claimed in previously published works, the availability of a real time EMG fatigue monitor is a tool of interest, for instance, in sport, space and rehabilitation medicine. A software was developed and patented for this purpose to monitor electromyographical manifestation of fatigue in real-time during electrically elicited contractions. The variable selected as fatigue index was the mean frequency (MNF) of the EMG signal spectrum.

Methods: The software allows to define protocols consisting of different sessions with different stimulation frequencies and durations. During the protocol, EMG signals (recorded with linear array of eight electrodes) are acquired, M-waves and the corresponding MNF are graphically shown in real-time on a PC. At the end of the protocol, the entire time course of the fatigue index during the sessions is stored. In addition, a number of parameters (initial value and rate of change), characterizing each stimulation session, are automatically extracted and stored. A protocol was designed to test the quality and the robustness of the method. For these purposes two groups of ten athletes (sprinters and long distance runners) were selected, assuming they fit at the extremes of the muscle composition range of variation in term of fiber types. Vastus lateralis (VL) and vastus medialis (VM) muscles were tested. The protocol was made by three different sessions: 1) basal (10 s at 2 Hz); 2) fatigue (30 s at 20 Hz) and 3) recovery (600 s at 2 Hz) for online monitoring fatigue and recovery by means of the fatigue index time courses.

Results: Results showed that the rate of change of MNF (both absolute and normalized with respect to the initial value) during the fatiguing session was greater in the sprinter group (-1.1±0.4 %/s) than in the long distance runners group (-0.75±0.25 %/s) for both muscles ($p<0.05$, Mann Whitney U test).

Discussion: These findings allow to confirm, according to previous literature results, MNF as a good candidate for on-line monitoring of the myoelectric manifestations of peripheral fatigue and to suggest its use to distinguish between different athletes' phenotypes, to monitor the effectiveness of rehabilitation treatments and of training protocols.

363 - Motor Unit Firing Rate and Surface EMG Amplitude Behavior During Maximal-Effort Fatiguing Contractions In Young And Older Adults

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Introduction: The inability of older adults to produce maximal force equal to that of younger adults is accompanied by a reduction in motor unit discharge frequency. However, previous work has shown that under certain conditions, older adults are able to maintain their normalized, maximal-effort force for longer periods of time compared to younger adults. The purpose of this study was to compare changes in individual motor unit discharge rates during maximal-effort fatigue in older and younger adults.

Methods: Seven younger (18-25 yr) and six older (>70 yr) females performed a muscle fatigue protocol involving 15 maximal isometric dorsiflexion contractions (30-sec) of the dominant tibialis anterior muscle, each separated by a 10-sec relaxation period. Indwelling action potentials from concurrently active motor units were detected with a four-wire needle electrode, amplified by a Dantec electromyograph, and identified off-line using custom template matching software. A trained operator manually ensured accurate identification of individual motor unit action potential trains. Surface electromyography (EMG) was detected using pre-amplified electrodes.

Results: The maximal force was determined during the initial 10 seconds of each contraction. The area under the force-time curve, root-mean-squared (RMS) amplitude of the surface EMG, and motor unit discharge frequency were evaluated for three seconds following peak force. Older subjects fatigued significantly less, as shown by a 13.2% reduction (pre-fatigue 35.5 Nm-s, post-fatigue 30.8 Nm-s) in maximal force area compared to a 31.8% reduction in younger subjects (pre-fatigue 43.9 Nm-s, post-fatigue 29.9 Nm-s) ($p = 0.035$). When repeated measures comparisons were extended across all 15 trials, a strong trend towards less fatigue existed in older adults ($p = 0.057$). Orthogonal polynomial comparisons showed a significant linear component ($p < 0.001$), with no higher order components. The RMS amplitude of the surface EMG decreased by 17.5% in older subjects (pre-fatigue 0.315 mV, post-fatigue 0.260 mV) and 32.9% in younger subjects (pre-fatigue 0.237 mV, post-fatigue 0.159 mV), however, this was not a significant interaction ($p = 0.582$). No significant age by trial interaction existed for RMS amplitude across all 15 trials ($p = 0.711$). Older subjects demonstrated a 17.4% decrease in motor unit discharge frequency (pre-fatigue 21.3 impulses/s, post-fatigue 17.6 impulses/s), while younger adults showed a 36.3% decrease (pre-fatigue 27.2 impulses/s, post-fatigue 17.3 impulses/s) ($p = 0.082$).

Conclusion: This study demonstrates that older adults may be less fatigable than younger adults as shown by a smaller reduction in normalized, maximal force production. The surface EMG amplitude decreased by similar amounts in both age groups suggesting less motor unit recruitment and a decrease in motor unit discharge frequency during the last trial. Older adults, however, showed a trend towards a smaller reduction in motor unit discharge frequency. Therefore, in addition to the greater force contribution of their slow twitch motor units, older adults may be able to maintain higher motor unit discharge rates to minimize fatigue during maximal-effort contractions.

369 - Analysis of Muscle Fatigue in Pathological Subjects During Biking

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Introduction: The biking exercise is widely used in clinical applications for rehabilitation or training purposes. Since during 30 minutes of biking pathological subjects show modifications in the activation pattern of their muscles and in their level of contraction, the quantification of muscle fatigue can be difficult. In this work, we propose a methodology for the analysis of muscle fatigue during biking that takes into account three parameters derived from the surface recorded myoelectric signal (SMES): the activation intervals of the observed muscles and their duration, the root mean square value of the SMES, and its instantaneous mean frequency (IMNF) during the activation bursts.

MATERIAL AND Methods: SMESs were acquired from the vastus lateralis (VL), biceps femoris (BF), and lateral gastrocnemius (LGSC) muscles of the subjects by means of single differential active probes, digitized by means of a 12-bit A/D converter, and bandpass filtered between 40 Hz and 350 Hz. The subjects were asked to pedal for 30 minutes at a constant rate of 60 rpm and exerting a constant power equal to 25 W. SMESs were acquired during epochs lasting one minute each and three minutes apart. We tested seven subjects affected by stenosis of the iliac or femural arteries. The degree of stenosis was previously assessed for each specific subject. To observe the activation pattern during biking, we processed the SMESs by means of a previously developed statistical detector. For each activation burst – approximately 60 per minute - we computed the average rms and IMNF of the signal. To lessen the variability of these parameters over each one-minute epoch, we applied a statistical outlier rejection procedure. Finally we considered the average value of the computed parameters over each one-minute epoch. Muscle fatigue was quantified by means of the percent decrement of the IMNF during the entire exercise.

RESULTS: The outlier rejection procedure proved to be essential for the quantification of muscle fatigue during biking: in fact, the variability affecting the observed parameters was reduced to approximately 30% of its original value. Our results showed that there is a good correlation between muscle fatigability and the symptoms reported by the subjects: ischemic muscles show significantly higher fatigability, lower SMES rms value, and shorter activation bursts than unaffected muscles. In terms of localized muscle fatigue, the IMNF percent decrement observed in ischemic muscles was always statistically higher than that observed in the same muscles of normal subjects performing a more intense exercise. Specifically, whether in normal subjects the percent decrement over a 30-minute exercise is generally lower than 1-2%, in some pathological subjects was higher than 10%.

DISCUSSION: Our results suggest that electrical manifestations of localized muscle fatigue are strongly correlated to the degree of ischemia affecting a specific muscle. Moreover, we observed that it is necessary to consider also the SMES rms value and the duration of the activation bursts to a) apply an efficient and effective outlier rejection procedure and b) explain the residual variability of the IMNF values. In conclusion, the test protocol adopted was suitable to pathological as well as normal subjects and allowed us to quantify the effects of ischemia on muscles fatigability. Currently we are applying the same protocol to the longitudinal assessment of subjects suffering from vascular diseases of the lower limbs enrolled in rehabilitation programs to objectively quantify the improvement of their conditions

395 - The Effect of 1 KHz NMES on the Fatigue of Wrist and Finger Flexor Muscles

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Introduction: The selection of a frequency for neuromuscular electro-stimulation (NMES) training is important for increasing muscle size. However, the fatigue that is induced by such training can be a disadvantage to the technique. For NMES frequencies between 1-15kHz (amplitude modulated at 50 Hz), it has been shown that training using stimulation frequencies of 1 kHz led to the highest torque production. However, the immediate effect of this stimulation frequency on muscular fatigue was not studied [1]. The objective of this work is to analyze the fatigue effect of NMES at this optimal stimulation frequency.

Methods: 20 healthy females (age range 18 -22; mean = 19.35 ± 1.34) participated in the study. The NMES was performed using the DUALPEX 961 – QUARK neuro-stimulator. The electromyographic (EMG) signals were acquired from sensors placed longitudinally in the ventral region of the flexor muscles of the wrist and fingers, in the non-dominant hand. The EMG and NMES sensors were located at the motor point, which was identified using a monophasic Faradic current set to 50 Hz frequency. The subjects were randomly assigned to two groups. One group (G1) performed isometric contractions at 40% of the maximum voluntary isometric contraction (MVIC) and the second group (G2) produced contractions at 70% of the MVIC, in order to assess possible differences due to motor unit recruitment. The EMG signals were collected during four 4s contractions at these % MVIC during different stages of the NMES protocol: a) before the NMES; b) after 15 minutes of NMES; c) after 30 minutes of NMES; and d) after 15 minutes of rest. The details of the stimulation protocol are presented in table 1.

Results and Conclusion: The average median frequencies at the 4 acquisition stages, for the two groups, are shown in figure 1. Although there is some visual variation in the median frequency for both groups, the results of an ANOVA test showed that there is no significant time variation in the EMG median frequencies for both groups (p=0.96 for G1 and p=0.14 for G2). The results suggest that the use of 1 kHz frequency NMES does not cause significant muscle fatigue. This feature may turn out be useful in the process of muscular training, since fatigue is considered an undesirable side effect of NMES. Although the results were not conclusive, they indicate that further investigation on this protocol, with a larger number of subjects, may be worthwhile.

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Parameters	G1	G2
M.V.I.C. (%)	40	70
Frequency (Hz)	1000	1000
Pulse width (µs)	200	200
Amplitude modulation (%)	50	50
Freq. of amplitude modulation (Hz)	50	50
Rise time (s)	2	2
Sustaining time (s)	10	10
Fall time (s)	2	2
Ton:Toff	1:2	1:2
Stimulation time (min)	30	30

Table 1 – NMES protocols

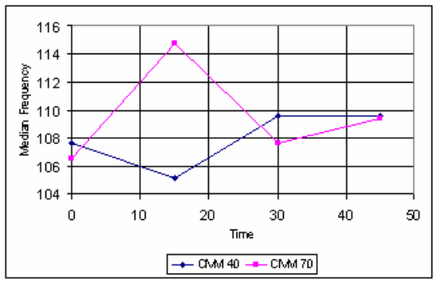

Figure 1 – Fmed for the two NMES protocols

404 - Comparison Between Fourier and Wavelet Transforms in EMG-based Muscle Fatigue Analysis

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Introduction: This work presents a methodology for analysis of localized muscular fatigue in intense isometric contractions of the brachial biceps muscle [1], based on wavelet transforms. The evaluation of the technique was accomplished by the confrontation of two operators: Median Power Frequency (MPF), computed with the Discrete Fourier Transform, and Median Power Scalar (MPS), computed with the Discrete Wavelet Transform. The MPF and MPS are used for characterization of muscular fatigue, which is associated with power increase in the low frequencies of EMG signals during intense isometric muscular contractions.

Methods: A signal data bank was built. Besides EMG signals, force signals were also acquired during the experiment. The experimental protocol was implemented in three stages. In the first stage, the methodology was presented to the subjects, and a registration of the Maximum Voluntary Contraction (MVC) was made, with the elbow of the subjects positioned at 90º in the right arm. Also, in the first stage, the measurement of EMG and force signals was performed. The protocol establishes that the subject starts with 60% of MVC, and the experiment continues until 40% of MVC is reached, as a result of muscular fatigue. In the second and third stages, implemented in different days, this process is repeated. The EMG signals were pre-processed by soft-threshold Daubechies-3 wavelet transform de-noising and then filtered using an FIR band-pass filter with cut-off frequencies of 20Hz and 500Hz. Since the data bank has three signals collected from each subject, and each signal has a different length, an interpolation process was applied, in order to get signals with the same length and signal averaging is performed. Finally, the pre-processed EMG signals were segmented using several rectangular windows of 250 ms. The MPF and MPS parameters were computed for each window and plotted against time, as muscular fatigue takes place.

Results: The average age was 28.3 years with standard deviation of 9.5 years, the average height was 1.75 m with standard deviation of 4.08 cm and the average weight was of 690.90 N with standard deviation of 64.26 N (g = 9.8m/s^2). The table shows a small sample of results of final perceptual values of MPF and MPE computed in experiment.

Conclusion: The experimental results have shown that MPF and MPS parameters have similar behavior. A significant difference can be observed when the original data signal is used without pre-processing with de-noising and filtering. The MPF parameter has shown a slightly higher dynamic range when compared with the MPS parameter.

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SUBJECT	% of MPFmax	% of MPEmax	SUBJECT	% of MPFmax	% of MPEmax
Subject A	45±12	57±10	Subject C	53±06	59±06
Subject B	55±09	61±08	Subject D	41±08	59±08

466 - Musculoskeletal Adaptations After Spinal Cord Injury are Prevented With a Minimal Dose of Daily Electrical Stimulation Exercise.

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After complete spinal cord injury (SCI), the skeletal muscles undergo significant adaptation leading to fast and fatigable properties (Shields et al. 1995, 2001, 2002). Loss of chronic activity is the likely mechanism underlying these adaptations. Moreover, the skeletal system loses bone density (osteoporosis) at the rate of 2-3 % per month leading to chronic fractures and other secondary complications including renal calculi. Renal failure is an important contributor to the mortality rate in individuals with chronic spinal cord injury. The purposes of this study were to 1) determine the temporal changes in paralyzed muscle after spinal cord injury; 2) determine the temporal changes in the skeletal system after spinal cord injury; 3) establish the extent to which these changes can be prevented via a daily exercise protocol using electrical stimulation and; 4) propose a new innovative method to load the lower extremity musculoskeletal system. We hypothesized that daily isometric contraction of the plantar flexion muscles (primarily soleus) would prevent the longitudinal changes (3 years) of increased muscle fatigue and decreased muscle torque associated with chronic disuse from SCI. We also hypothesized that the adaptations leading to decreased bone density would be attenuated during this program. Nine individuals (ages 21 to 57) with acute and complete spinal cord injury (< 3 months) received electrical activation of the calf muscle (isometric) for 5 days each week for 3 years. The opposite leg served as a control. The custom designed stimulator was programmed to deliver 120 contractions every 2 s for 667 ms on and 1333 ms off. The stimulator could be turned on only if there was detectable skin impedance. To measure compliance, memory within the stimulator recorded the date, time, and number of activations delivered. The intensity was supramaximal and was programmed into the stimulator. Plantarflexion (soleus) muscle fatigue, peak force, contractile speed, and cross-sectional areas (MRI) were analyzed every 3-6 months. Subject compliance was measured monthly and supported that the subjects were compliant. Bone density was measured at the hip, spine, femur, and tibia. Quantitative computerized tomography (pQCT) was also used to assess the tibia. The muscle fatigue index, contractile properties, and peak torque was maintained in the trained leg even 3 years after the SCI, while the untrained leg was significantly adapted ($p<0.05$). The trained leg was slow and endurant while the untrained leg became fast and fatigable. The trained leg was nearly 40 % larger in cross-sectional area than the untrained leg. The peak force increased in the trained leg while the untrained leg increased its peak force. The muscle cross-sectional area was 40% greater in the trained as compared to the untrained leg. Near 100 % compliance with the prescribed dose was necessary to optimally maintain the muscle properties. The trabecular bone was nearly 20% greater in the trained leg as compared to the untrained leg. These findings provide evidence to support that less than 16 minutes of activity per day was adequate to prevent muscular and skeletal adaptations after SCI. This study included a within subject control so that the impact of daily exercise could be ascertained within the same subjects. Given the findings of this study, we have now designed a functional method to load the entire lower extremities to maintain the musculoskeletal properties after spinal cord injury. The implications of this newly developed system will be discussed.

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Neurophysiology

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029 - Estimation of Postsynaptic Potentials in Human Motoneurons

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We describe a new method for estimating the sign and the profile of stimulus-induced compound postsynaptic potentials as well as common input potentials in human motoneurons. To develop and test this method, we injected currents simulating evoked synaptic inputs or common synaptic drive into hypoglossal motoneurons in rat brain slice preparations. We injected a current step with superimposed noise to evoke repetitive discharge with mean rates and interspike interval variations similar to those observed tonically active human motor units. We then added a train of injected current waveforms that developed single, double and complex PSPs and excitatory, inhibitory and mixed common input potentials in order to simulate the assumed membrane potential changes in human motoneurons in the literature. We then examined the discharge of the motoneuron spike data using both the probabilistic and discharge rate analyses in parallel to find out the best representation of the size and the profile of the injected current and changes in membrane potential. Our results indicate that the probabilistic analyses such as the PSTH and the rectified averaged SEMG illustrate not only the underlying current but also errors that are generated by the advancement or delay of the spikes. These phase-advanced or -delayed spikes (count-related errors) are followed by secondary and tertiary peaks and troughs due to synchronization of the spikes in relation to the stimulus/spike (synchronization-related errors). These errors are minimized when the discharge rate information is used in a peristimulus / perispike frequencygram (PSFreq) and used along with the probabilistic analyses. We therefore recommend that the researchers who estimate the synaptic or common input potentials in human motoneurons seriously consider using discharge rate analyses together with the classical probabilistic analyses.

066 - Motor Learning of Hands in Patients with Parkinson's Disease

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Introduction: The involvement of the motor cortex in learning movements has recently attracted much attention. Transcranial magnetic stimulation (TMS) has proven to be a valuable and non-invasive tool for investigation of the central motor system. The aim of this study was to evaluate the differences in motor control reorganization between PD patients and normal control during thumb exercise with and without rhythmic sound assessed by the directional change of TMS-induced thumb movements.

Methods: 12 Parkinson patients aged 52-77 years (65.1±7.5) and 9 normal age matched volunteers 45-75 years (64.3±8.5) were included in this study. Parkinson's patients were divided in two groups according to presence and absence of freezing phenomena. Type I (n = 7, 6 males and 1 female, 68.1 yrs± 6.3), those had freezing phenomena. Type II (n = 5, 2 males and 3 females, 61.0 yrs±7.7) who did not have freezing phenomena. According to Classen's method, the changes in the direction of thumb movement due to motor training or thumb movement exercise such as extension with and without rhythmic sound executed on a splint of a strain gauge which is attached with a highly sensitive amplifier (WGA-710 A) were recorded by Neuropack Σ using 50 Hz and .01 Hz as high and low cut filter. The TMS induced directions of movement with sound and without sound were compared from the graphic plot.

	5 minutes exercise		10 minutes exercise		15 minutes exercise	
	Self-paced	Metronome-paced	Self-paced	Metronome-paced	Self-paced	Metronome-paced
Normal (n=5)	166±7.8	204±6.6	352±20.2	360±14.7	414±20.7	420±13.3
Non-freezer (n=4)	132.5±8.2	150±10.1	252.5±3.0	295±6.6	377.5±14.9	400±7.5
Freezer (n=5)	174±7.7	210±11.3	236±5.6	362±9.8 a	320±4.6	490±16.0 b

a b p= .022 and .018 respectively (two tail paired t- test)

Results: To initiate a change of movement direction, 5 minutes thumb extension exercise was required in most of the subjects (14 out of total 21 subjects). 10 or 15 minutes continuous training were required to initiate a change of TMS-evoked movement in two occasions. Four subjects (3 normal and one PD patient) did not produce a directional change in TMS-induced movement but a trend of reduced amplitude has seen in those subjects. PD patients with frozen phenomena showed poor change in direction of TMS-induced movement after self-paced movement, the marked change in direction of TMS-induced movement was observed after training with auditory cue (Metronome-paced).PD Patients with non-freezing phenomena showed good effect with auditory cue and produced a similar result as the normal control subjects. And, this change of directions of MEP-induced movement in PD persisted even after the interruption of training, as similar as in normal control subjects. Table showed

differences of TMS-induced movement amplitude (gm) at self-paced and metronome-paced rhythms between time intervals in groups.

Discussion: In accordance with other studies we could also show that short training of thumb movement exerted a change in TMS-evoked movement direction suggesting a transient change in the representing cortical area. There are two routes in voluntary movement in the nervous system. The decreased function of basal ganglia due to PD impaired the route from basal ganglia to the supplementary motor cortex. These data suggested that the route from sensory input to cerebellum to premotor cortex could compensate for the decreased function of the route via basal ganglia to premotor cortex. Once the change in the motor cortex occurred, the change persisted even after the interruption of training. These suggested that the motor memory could be stored in the motor cortex in PD patients similar to normal control.

081 - Effect of Sustained Volitional Muscle Relaxation on the Excitability of the Anterior Horn Cells: Comparison between the F Wave and Transcranial Motor Evoked Potential (MEP)

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F wave and transcranial motor evoked potential (MEP) recorded from the abductor policis brevis in 10 and 6 healthy subjects showed a progressive suppression after 1,3,6 and 12 hours of volitional muscle relaxation. Both responses recovered quickly upon a brief, standardized voluntary muscle contraction. These findings indicate 1) MEP amplitude commonly used as a measure of cortical excitability reflect at least in part, a reversible suppression of the anterior horn cell, and 2) the absence of F wave, usually taken as a sign of conduction block of the peripheral motor axons, may also result from in excitability of spinal motor neurons after volitional immobilization.

084 - Electrophysiological Examination of Pyramidal Tract Functions in Patients with Subacute Myelo-Optico Neuropathy (SMON) Studied By Magnetic Stimulation

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Introduction and Objects: In order to investigate the subclinical disturbance of pyramidal tract functions in patients with subacute myelo-optico –neuropachy(SMON), magnetic stimulation was applied to the motor cortex and the spinal cord.

Methods: The motor evoked potentials(MEPS)were elicited from the abductor pollicis brevis muscle and abductor hallucis muscle by the transcranial magnetic stimulation of motor cortex. The central motor conduction times(CMCTs) were calculated from latency differences between the MEPs elicited from motor cortex and cervical cord or the MEPs elicited from motor cortex and lumbar cord.

Results: As the results, CMCTs from motor cortex to cervical roots were in normal range in SMON patients, but the CMCTs from motor cortex to lumbar root were significantly prolonged in 24 cases of moderate and severe cases. In 6 cases of severe cases, evoked potentials could not be evoked from the leg muscle by transcranial

magnetic stimulation. Furthermore, in mild cases having not the pyramidal tract signs, 5 cases out of 6 cases also showed the prolonged CMCTs.

Discussion: The CMCTs elicited by transcranial magnetic stimulation reflect the disturbance of pyramidal tract1,2,3). In the SMON patients with the disability of severe or moderate degree, the pyramidal tract signs were also clinically involved as well as the paresthesia which is the main symptom of SMON. However even in SMON patients with

mild disability scale involving no pyramidal tract signs, the CMCTs were also disturbed. Since the CMCTs elicited by transcranial magnetic stimulation reflect the subclinical disturbance of pyramidal tract signs. Our results suggest that the presence of subclinical pyramidal tract signs even in the SMON with the mild degree.

Conclision: The CMCTs elicited by transcranial magnetic stimulation reflect the subclinical disturbance of pyramidal tract. These results in SMON may suggest that the magnetic stimulation is beneficial for evaluating the subclinical disturbance of pyramidal tract signg even in the SMON patients with mild degree.

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108 - Changes of Auditory Tone Modulates Human EEG Activity

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Introduction: Cortical activity relating to auditory stimulation has been widely studied by auditory brainstem response (ABR), and electroencephalogram (EEG). Generation of components of ABR has been investigated using simple auditory stimulation, for example, click or burst sound. In contrast, EEG gives useful information about overall brain activity and recent work of frequency analysis of cortex. However, there are few studies showing the effect of changes of auditory tones on EEG activity. Therefore, to clarify a relationship between EEG activity and auditory tones, we investigated the power of Human EEG related changes of auditory tone.

Methods: Eight healthy student volunteers aged 21-25 years old were selected from students. All subjects provided informed consent for the study. All subjects were right-handed according to their writing and exercising behavior. None of them had a previous history of neurological illness. To investigate the activity of cortical potentials, EEG signals were recorded with digitally linked-ear reference from Fp1, Fp2, C3, C4, O1 and O2 of the 10-20 International System of electrode placement. Electrode impedances were all under 5 kΩ. The EEG signals were amplified by a bandpass of 0.5-60 Hz, with the 60-Hz notch filter in and digitized at the sampling rate of 2 kHz (EEG/DAE-2110 Neurofax NIHONKODEN). The alpha power spectra (8-13 Hz) were computed by a Fast Fourier Transform algorithm. Auditory stimulation was presented binaurally, through the headphone, at a level approximating 73 dB A-weighted sound pressure level. For the auditory stimulation, twelve pure tones, 30, 60, 100, 200, 400, 700, 1k, 2k, 4k, 8k and 10k (Hz), and white noise as a control were used. Auditory stimulation was 30 s in duration and performed randomly. During the experiment, subjects were seated on a comfortable chair with eye close.

Results

In most of the subjects, the EEG of the alpha power increased remarkably when subjects heard pure tones of 1 or 2 kHz. In contrast, when subjects heard pure tones of 4 kHz to 10 kHz the EEG of alpha power decreased (Fig 1). Pure tones under 1kHz did not show changes of the EEG of the alpha power in all electrode.

Conclusion: These results indicate that overall alpha power activity has a particular frequency response relating to changes of auditory tones. We assumed that a definite relationship exists between auditory tones and alpha power. This is shown by the specific characteristics of frequency response of brain activity generated by the different auditory tones.

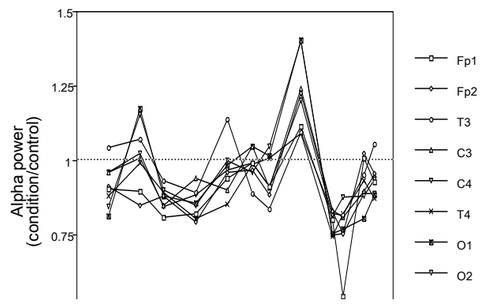

Fig.1 Example of alpha power for the changes of frequency of pure tones.

115 - Activity-dependent Plasticity of Spinal Reflexes Associated with Locomotor Training in Individuals with Complete and Incomplete SCI

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Introduction: Spinal reflexes are abnormal in individuals with chronic spinal cord injury (SCI). Movement disorders such as spasticity, co-contraction, clonus and flexor spasms may be related to disorganization of spinal circuits. This investigation assessed whether participation in a body weight-supported locomotor training (BWSLT) program resulted in more normal reflex activity.

Methods: Seven subjects with incomplete SCI and three subjects with motor-complete SCI participated. Data were acquired on the following neurophysiologic measures prior to and following 3 months of BWSLT:

1) Agonist-antagonist reciprocal inhibition (PI) was measured using a test-conditioning paradigm. The test response was soleus H-reflex elicited by tibial nerve stimulation. RI-conditioning of the H-reflex was achieved via common peroneal nerve stimulation 2–3ms preceding tibial nerve stimulation. 2) Presynaptic inhibition (PI) was measured with the same technique using a 10–25ms test-conditioning interval. 3) Low frequency depression (LFD) was assessed by repetitive H-reflex activation at 1Hz.

Results: Increased effectiveness of RI , expressed as increased agonist-antagonist reciprocal inhibition, was observed following training both in subjects with incomplete injury and those with complete injury ($p < 0.05$). While there was a trend toward increased PI and LFD, the difference between pre- versus post-training levels was not statistically significant.

Disussion: These data suggest that repetitive performance of functional activity may be associated with plasticity of some spinal reflexes. In the case of RI, increased effectiveness of inhibition may be functionally important for reducing agonist-antagonist cocontraction. It is hypothesized that spinal reflex normalization may form the basis of more normal motor output following training.

142 - Modulation of Motor Evoked Potentials (Meps) and Maximal Voluntary Contraction (MVC) After Ischemic Nerve Block

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Introduction: In rehabilitation of individuals with central nervous system (CNS) lesion, sensory stimulation is a common approach to facilitate motor response. However, the role of afferent input on the excitability of corticospinal tract is not known. The purpose of this study was to investigate the changes of the excitability of corticospinal tract after acute ischemic block of afferent input.

Methods: Ten healthy subjects participated with their upper arm being occulted by a blood pressure cuff inflated to 240 mmHg for 13 minutes. This ischemic protocol was previously proved to result in Ia block without the changes in the alpha motor neuron. The maximal voluntary contraction (MVC), motor evoked potential (MEP) of flexor carpi radialis(FCR) were recorded before, immediately, 5 min and 10 min after the ischemic block.

Results: The result revealed that the MVC and the amplitude of MEP decreased significantly after ischemic block (23% and 41% decrement, in respectively). After 5 min restoration of blood flow, the MVC almost recovered to the pre-test value (93% of initial) but the MEP did not (67% of initial). After 10 min restoration of blood flow, both the MVC and the MEP recovered to the pre-test values (3.5% and 1.6% decrement, in respectively).

Discussion: The afferent input influences the excitability of corticospinal tract at rest. The dissociation in the recovery of MVC and MEP indicates that the excitability of corticospinal tract at rest does not influence the voluntary force generating capacity. This study suggests that facilitation of corticospinal tract during rest may not be appropriate for the recovery of voluntary movement after CNS lesion.

145 - Electrically-Elicited Somatosensory Evoked Potentials in Drowsy and Awake States of Free Moving Rats

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Introduction: The multi-site recording techniques of electrocorticography (ECoG) data have been used for characterizing the activities among large populations of neurons involved in brain processing. The extraction of somatosensory evoked potentials (SEPs) induced by electrical stimulus for observing the brain processing can be obtained from the ensemble average of signals as well as from the time-frequency analysis of rhythms. The aim of this study was to analyze the SEPs of multi-site recording during drowsy and awake states for identifying the underlying brain information in free moving rats studies.

Methods: The male Wistar rats were first anesthetized and then transferred to stereotaxic apparatus for the implantation of multi-wire electrode located in primary somatosensory cortex (SI). During the experiment, sessions of the SEPs induced by electrical stimulus at rat's tail base were recorded. With the multi-site recordings, independent component analysis (ICA) was used to remove the electrical stimulus artefacts. The decomposed signals, reconstructed from the selected components based on the cumulative power spectra, were represented in a topographic form to observe the spatiotemporal distribution of the brain mapping. In addition to the ensemble averages of SEPs, time-frequency analysis was used to observe the time course of noise-free ECoG components in terms of rhythmic frequency of brain activity. The temporal changes of frequency distribution are essential to observe the dynamic changes of across stimuli during drowsy and awake states.

Results and Discussion: Our results indicated that the ICA can extract the dominant components of SEPs related to different vigilance states of somatosensory stimuli. The dominant peaks of averaged SEPs for drowsy rats were closed to those of the anesthetized condition. However, the multi-site SEPs recorded in the awake state exhibited different patterns. Moreover, dynamic changes of cortical rhythms were significantly different between drowsy and awake states which were confirmed by time-frequency analysis of multiple-site recordings. A more complete understanding of cortical rhythms could help to explain the nature and locus of regulation of brain activity. The techniques developed in this study would benefit the neuroscience studies of awake, free moving rats while performing neuropsychological tasks.

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190 - Intrinsic Activation of Human Motoneurons in Spinal Cord Injury

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It is common that after spinal cord injury patients develop a spastic syndrome that is characterized by hyperactive tendon jerks, increased muscle tone, clonus and involuntary flexor withdrawal and extensor spasms. These symptoms are very debilitating and distressing as they can interfere with residual motor function, produce pain and disrupt sleep. The neuronal mechanisms that produce muscle spasticity in the human remain largely unknown. However, recent studies from spinal cord injured rats have shown that the development of muscle spasticity is produced by a recovery of the excitability of motoneurons below the injury through the activation of dendritic persistent inward currents (PICs). These PICs produce sustained depolarizations of the cell (plateau potentials) and amplify and prolong the response of motoneurons to transient sensory inputs and ultimately generate exaggerated and sustained reflex responses characteristic of the spastic syndrome. Surprisingly, the redevelopment of motoneuron PICs occurs even though the levels of monoamines that facilitate PICs, such as serotonin and noradrenaline, are greatly diminished below the injury site.

Through the use of paired motor unit analysis techniques in the human we have been able to distinguish activation of the motoneuron from intrinsically mediated PICs from synaptically mediated activation. In this presentation I will provide evidence of enhanced PIC activation in motoneurons of subjects with spasticity from spinal cord injury and its role in producing prolonged and low frequency discharge of motoneurons.

219 - Changes in Motoneuron Synaptic Properties in Human Spastic Hemiparesis

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Introduction. Spastic hypertonia is a classic feature of injury to the neuraxis, often characterized by hyperactive stretch reflexes. The objective of this study was to compare estimates of excitatory postsynaptic potentials elicited by transient muscle afferent inputs, delivered to motoneurons innervating spastic and non-spastic muscles. By this analysis, we hope to provide insight into potential neuronal mechanisms governing the emergence of hyperactive reflexes in spasticity. Methods. Three men with left-sided hemiparetic stroke with spasticity and two neurologically intact men participated. All participants gave informed consent via protocols approved by the Institutional Review Board at Northwestern University. Unitary EMG and biceps brachii surface EMG, as well as elbow joint force were recorded, digitized and stored on a computer for subsequent analysis. Subjects were asked to maintain a constant flexor contraction at a designated force level, governed by the ability to identify and discriminate at least one MU firing at a relatively low rate of 8-11 Hz. The biceps tendon was then percussed with a position-controlled (2 mm) tapping device (Linmot, Inc.) at 0.5 Hz. Post-stimulus time histograms(PSTHs) and cumulative sums(CUSUMs) were constructed for all selected MU trials.

TABLE 1:

Hemispastic Subjects

Subjct		CUSUM RISE TIME		CUSUM AMPLITUDE	
	Ashworth(1(1+)-5)	Spastic Muscle	Non-Spastic Muscle	Spastic Muscle	Non-Spastic Muscle
	Affected side	Average (Std Dev)		Average (Std Dev)	
HS001	3/5	8.89 (1.45)	18.00 (1.79)	284.59 (53.63)	273.17 (51.21)
HS002	3/5	6.44 (1.94)	16.00 (2.14)	361.76 (74.92)	336.48 (32.36)
HS003	2/5	11.11 (2.26)	20.14 (2.05)	241.38 73.97)	264.09 (34.36)
Neurologically Normal Subjects					
		Left Muscle	Right Muscle	Left Muscle	Right Muscle
NN001	NA	22.01 (7.4)	16.59 (3.6)	115.74 (21.79)	174.66 (49.70)
NN002	NA	20.01 (4.3)	22.55 (7.5)	141.96 (69.67)	174.57 (50.39)

Results. 25 single motor units were analyzed from the paretic/spastic biceps and 24 units from the contralateral biceps of 3 stroke survivors. In the neurologically intact subjects, 14 units were recorded from the left biceps and 12 units from the right biceps. Table summarizes the results from all subjects. The table shows that there were no significant differences in the amplitude of the CUSUM between the two sides of our hemiparetic participants. However, we observed a substantial and consistent difference in the CUSUM rise time, with the average rise time value of the spastic muscle about half that on the spastic side. Similar findings emerged for motor units in all three stroke subjects. Comparable differences were not recorded between sides of the two neurologically intact subjects (Table 1).

Discussion The results of our study suggest there is no systematic difference in CUSUM peak values, and thus in estimated Ia EPSP amplitude between spastic and contralateral muscles of a hemi-spastic individual. There were changes however in PSTH and CUSUM time course, potentially reflecting the impact of muscle disuse. It appears that hyperexcitable stretch reflexes in spasticity result from mechanisms other than enhancement of Ia synaptic input, potentially including changes in motoneuronal properties, or changes in tonic excitatory drive. We are unable to distinguish between these possibilities in the present study.

258 - Effects of Task Instruction on Cortical And Segmental Reflex Excitability

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Introduction: Previous studies have indicated that the long-latency stretch reflex response (M2) is enhanced when subjects are instructed to resist the applied perturbation1. It has been proposed that this reflects an adaptive modulation that specifically influences the long-loop component of the reflex. Other authors have claimed that the facilitation of response size can be accounted for by changes in background electromyographic (EMG) activity2, or by incorporation of voluntary EMG in the M2 response3. The aims of the current study were to a) determine if the M2 response is modulated with task instruction when background EMG and the level of voluntary EMG activity are controlled, and b) investigate corticomotor excitability during the different task instructions and the relation, if any, to alterations in response size.

Methods: Stretch reflex responses were recorded in the biceps brachii muscle following a rapid extension movement of the elbow joint. Subjects were instructed to not intervene with (LET GO) or to resist (RESIST) the applied perturbation. Two velocities (SLOW, FAST) and two durations (SHORT, LONG) of perturbation were employed. The SHORT duration stimulus was insufficient to elicit a M2 in the target muscle, thus in the SHORT-RESIST conditions it was possible to identify the onset of voluntary EMG more easily. Perturbations were only delivered when the target muscle was at 5±2% of maximum voluntary activation. In half of the trials, transcranial magnetic stimulation (TMS) was applied over the motor cortex to examine corticomotor excitability in the different conditions. The response to TMS (motor evoked potential; MEP) was timed to arrive at the motoneuron at the onset of the M2 response. This meant that cortical excitability was probed at a time period approximately coincident with the arrival of an afferent volley from the imposed perturbation.

Results: EMG activity in the time period corresponding to the M2 response was significantly facilitated in the RESIST condition at all perturbation velocities and durations, whereas the short-latency response (M1) was unaffected. The increase in EMG evident at the LONG duration, where an M2 was present, was greater than that seen at the SHORT duration. This likely reflects a facilitation of reflex amplitude that is additional to any voluntary activation present. MEP amplitude at the M2 response was significantly larger than the sum of the M2 and MEP when presented alone. This facilitation of MEP amplitude was greater in the LONG duration perturbations (where a M2 was present) compared to SHORT duration and to a control condition in which the MEP was timed to arrive at the onset of the M1. MEP amplitude was further facilitated during RESIST compared to LET GO. Background biceps EMG prior to perturbation onset was equivalent in all conditions.

Conclusion: The long latency stretch response in the biceps muscle is enhanced during RESIST conditions independent of background EMG. This facilitation also cannot be accounted for by voluntary EMG in the M2 response, suggesting an adaptive modulation of the long-loop component of the reflex response. Corticomotor excitability is heightened during the time period corresponding to the passage of an afferent volley from the stretch passing through the cortex specifically in conditions in which a M2 response is elicited; this does not occur during the M1 response or when the perturbation is too short to evoke a M2. The significantly enhanced MEP amplitude during RESIST indicates a further increase in corticomotor excitability in this condition. This increase may contribute to the enhancement in M2 size when subjects resist the perturbation.

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270 - An Evaluation of the Utility and Limitations of MUAP Counts in The Surface EMG

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Introduction: Current surface electromyogram (EMG) processing methods such as amplitude measurement, power spectrum estimates, time-frequency representations and nonlinear dynamic analysis, etc. do not directly yield information about motor unit control properties. The number of motor unit action potential (MUAP)s appearing in surface EMG, which can be viewed as a product of the number of active motor units and the mean motor unit firing rate, better reflects the properties of the command from the central nervous system to control the muscle. In this study, direct counts of individual MUAPs were explored as a means to provide MUAP number estimates in the surface EMG.

Methods: Conventional surface electrodes routinely have a large pickup area, and the recorded EMG signals reflect considerable superposition of MUAPs from many motor units. This constitutes a major obstacle for identification of single motor unit activity necessary for direct MUAP counts. To reduce MUAP superposition, efforts usually focus on increasing the spatial selectivity of the recording method either by reducing the electrode size or applying a spatial filter [1,2]. We developed a surface electrode which has a tiny skin contact area for this purpose. The electrode was constructed from standard tungsten needles (FHC Inc. Bowdoinham, USA). The sharp tip of each needle was cut, and the cross section used as the recording surface of the electrode. The needles were connected to standard Delsys surface electrode (Delsys Inc. Boston, USA) by springs, providing a differential recording. Several data signal processing techniques were applied including signal de-noising, low pass differentiation, MUAP template description and MUAP detection, etc. MUAPs were counted at different force levels from the highly selective surface EMG recordings.

Results: Based on the application of this very selective surface electrode, we found that MUAP counts from surface EMG appeared effective at low force levels (<20% maximum voluntary contraction). However, with increase of the muscle contraction level, the difficulty of MUAP superposition still arose, causing deviation of direct MUAP counts from the (presumptive) actual MUAP number present in the signal. It was usually the case that some small MUAPs identifiable at low force levels could not be consistently counted at high force levels, a finding indicated by comparing the peak amplitude histograms of the MUAPs detected at different force levels. Because of this, it remains very difficult to build a reliable MUAP number-force relation up to middle or high muscle contraction levels from direct MUAP counts in surface EMG.

Discussion: MUAP counts are different from surface EMG decomposition. A central issue for MUAP counts (and also for surface EMG decomposition) is to optimize recording methods to reduce MUAP superposition, so as to increase the prospects for identification of individual MUAPs. To estimate the number of MUAPs in surface EMG which contains substantial MUAP superposition, rather than direct MUAP counts, indirect methods such as quantifying the relation between the MUAP number and some EMG processing parameters are pursued.

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272 - Can Standard Surface EMG Parameters Be Used To Estimate the Number of MUAPs in the Surface EMG?

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Introduction: Because motor unit action potential (MUAP) superposition occurs routinely in surface electromyogram (EMG) recordings, it is very difficult to estimate MUAP number by direct MUAP counts. In our current study, we use a simulation approach to examine the relations between the number of MUAPs in the surface EMG and the parameters derived from different kinds of EMG processing methods. Our primary aim is to evaluate the performance of standard EMG parameters for general motor unit firing rate estimation from surface EMG, with the view towards better interpretation of experimentally recorded surface EMG signals.

Methods: Surface EMG signals were simulated based primarily on reported properties of the first dorsal interosseus muscle in man. The simulation used various factors focusing on the relation between motor unit electrical and mechanical outputs, and on motor unit firing rate strategies, about which various and even conflicting observations have been reported [1-3]. The utility and limitations of using different EMG parameters for general motor unit firing rate estimation were evaluated based on their relation with respect to the number of MUAPs in the simulated surface EMG signals. The parameters evaluated in this study include the average rectified value of EMG, characteristic point (turn or zero crossing) counts per unit time, and the median or mean frequency the EMG power spectrum, etc.

Results: The simulation findings indicate that the relation between motor unit electrical and mechanical properties, and the motor unit firing rate scheme are both important factors deciding the form of the relation between surface EMG amplitude measurement and motor unit general firing rate. These factors appear to have less impact on the relation between the turn or zero-crossing point counts and the number of MUAPs in surface EMG. However, the number of turn or zero-crossing points tends to saturate with increase of the MUAP number in surface EMG. The simulation results also indicate that the mean and the median frequency of the surface EMG power spectrum is a poor indicator of the general motor unit firing rate.

Discussion: An "ideal" parameter for general motor unit firing rate estimation from surface EMG should satisfy two conditions: 1) its relation with respect to the MUAP number in surface EMG should be sensitive just to the MUAP number, and remain independent of other factors, so that uncertainties such as the twitch-MUAP relation and motor unit firing strategy will not influence the estimation result; and 2) its parameter magnitude does not saturate with increasing MUAP numbers contained in surface EMG, so it has enough resolution for general motor unit firing rate estimation at relatively high muscle contraction levels. Whether such an "ideal" parameter is available remains an open question.

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284 - Somatosensory Evoked Magnetic Fields Following the Saphenous Nerve Stimulation

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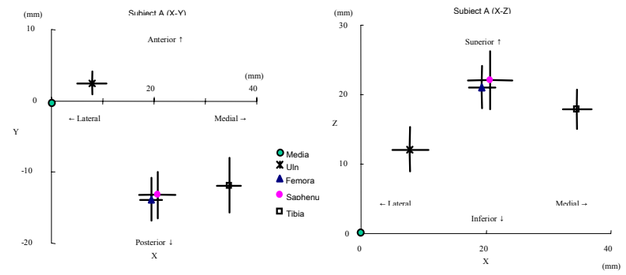
Introduction: The purpose of this study was to compare the latencies and distributions of the primary cerebral responses after stimulation for the median, ulna, tibial, femoral and saphenus nerves using somatosensory evoked magnetic fields (SEFs).

Material and Methods: Two normal volunteers participated in this study. Informed consent was obtained from each subject before the experiments. The right median, ulna, tibial, femoral and saphenus nerves were stimulated with an electrical rectangular pulse train at 2 Hz. We used a helmet shaped neuromagnetometer (Neuromag 204; Elekta-Neuromag, Finland) to measure SEFs. Data were digitally collected at 1000 Hz sampling rate with a low pass filter of 330 Hz and by on-line averaging 500 epochs. The ECD for the primary component was calculated in a single spherical model. More than 6 trials were performed for each nerve and mean ECD locations were used for evaluation. We compared the latencies and ECD locations among all nerves. The relationship among ECD locations was determined in the 3-dimensional frame referred to the ECD for median nerve stimulation.

Results: The peak latencies of the initial component of the SEF following stimulation of the median nerve was 21.0 and 20.8 msec (subject A and subject B), ulna nerve 23.7 and 23.8 msec, femoral nerve 30.9 and 33.5 msec, saphenus nerve 36.8 and 41.7 msec and tibial nerve 40.9 and 42.2 msec. Fig. 1 showed the mean ECD locations for individual nerve stimulation in the subject A. The ECD location for saphenus nerve stimulation was very close to that for femoral nerve stimulation in both subjects. The distance between ECD locations for saphenus nerve and tibial nerve stimulations was relatively large.

Discussion: Shimojo, *et al.,* [1)] reported the SEF following nerve stimulation of the lower limb except the saphenus nerve in 1996. We attempted to compare the various SEFs including that for the saphenus nerve at thigh. We conclude that the SEF for the saphenus nerve stimulation is also stable in its latency and ECD location, and feasible to detect the receptive fields of the lower limb as well as the SEF following the tibial nerve stimulation.

Fig.1. ECD location following stimulation of the median, ulna, femoral, saphenus and tibial nerves.



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295 - Input-Output properties in the Human Corticospinal Pathway and Intracortical Inhibition/ Facilitation Functions after Immobilization

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Introduction: Our previous study showed the input-output relationship (the so-called 'gain') in the primary motor cortex (M1) examined during fine motor output increased after immobilization compared to that before immobilization. First, the present study aimed to clarify the input-output relationship in the corticospinal pathway after immobilization again by means of precision analysis. The second purpose of this study was to reveal changes of function on intracortical inhibition and facilitation, which could be a background of the change of gain.

Materials & Methods: Eight healthy male adults aged 21-25 years participated in the present study. Their right leg was immobilized from the distal thigh with a plaster cast for 7 days. Measurements were taken before and after the immobilization. Surface EMG was recorded from the soleus. First the maximal voluntary contraction (MVC) force of the ankle plantar flexion was measured. Transcranial magnetic stimulation (TMS) was performed using a double cone coil to elicit motor evoked potentials (MEP) at rest and during 5%MVC. In the test stage after immobilization, the target level of the motor output during TMS adopted a ratio of the 5% root mean square (rms) to the maximal M-wave amplitude. TMS were composed of two kinds of sessions (single pulse, and paired pulse). The single pulse stimuli session included 6 to 11 grades of TMS intensities. The sigmoidal function was used to fit the data points of MEP amplitude during 5%MVC in order to clarify the difference of the gain (slope) of the input (stimulus intensity)-output (MEP) relationship before and after immobilization. The inter-stimulus intervals (ISI) of the paired pulse TMS were 3 ms and 15 ms.

Results: 1) Motor threshold after immobilization was not significantly different from that before. 2) Input-output relationship: At the resting condition, there was significant interaction of MEP amplitude between factors of stimuli intensities and test stage. MEP amplitude after immobilization significantly increased depending on the stimuli intensities. The slope of the sigmoidal curve adapted to a scatter plot of MEP amplitude recorded during 5%MVC was significantly increased after immobilization. 3) Intracortical inhibition/ facilitation: There was no significant change of MEP amplitude recorded after paired pulses of ISI 3 ms. A significant main effect of the conditioning stimulus intensity of ISI 15 ms paired pulses was found in MEP amplitude after immobilization.

Discussion: The present results indicated again that the gain in the corticospinal pathway during fine motor output was increased after immobilization though this contradicted the Faccini's report (2002). Increased intracortical facilitation after immobilization was found in parallel with the change of the gain

309 - Dynamic Asymmetry of Cerebrum with Sport Activity

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Introduction: The changes in asymmetry of cerebral interhemisperes (ACI) with physical load play a great part in moving activity of a athlet. There is a tendency to improve ACI with physical loads having monotonous characteristics to equalize ACI expressed much brighter with the persons who live in active life. The difference of frequency in amplitude characteristics EEG of both cerebral hemispheres and conventional negative wave (CNW) may serve as a criterion for psycho-physiological condition of cerebrum [2], particularly, strongly expressed with the representatives of sport games [3]. The tiredness of a athlet can be judged by changes in a number of functions shown in systematic researches in different periods of training [1].

Methods 15 basketball players were examined by means of tests and EEG left-handers (L), right-handers (R) and ambidextrous (A). All measurements were taken before in the middle of the intensive training and after it during the pre-competition period and physical load was increased by 30%-50%. The asymmetry was seen in a number of functional indices: muscular power, velocity quality, endurance. If the power of the right hand is F1and of the left hand is F2, the coefficient of asymmetry (CA) in per cents is CA=(F1-F2)/F 100. Moreover, if the level of CA is positive, the tested person is right-hander, and the negative is left-hander. Striking power has been fixed by means of the following formula: Fmax=mVcp\t, where m=0,05kg, V-S\t, t=0,01sec, S-30m.

Results: The results of EEG showed that the cerebral hemisphere opposed to leading limb shows more frequent electric activity (13-30h) than none dominating one (13h). With tiredness right-handers have the focus of electric activity in the left hemisphere (70%) and left-handers in the right hemisphere (20%) ambidextrous have also in the right hemisphere (10%). It is mentioned by oppression of α-rhythm and reinforcement of β-activity. In this case depression of α-rhythm is expressed more with right-hander in the left hemisphere, and with left-hander in the right one, and on the whole the reinforcement is registered in the intercentral tracts. Simultaneously with this, it is marked the increase of amplitude of biopotential on the leading limbs. The right and left hands of ambidectors show approximately the same results; the left hand of left-hander shows the result of 5 kg more; and right-handers don't show any stable results (from 2 to 13 kg). After physical load left-handers and right-handers` coefficient of asymmetry decreased and ambitectors` one didn't change. So, the velocity quality of the left-handers` leading hand is higher, but we aren't able to explain this fact yet.

Conclusion: 1. The coefficient of asymmetry and corresponding physiological indices are change in the presence of intensive physical activity. 2. All showing of left-handers are higher than right-handers, so they endure physical and psychological loads more easily. The results of throwing after the physical load has become worse with the right-hander as well as with left-hander and it hasn't almost been changed with ambidectors. 3. Right-hander in have much lower electric activity by amplitude and much higher one by frequency, but left-handers in it's perverted and with fatigue it's leveled.

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372 - Motor Unit Firing Patterns In Patients With Cerebellar Ataxia

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Introduction: Cerebellar ataxia refers to oculomotor signs, speech difficulties, abnormal gait and posture, and disturbances in limb movements. Although cerebellar ataxia is a very disabling disorder, there is no effective rehabilitation method for ataxic patients. The main reason is that mechanisms of cerebellar ataxia remain unsolved. Knowledge of motor behavior as a function of the lesion in the cerebellum is thought to enable prescription of selected rehabilitation therapy. Thus far, the behavior of motor units has not been identified in patients presenting an acute cerebellar injury or chronic progressive cerebellar degeneration. Consequently, we wished to analyze the motor unit firing properties in patients with cerebellar stroke.

Methods: We investigated the motor unit firing behavior of the first dorsal interosseous muscle during isometric contractions maintained at 20% and 50% of the maximum voluntary contraction (MVC) force in three patients with acute, unilateral cerebellar stroke. Prior to testing, all subjects underwent standard neurological tests and MRI imaging of the brain to quantify the extent and location of the cerebellar lesion. Electromyographic (EMG) signals were recorded via a quadrifilar needle electrode and subsequently decomposed into their constituent motor unit action potentials to obtain the motor unit firing times. Data collection and processing was performed in the clinic using the newly developed Precision Decomposition II system.

Results: On the affected side subjects displayed the classical signs of acute ataxia, such as ipsilateral weakness, target overshoot or undershoot, and large trial-to-trial variability, while attempting to track the force trajectories via visual feedback. These effects were much less pronounced on the unaffected side. Preliminary analysis on the firing behavior for motor units showed ordered recruitment and firing rate modulation consistent with a common drive activation of the motoneuron pool in both hands. The common drive on the unaffected side was less than that found in age-equivalent normal subjects. This observation warrants further study. One subject exhibited periods of tremor in the range of 3-4 Hz, which corresponded to large common fluctuations in the mean firing rate of concurrently active motor units. The tremor appeared to be induced by an excessive amount of common drive to the motor units and it diminished as the common drive diminished.

Discussion: Precise timing of the sequence of activation between distinct motoneurons is a prerequisite for accuracy in movement. Detailed information about motor unit firing patterns should prove useful to establish a correlation between the clinical signs observed in daily practice and the underlying behavior of motoneurons pools. In particular, recruitment threshold, firing rates and discharge variability in affected muscles could be determinant parameters in this clinical/neurophysiological assessment of cerebellar function.

Acknowledgements

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381 - Vestibular Influences on Human Muscle Spindles

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Introduction: For over three decades, research of the human fusimotor system has failed to find much convincing evidence to support the idea that human gamma motoneurones enjoy the same degree of independence from the alpha motoneurones as has been demonstrated in the cat. Evidence of robust projections from the vestibular apparatus in the cat suggests a direct role for vestibular information in modulating the fusimotor drive (Pompeiano 1972). Data has also been reported in human subjects suggesting an involvement of vestibular inputs in altering the volitional firing thresholds of muscle spindles, inferring modulation of fusimotor neurones (Burke et al. 1980). Our objective was to assess whether the background discharge of muscle spindles in relaxed leg muscles could be modulated by vestibular inputs.

Methods: A tungsten microelectrode was inserted percutaneously into muscle fascicles of the common peroneal nerve at the fibular head and manipulated until a spontaneously active muscle spindle afferent was isolated. Surface EMG electrodes were applied over the parent muscle, identified by its responses to intraneural electrical stimulation and the afferent responses to muscle stretch. The presence of fusimotor drive was investigated initially using voluntary ramp contractions. Examination of vestibular influences on fusimotor drive was then performed using Galvanic Vestibular Stimulation (GVS), a technique which alters the firing rate of peripheral vestibular afferents, independent of additional influences. Sinusoidal GVS (2 mA) was delivered at three different frequencies (0.2, 0.5, 0.8Hz) for 100 cycles while the subject remained in a relaxed seated position.

Results: We collected a total of 27 muscle spindle afferents (both primary and secondary), all of which exhibited a spontaneous discharge. GVS demonstrated a frequency-dependent modulation of the resting discharge of human muscle spindles in relaxed leg muscles, while producing a robust illusion of “rocking in a boat”. The modulation of spindle firing was shown to be phase locked with the sinusoidal vestibular perturbation.

Conclusion: The observation that there were no apparent increases in EMG concomitant to the increased spindle activity during the stimulation suggests that vestibular inputs can act on gamma neurones independently of alpha motoneurones.

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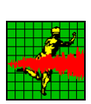

422 - Motor Unit Reinnervation and Control Properties in Intrinsic Muscles of a Transplanted Hand

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Introduction: more than 20 hand/digital transplantations have been performed so far in the world [2]. Sensory and motor recovery in these patients is conditioned by nerve regeneration [1] which was shown to take place rapidly in transplanted hands, even many years after the trauma. However, until now there has been no direct assessment of muscle control properties in transplanted hands. The main objective of this study was to assess the motor unit (MU) reinnervation process and control properties in intrinsic muscles after hand transplantation.

Methods: the Italian Hand Transplantation Program was approved by the Italian Health Ministry and the Ethical Committee of the University of Milan-Bicocca. The selected recipient was a 35-year-old male who had lost his right dominant hand in a farming accident when he was 13. The multiorgan cadaveric donor was a 43-year old male who died from a stroke. The surgical procedure was similar to that followed during hand replantation, and included bone fixation, revascularization with microsurgical anastomoses of arteries and veins, tendon repair or tendon transfer when necessary, microsurgical nerve repair, and skin closure [1]. The rehabilitation protocol started as soon as swelling subsided and was performed twice daily for 138 days, and once daily thereafter as the patient returned to work. The functional outcome of the transplanted hand was assessed by clinical sensory and motor tests. Multi-channel surface EMG signals were detected (-3 dB bandwidth 10-500 Hz, sampling 2048 samples/s, 12 bit, real-time displayed) by a linear array of 16 electrodes (2.5 mm interelectrode distance). The first experimental session was at day 205 postoperatively, followed by a second evaluation at 11 months and then monthly thereafter, until reaching 10 sessions. An additional session was performed four months later. The muscles investigated were the abductor digiti minimi (ADM), abductor pollicis brevis (APB), opponens pollicis (OP), first dorsal interosseous (FDI), and first lumbricalis (FL) of the transplanted hand. For each muscle, the subject was asked to perform a 60 s contraction at the maximal perceived force level. When a single MU was identified, the subject was provided with a visual feedback on the average firing rate of that MU and was asked to increase the firing rate from the minimum to the maximum in 60 s.

Results: eleven months postoperatively, the first MU action potential train was detected from the ADM. One month later, also the APB and OP muscles showed MU activity, while after 15 and 24 months the FDI and FL muscles, respectively, showed the first active MUs. An increase of the number of active MUs was observed after the first signs of reinnervation, although the process was rather slow. The subject was able to voluntarily modulate the MU firing rate by the visual feedback provided. The average firing rates of the detected MUs were within normal physiological values, although the presence of multiple discharges at short distance (12-20 ms) between each other was often observed. Stable average firing rates were never below approximately 8 or above approximately 45 pulses per second. In sustained maximal contractions the MU firing rate significantly decreased in all sessions, although encouragement to maintain a maximal activation. This indicated a potential peripheral reflex inhibition of MU firing rate with sustained activation, as in normal subjects.

Conclusion: for the first time, reinnervation of single MUs of intrinsic muscles after hand transplantation and central control properties of these muscles were analysed with new insights into the central mechanisms of muscle control.

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428 - The Effect of Forearm Position on the Size of Response to Transcranial Magnetic Stimulation in Human Extensor Carpi Radialis Longus

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Introduction: We proved in our previous study that the activities of the extensor carpi radialis longus (ECRL) were significantly higher in forearm pronation as compared with supination. We hypothesized that corticospinal influences in the ECRL differed with forearm position. The purpose of this study was to determine the effects of difference of forearm position on motor evoked potentials (MEPs) in the ECRL of normal subjects following transcranial magnetic stimulation (TMS) of motor cortex.

Methods: The experiments were carried out on 6 normal human subjects. They all gave their informed consent for the experimental procedure. The subjects sat on comfortable armchairs with their elbow flexed at 90° in a totally relaxed position. Their wrists were immobilized at neutral position by a splint. Their heads were fixed in a perpendicular bar clamped to the coil and fixed firmly under the coil. The hand area of the motor cortex was stimulated using TMS (Magstim 200, Magstim Company Ltd, UK); a standard round coil was used, with an inner diameter of 9 cm, while the right forearm was positioned in 1) *supination* and 2) *pronation*. Stimuli ranging from 70 to 80 % of the maximum stimulator output were used in the various subjects, so as to adjust the stimulus strength to about 1.5 times the motor threshold (with muscle at rest during forearm supination). Twenty stimuli were given to each subject during each forearm position. MEPs were detected through bipolar Teflon-coated stainless steel wire electrodes (AM system, USA) from the ECRL. The wire electrodes had the tips uninsulated a distance of 2mm and with an inter-tip distance of 5 mm. After electrode insertion by a trained electromyography technician, the placement was confirmed by electrical stimulation through the wire electrodes. EMG sweeps were amplified and band-pass filtered (20Hz to 3000Hz), digitized, and recorded on a PC. In both muscles, the responses in supination and pronation obtained at a common prestimulus background EMG levels were adopted. In addition, in four subjects, H reflexes in the ECRL were elicited by electrical stimulation of the radial nerve through the wire electrodes in both forearm position.

Results: MEPs were evoked in the ECRL in forearm supination and pronation. The amplitude of the ECRL obtained in forearm pronation was significantly greater than that recorded in forearm supination ($P<0.01$). The amplitude in pronation was about twice the size of that in supination. There was no significant difference of H reflex amplitude between two forearm positions.

Discussion: The cortical response to TMS is influenced by input from muscle receptors. The facilitation mechanism by input from muscle receptors may exist at both a spinal and cortical level. We observed statically significant increase in size of MEPs in pronation comparing with in supination, but we observed no significant changes in H reflex amplitude in both forearm position. These findings suggested that forearm pronation contribute to the excitability of corticospinal neurons in the ECRL. In addition, the excitability may be influenced by input from joint receptors and/or interosseous membrane because the ECRL doesn't have remarkable changes of the muscle length during forearm rotation.

Occupational Medicine

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008 - Static Load Repetition is a Risk Factor in the Development of Lumbar Cumulative Musculoskeletal Disorder

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Introduction. Repetitive static loading results in accumulation of creep in the lumbar viscoelastic tissues leading to a neuromuscular disorder, characterized by spasms during loading and hyperexcitability of lumbar muscles during following rest. The increased number of repetitions of static lumbar loading represents a major risk factor in the development of cumulative low back disorder. This study was designed to determine the influence of the number of repetitions as a risk factor in triggering a cumulative low back disorder in a feline model.

Methods. Static lumbar flexion of 10-min followed by 10-min rest was repeated three times in one experimental group, six in the second and nine in the third group. Creep development in the lumbar viscoelastic tissues and reflexive EMG from the multifidus were monitored in all groups during the flexion-rest periods and during the following recovery allowed (7 hours).

Results. Creep developed and accumulated during the flexion-rest periods in all groups, with larger residual creep at the end of the nine repetitions protocol. A residual creep was still present at the end of the 7-hour recovery in all groups. During the flexion-rest sessions, EMG spasms were present, and initial hyperexcitability was detected during the 7-hour recovery in all the preparations. Delayed hyperexcitability was revealed in the nine flexion-rest group, while it was not observed in the three and six flexion/rest groups. The statistical analysis (Post-Hoc Fisher test) performed on the NIEMG and displacement data during the recovery phase showed a significant difference between the nine repetitions group and the other two groups ($p<0.0001$). The ANOVA analysis showed a significant effect of time ($p<0.005$) and number of repetitions ($p<0.0001$) on all considered parameters during the recovery.

Discussion. It was concluded that a cumulative neuromuscular disorder develops due to repetition of static lumbar flexion, and the number of repetitions past a threshold point magnifies the severity of the disorder provoked.

042 - Muscle Activities of Emergency Medical Technicians (EMT's) During Patient Transfer with and Without Transfer Aids

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Introduction: Recent studies show high rates of low back pain and injury in EMT's, accounting for the greatest numbers (20–36%) of work injuries in as many as 25% of EMTs. Transferring patients from bed to stretcher was among the greatest risk factors. Therefore, this study examines muscle activities in transfers with and without transfer aids.

Methods: Four EMT workers servrd as subjects. Surface EMG electrodes were placed at the trapezius, upper thoracic (T3-4), lower thoracic (T8-9) and lumbar erector (L3-4) spinae, gluteus maximus, and biceps brachii. A 90kg male acted as the patient, laying supine on a bed. The subjects stood at either side of the patient, transferring him with 4 methods: No transfer aid, a 75X45 cm polyethylene board placed parallel to the patient, the same platform perpendicular to the patient, and the BeasyGlyder® transfer aid. EMG signals were collected at 1 kHz, and processed via Mean Absolute Value (MAV). MAV duration, integrated, average and peak were used to assess aspects of muscle effort. Split-Block ANOVA was used to analyze the results ($\alpha = 0.05$).

Results: In the bed side subject, effects of technique were found for the duration of the Biceps and LES activities; Maximum MAV was significant for the LTES. For the Average EMG level, there were significant effects in the Biceps, LES, LTES, and Gluteus. Integrated EMG was significant in the biceps and UTES. In the stretcher side, duration was significantly affected by method in all muscles except Gluteus. The maximum MAV had significant effect in the Biceps, deltoid and Gluteus. For the average EMG, there was significant effect in the deltoid, LTES, LES and Gluteus. Biceps, UTES, LTES, and LES also had significant effect.

Discussion: In most parameters with significant effects, the unassisted condition had values indicating greater muscle effort. Post hoc tests suggest that in general, transfer aids require less effort than not using one. There are other differences among devices, but the general pattern is that the Beasy-Glider and the parallel board have lower effort indices than the board perpendicular to the body. The devices help support the patient's weight and reduce friction. We conclude that these reductions in effort may lead to reduced incidence of musculoskeletal injuries.

049 - Neuromuscular Control of Neck Stiffness during Frontal and Rear-End Car Collisions

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The purpose of this study was to investigate differences in muscular coordination patterns of car occupants in frontal and rear-end collisions of small vehicles with low speed.

Six male subjects performed five frontal and rear-end collisions with a bumper car (speed = 2.6 m/s). The instant of collision and head move-ment of the occupant was recorded by accelerometers. Kinematic data was collected using side view high-speed video (1000 Hz). Body motion was related to car motion. In a 2D-model angular amplitude and angular velocity of defined joints located at the cervical spine, between head and neck (HN), neck and shoulder and at the elbow were analyzed in the sagittal plane. Myoelectric activity of specific neck, upper trunk and arm muscles of either body side was recorded using surface EMG. The signals were pre-amplified and digitized (1000 Hz) to a PDA. After online verification using W-LAN the signals were stored on a PC. EMG-Signals were rectified and filtered using the moving average (MA) method. The analyzed EMG parameters included time, mean amplitude (RMS) and integrals (iEMG) of pre-activation (prior to relative body motion) and main-activation (during relative body motion). RMS and iEMG were described relative to the maximum MA values of the respective muscles and subjects. In the statistical analysis a MANOVA was performed.

During rear-end collisions a nearly stationary head position observed in the first 70±6 ms of the crash could be attributed to head inertia. This caused significantly higher and earlier occurring maximum flexion in the HN joint and higher maximum extension in the other joints compared to frontal crashes. In rear-end collisions EMG showed reflex induced pre-activation of about 50 ms with low intensity for all muscles. They seemed to be insufficient to interlink the head to the forward motion of the trunk. Due to anticipation during frontal crashes all subjects demonstrated significant longer and higher muscular pre-activation. This probably enabled a muscular induced neck stiffness to interlink head and body motion. The results especially for the rear-end collisions may help to improve occupant safety in ongoing development of headrest concepts.

052 - Evaluation of back muscle strength and fatigue in healthy and low-back pain subjects: A comparative study of three assessment protocols.

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Introduction: Low back pain (LBP) disorders are among the most common musculoskeletal complaints of persons seeking medical care [1]. Excessive fatigability of lumbar paraspinal muscles is often associated with chronic LBP [2]. Muscle fatigue assessments based on surface electromyographic (EMG) techniques have been proposed for back muscle evaluation and classification [3]. Historically, three EMG-based measurement protocols have been used to measure back muscle fatigue isometrically. These three fatigue protocols have never been compared before with regards to their relative ability to induce back muscle fatigue and to discriminate LBP patients from control subjects. The purpose of the present study was to compare back muscle fatigue (EMG criterion) and strength of controls and LBP subjects while performing isometric back extension tasks using three different assessment protocols.

Methods: Thirty-one male volunteers (18 healthy, 13 with low back pain) were assessed on 3 different protocols: 1) standing in a dynamometer with the trunk in an upright position [4]; 2) standing in a semi-crouched position pulling against a force transducer attached to the floor [5]; 3) holding the unsupported trunk horizontally while lying prone on an examination table (Sorensen test) [6]. For each assessment protocol, back muscle strength (L5/S1 static extension moment) was measured during two maximal voluntary contractions (MVC) while back muscle fatigue, as quantified with EMG was assessed during a 50% MVC static trunk extension contraction lasting 60 s. Surface EMG activity was recorded bilaterally from 4 homologous back muscles (L5, L3, L1 and T10). The slopes of the linear regression of the EMG indices over time in the temporal and frequency domains were indicative of the fatigue rate.

Results: The LBP subjects presented low pain intensity scores (50 ± 1.8 – VAS) and low physical disability score (12 ± 7 – Oswestry). The back muscle fatigue and strength scores were not significantly different between the two groups in any of the three protocols. The EMG fatigue indices revealed that the Sorensen and upright position tests for both groups fatigued more the back muscles than the semi-crouched position test.

Conclusions: The LBP subjects offered a equivalent performance to healthy subjects relative to back fatigue and strength. In general, the Sorensen and upright position tests produced more back muscle fatigue as compared to the semi-crouched position test. However, a lack of control of lumbar lordosis during the semi-crouched position fatigue test may explain these results. None of the three fatigue tests led to between-group differences so it was not possible to identify which protocol was the most discriminative. Future studies comparing different back fatigue and strength assessment protocols should be performed to compare healthy subjects to more severely affected chronic LBP subjects.

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070 - Use of EMG Techniques in Ergonomics Analysis to Prevent Muscle-Skeletal Injuries in Industrial Jobs

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Prevention of muscle-skeletal injuries often presents a great challenge for those organizations who must solve this kind of problem. It is helpful to measure the ergonomic effectiveness of workplace interventiona and adaptation of a job. Otherwise, these interventions could be ineffective in practice.

The strategies of interventions to confront problems in industry that cause muscle-skeletal injuries, often includes::

To evaluate if the operations that are made in a job can cause a muscle-skeletal injury.

To identify in a job which is the operation or operations that have the greater incidence in producing damage, with the object to prioritize the ergonomic intervention to redesign the workplace.

To compare between two alternatives of ergonomic design or two ways to work and to decide which is the optimal one at the time of reducing effort.

To alternate different activities or jobs with the purpose of reducing the physical load and allowing a recovery of the worker.

This work presents three strategies of intervention by means of the use of surface electromyography in workers under real conditions of work in the industry. In the same one the different stages of preparation appear from the study, registry EMG, analysis of the results and program of intervention in the workplace.

Strategies of intervention:

Arrangement of interventions of ergonomic preparation within a complete work cycle by means of EMG.

Comparison of the local physical effort for two ergonomic designs.

System of rotation between jobs of a manufacture line by means of the use of elaborated graphical tools from EMG analysis.

The result obtained after ergonomics interventions has been satisfactory, as much by the improvements that were implemented in the job and which they were verified by the reduction of the physical discomfort perceived by workers and the reduction of labor disagreements. The effectiveness and efficiency of the EMG method in the workplace improve upon methods of observation and tabulation by means of ponderation tables of the risk.

095 - Comparative Study of the Women's Lumbar Concavity with 35 Weeks of Gestation and In Post-Partum Period through the Cifolordometry

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Introduction: the physical changes, which have occurred during pregnancy, undergo a subsequent modification during the post-partum period. A series of diminishing anatomical, physiological processes occur with the return of all the reproductive organs to normal and the gradual modification of the center of gravity. The post-partum woman will appear pregnant for several months due to the adjustments, which had been previously made and stabilized. The goal of this study was to quantify and compare the degree of lumbar concavity in pregnant and post-partum women through the use of the cifolordometer as well as to identify the amount of time needed to correct the lordosis curvature during the post-partum period.

Methods: twenty-five lumbar curvatures were evaluated through the cifolordometer in women who were in their 35th week of pregnancy and were seen at the "Unidade Básica de Saúde da Lagoinha" (Basic Health Center of Lagoinha), in Uberlândia, during the period from January to December 2002. Reevaluations occurred on the 30th, 60th, and 90th days post-partum. The sample was made up of 18 to 35 year-old women either in their first pregnancy (52%) or with multiple pregnancies (48%). The cifolordometer was used to provide a record of the curvatures of the spine along the sagittal plane in a rapid, efficient, and non-invasive way.

Results: the results obtained indicated significant differences, in accordance with the Wilcoxon test of significance, in the measurements of lumbar concavity in pregnant women at 35 weeks as compared with woman in the third month post-partum. Separating the volunteers into first-time pregnancies and multiple pregnancies and utilizing the same statistical test, a significant difference was obtained only in the first-time pregnancies looking at the comparison of the 35th week of pregnancy with the third month post-partum. Significant differences were also found in these women comparing the second post-partum month with the third. We did not obtain significant differences in the other comparisons, that is, the comparison of 30 and 60 days post-partum with 35 weeks and the comparison of curvature with the type of delivery experienced by the volunteer.

Conclusion: The results of this study that the alterations of the lumbar curvatures in the pregnant and post-partum women were quantified, significant differences were found, and that a minimum of three months post-partum is necessary to correct the lumbar curvature.

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156 - The Biomechanical Characteristics of Rotational Mobilisation of the Lumbar Spine

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Introduction: Information obtained would shed new light on the mechanical mechanisms of therapy.

Methods. Different magnitudes of mobilisation loads were applied onto the lumbar spines of twenty healthy volunteers. The initial starting positions of the spine were measured by electromagnetic sensors. Both of the motions produced during mobilisation and the load transferred to the lumbosacral junction were recorded. The mean amplitude of the oscillatory loads and movements were determined.

Results. The measurement method was found to be highly repeatable among the different trials, which have ICC value range of 0.697 to 0.994 (mean = 0.93). For the right rotation currently tested, subject was found to be initially positioned in a right axially rotated, flexed and slightly left side bended posture. The coefficient of mean axial rotation stiffness of the spine during grade I, II, III and IV were found to be 3.65 Nm/deg, 3.78 Nm/deg, 5.37 Nm/deg. 7.12 Nm/deg respectively.

Conclusions. The measurement method allows therapist to visualise the mechanical response of mobilisation in real time. This is useful for clinical assessment and decision making. Rotation mobilisation induced a complex loading pattern rather than simply twisting moment. The resulting motion pattern was also complex.

165 - The Effect of Abdominal Hollowing on Trunk Muscle Activation During Lifting

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Introduction: Lifting is a risk factor for low back disorders (Marras et al, 1995) with spinal instability associated with injury mechanism. Many therapeutic exercise regimes have been developed to enhance trunk stability through improved muscle co-activity. A group of exercises incorporate the Abdominal Hollowing (AH) manoeuvre to train neuromuscular control strategies for enhanced stability, however, the value of transferring AH to functional tasks has not been examined. The objective of this investigation was to compare the activation amplitudes of 5-abdominal and 2-back muscles for healthy subjects performing lifts using two techniques; their Preferred Lifting Style (PLS) and incorporating the AH manoeuvre. The results will help us understand how the AH affects muscle activity during functional tasks.

Methods: Healthy college-aged females (4) and males (12) performed a 2-hand lift of a 3.8-kg load 5cm off a surface (elbow height adjusted) using 3-horizontal reach conditions (normal, maximum, extreme). For each condition subjects were instructed first to perform the lift in their PLS and then using the AH technique. Conditions were randomized within each technique. Surface electromyographic signals were recorded from the lower and upper rectus abdominus, the anterior, lateral and posterior fibers of the external oblique, the erector spinae, and the multifidus during the lifting trials. Raw EMG signals were pre-amplified (500x) then further amplified (bandpass 10-1000Hz; CMRR 115dB, input impedance 10-Gohm) using a Bortec AMT-8 system. The raw EMG was sampled at 1000Hz using Labview TM and a 12 bit, National Instruments TM A/D card. Pelvic angle was measured using markers placed at L1 and S1 during the normal and maximum reaches. Each lifting trial was divided into a reach and lift phase. The Root Mean Squared (RMS) amplitudes were calculated then normalized to a Maximum Voluntary Isometric Contraction (MVIC) for each phase. Two 4-factor (subjects, reach, technique, muscle) repeated measures analysis of variance (ANOVA) models tested the main effects and interactions for each phase separately. Alpha was set at 0.05 for all tests and a Bonferroni correction was used for the post-hoc analyses of significant results.

Results: The ANOVA revealed a statistically significant reach*muscle and technique*muscle interaction ($p<0.05$) for both phases. For both phases and reaches, the external oblique muscle sites were activated to higher amplitudes for the AH technique than the PLS. The highest RMS amplitudes for the abdominals were found for the anterior external oblique site during the extreme reach condition using the AH technique (18% and 20% MVIC for reach and lift phases, respectively). The maximum abdominal activity for the PLS was 8% MVIC. The amplitudes of the back muscle sites were significantly higher ($p<0.05$) than all abdominal muscles for all conditions for both phase for the PLS, but not for the AH technique. Numerous significant differences were found among abdominal muscle sites for the AH technique whereas a higher anterior external oblique amplitude was the only significant difference among abdominal muscles for the extreme reach condition for the PLS. For the normal and maximal reach conditions and for both phases the pelvic angle was constant during the PLS, however, the pelvic angle was more posterior for the AH technique.

Discussion: In general, AH demonstrated differential recruitment of the abdominal muscle sites for both phases. The AH technique resulted in significant antagonistic co-activation of the external oblique muscle sites with the anterior fibers of the external oblique selectively recruited in extreme reach for both phases. For the PLS, the abdominal muscles were recruited to lower and consistent amplitudes suggesting the potential for greater spinal loading associated with the AH technique.

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193 - Manual Lifting Pattern Prediction Based On Key Postures

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Introduction: Alternative approaches have been proposed by researchers over the years of using the computer simulation with dynamic optimization theory to predict the kinematics of segmental coordination instead of employing a direct measurement method, such as the use of a specialized motion tracking system. In this study, we examined the hypothesis that an individual's joint trajectory can be approximately predicted based on major joint angle data coded only from photographic snapshots of four key working postures of a manual lifting video. A computerized postural coding and simulation program was designed based on this assumption. Laboratory experiments were performed to validate this method and to assess its applicability. The tolerance of joint loading estimates using this predicting method were compared to the results based on the joint data collected from a traditional motion tracking system under various lifting conditions.

Methods: Eight subjects participated in this study and were asked to perform various lifting. These combinations included three lifting ranges, three lifting speeds, and two loading conditions. An electromagnetic motion tracking system was used for comparative measurements of subjects' joint coordination. At the same time, a video camcorder recorded subject motion in a plane parallel to the subjects' sagittal plane. For each lifting trial, two biomechanical analyses were then performed, one using the data collected from the motion tracking system and the other using data predicted from the lifting pattern simulation results based on the posture coding method from video clips. The results based on the motion tracking system were referred to as the "gold standard," whereas the results generated from the prediction results of key posture coding was refereed to as the "prediction." A repeated measures analysis of variance was used to compare the difference between two approaches.

Results: Since peak spinal compression force of the lower back is one of several important factors often considered in analysis of a manual lifting task, this dependent variable was first selected to compare these two approaches in our study. The results showed that the mean difference tended to be small and most of the maximum absolute differences were less than 10%. The statistical analysis showed that, although there was a significant difference in the estimation between the "prediction" and the "gold standard," the practical mean difference was not substantial (about 109.2 N). There was no significant difference between the two methods caused by the load or the speed. But there was a significant lifting range effect. Additional analysis results showed that there existed a good correlation between the two approaches ($r^2 = 0.93$) of estimating peak spinal compression, with the prediction method providing slightly higher estimates.

Conclusion: For some industrial-based *in situ* analyses, this approach may provide an alternative for an analysis of the lifting tasks where a direct measurement method cannot otherwise be performed due to certain restrictions. The claim of this prediction method is not on the resolution of the measurement of complexity of the dynamic model. Instead, the significance of this method is that it may provide an effective means to quantify and exhaust the possible dynamic information from a single use of the video. However, further investigations still need to validate the accuracy and applicability of this prediction method to a wider range of lifting tasks that were not included in this study.

205 - The Influence of Different Unloading Positions Upon Stature Recovery And Paraspinal Muscle Activity

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Introduction: Rodacki et al. (2003) demonstrated that post-exercise stature recovery is significantly lower in individuals with chronic low back pain (CLBP), compared to healthy controls. As a consequence, individuals with CLBP are more exposed to the detrimental effects of prolonged spinal compression, such as increased intradiscal pressure and loading of the posterior elements of the spine, which have long been considered risk factors for spinal pain (Nachemson and Morris, 1964). It has been demonstrated that elevated paraspinal muscle activity subjects the spine to high compressive forces (Marras et al. 2001), which in turn could result in prolonged stature recovery. The aims of this investigation were firstly to determine if any difference exists in paraspinal muscle activity between individuals with and without CLBP, and secondly to examine the influence of different post-exercise unloading positions upon stature recovery and paraspinal muscle activity.

Methods: Eleven individuals with CLBP (age 33 ± 12.2 years, height 1.72 ± 0.08 m, body mass 75.9 ± 10.7 kg) and eleven matched controls (age 30.5 ± 9.7 years, height 1.75 ± 0.10 m, body mass 73.3 ± 11.7 kg) took part in the investigation. Following a loaded walking task (10% body mass) participants adopted four unloading positions on separate occasions (side lying, gravity inversion, supported sitting and hyperextension). Measurements of stature and paraspinal muscle activity were recorded at 5 min intervals for 20 min during each position.

Results: Individuals with CLBP exhibited significantly higher levels of paraspinal muscle activity and reduced stature recovery, compared to the controls, in all four unloading positions ($P < 0.05$). Both groups experienced significantly greater stature recovery and less paraspinal muscle activity during the gravity inverted position compared to the other unloaded positions ($P < 0.05$).

Conclusion: This investigation demonstrated that individuals with CLBP experienced less stature recovery and greater paraspinal muscle activity than individuals without CLBP during recovery from loaded walking. Elevated muscle activity would increase compression of the intervertebral discs and may reduce their capacity to regain normal height, thereby contributing to reduced recovery of stature. The role of the paraspinal muscles in the recovery of stature was further demonstrated by the gravity inverted unloading position, which resulted in the greatest amount of recovery in the presence of the lowest muscle activity. Further research is required to determine whether improving stature recovery has any clinical implications by reducing levels of perceived pain and disability.

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212 - Gender Influence on Fatigability of Back Muscles During Intermittent Isometric Contractions: A Study of the Neuromuscular Activation Patterns

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Introduction: Gender difference in the fatigability of muscles can be attributed to muscle mass (or strength), substrate utilization, muscle composition, and neuromuscular activation [2]. The purpose of this study was to assess the role of neuromuscular activation patterns to explain gender differences in back muscle fatigability during intermittent isometric tasks.

Methods: Thirty-one healthy subjects (15 males and 16 females) performed 3 maximal voluntary contractions (MVC) and a fatigue test to exhaustion while standing in a static dynamometer measuring L5/S1 extension moment [4]. The fatigue test consisted of repetitions of an 8-s cycle (1.5 s ramp to reach 41% MVC + 5 s plateau at 41% MVC + 1.5 s rest). *Strength* was defined as the peak MVC while endurance was defined as the time to reach exhaustion (*Tend*). Surface EMG signals were collected bilaterally from 4 back muscles (multifidus at the L5 level, iliocostalis lumborum at L3, and longissimus at L1 and T10). The median frequencies (MF) and root mean square (RMS) values corresponding to 80% overlapping 500 ms time-windows were averaged from the EMG signals of each plateau (3 to 5 s of data). Linear regression was applied to each time-series (MF and RMS of 8 muscles) to get the slope (*MFslp* and *RMSslp*) and intercept (*IMF*, *IRMS*) values. Likewise, linear regression was applied to the RMS time-series corresponding to the 1.5 s rest intervals (*RESTslp* and *IREST*). *IREST* and *IRMS* were both normalized to EMG maximal activation extracted from MVC contractions (*%IREST* and *%IRMS*). Finally, using RMS time-series (plateaus), variable load-sharing between back muscles was quantified [6,7].

Results: Males were stronger ($P < 0.05$) than females (316 ± 82 >196 ± 25 Nm) but showed significantly lower *Tend* values (7.1 ± 5.2 < 13.0 ± 6.1 min.), the latter result being corroborated by lower *MFslp* and higher *RMSslp* values (EMG criteria of fatigue). However, the gender effect on *Tend* disappeared when accounting for *Strength*. There were no gender differences neither in the initial activation of muscles (*%IRMS*), nor in the capacity to relax during rest intervals (*RESTslp* and *IREST*). However, females showed significantly more alternating activity (load-sharing) than males between contralateral muscles.

Conclusion: Gender difference in back muscle fatigue might be partly explained by the neuromuscular activation patterns. Gender differences were also observed in elbow flexors after immobilization [5]. However, these latter results identified a within-muscle activation strategy, that is different from the between-muscles alternating activity observed in the present study. Moreover, the immobilization paradigm might involve quite different motor control mechanisms. The finding that no *Tend* gender effect remained when accounting for *Strength* has been observed before [1,3] and supports the muscle mass hypothesis.

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242 - Relationship Between Nerve Conduction Studies And Preliminary Surface Electromyography Measurements On Carpal Tunnel Syndrome Subjects

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Carpal Tunnel Syndrome (CTS) is the most common human body entrapment neuropathy. Their prognosis and choice treatment are based on the disease stage, therefore bringing the need to understand each illness degree, modulated in mild, moderate and severe. The aim of this study was to verify which parameters of surface electromyography (SEMG) from thenar eminence (TE) muscles allow to differentiate healthy and CTS subjects, beyond to distinguish mild from moderate compression in CTS group, as well as the measures of nerve conduction studies (NCS), also called as invasive EMG. Twenty-three subjects had been selected in two groups, called CTS group (CTSG) and healthy group (HG). NCS was realized through the analysis of sensitive and motor parameters in accordance with You et al., 1999, and SEMG signals were acquired from TE muscles of both hands, using a differential surface electrode (with 10GΩ input impedance, 130 dB CMRR/2 ρfaraday, and 200 times of gain). SEMG data were acquired by sustained contractions (3 repetitions of 6 s, with 2 min of rest between them). The results showed that all NCS measures, except the motor potential amplitudes, had been able to differentiate significantly the mild from moderate CTS, while the preliminary SEMG data found (normalized RMS averages values) had not pointed out differences between mild and moderate cases, however, significant differences between HG and moderate CTSG appeared. The NCS founded results agree to literature, when pointing to the nerve conduction delay that does not occur only by myelin loss, but also due to a local ischemic compression, mainly in beginning stages of illness. In accordance to SEMG, this explanation seems to base the evidenced differences between HG and moderate CTSG. On the other hand, as these data are preliminary, this work still foresees the analysis of other SEMG parameters. These results allow concluding that the preliminary findings of SEMG had not been able to distinguish mild and moderate CTS, however distinguished HG from moderate CTS, apparently to coincide with the NCS motor parameters evaluations obtained.

285 - Effects of Back Pain on the Correlations of the Lumbar Spine and Hip

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Introduction: Low back pain is frequently associated with clinical changes in the movements of the lumbar spine and hip. Impairment of spinal mobility has been shown to result in various forms of functional disabilities, which have profound effects on the quality of life. An understanding of the kinematics of the lumbar spine and hip is clinically important as this would facilitate the development of effective prophylactic and rehabilitation programmes. The effects of back pain on spinal movements have been studied extensively [1-3], but information concerning movement coordination between the spine and hips is limited. The purpose of this study is to examine the effects of low back pain and limitation in straight leg raise on the kinematic characteristics of the lumbar spine and hip.

Methods: A real-time electromagnetic tracking system was used to measure the movements of the lumbar spine and hip. Kinematic analysis was performed in asymptomatic subjects (n=20), and back pain subjects with (n=17) and without (n=24) limitation in straight leg raise. Subjects were requested to perform forward, backward and side bending, and twisting of the trunk. One-way ANOVA was used to compare the maximum magnitude of movements among the three groups. Cross-correlation [4] was employed to reveal the relative time lag between lumbar spine and hips and the strength of correlation of the movements of the spine and hip.

Results: Back pain subjects exhibited significant reductions in the magnitude of spine movements in all directions, and limitation in straight leg raise was found to produce further decrease in the magnitude. Back pain was also associated with decrease in the magnitude of hip flexion, particularly in subjects with limited straight leg raise, but not hip movements in other directions. Back pain subjects were found to modify their joint coordination strategies, and their trunk velocities were significantly reduced. Cross-correlation analysis showed that the movements of lumbar spine and hip of back pain subjects were less coordinated for the movements in coronal and horizontal planes, but there was negligible time lag between spine and hip motions in normal and back pain subjects.

Conclusion: Back pain and limitation in straight leg raise are associated with significant changes in the kinematic characteristics of the lumbar spine and hips. It is clinically important to measure the movements of both the spine and hips to provide a complete evaluation. Future research should examine the effects of back pain on the mechanical characteristics of posterior hip tissues and their subsequent effects on spine and hip movements.

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358 - Surface EMG Signal Alterations in Carpal Tunnel Syndrome Patients. A Pilot Study

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Introduction: Carpal tunnel syndrome (CTS) is clinically assessed via needle electromyography. Many overuse syndromes are caused by degradation of the tissues rather than inflammation and some medical tests (such as Tinel's test) are of limited value due to their lack of sensitivity and specificity. For these reasons it is important to provide clinicians with objective tools for preventive monitoring of individuals exposed to a risk; this could increase the chances of early detection of the pathology before its definitive outcome. The aim of this project was to evaluate the differences in sEMG signals between healthy and pathological subjects at three levels of detail: visual inspection of the signal, "global" EMG variable estimates and single motor unit analysis.

Methods: Twelve volunteer female subjects participated in this study after giving informed consent. To compare two well distinct groups (symptomatic vs control), five patients (55.6±3.7 years, mean±SD) were selected from the group of 12 according to the following criteria: a) high severity of CTS diagnosis, b) long duration of occupational risk exposure and c) absence of surgical treatment. After this purging procedure, a matched control group of five healthy females (54.8±1.9 years, mean±SD) was selected. The opponens pollicis and flexor pollicis brevis muscles were selected for the study. They are both innervated by the median nerve. We investigated both their EMG signals and the force generated during a sustained isometric contraction. A tailored shell able to hold the wrist, the hand and the thumb in isometric position was designed and a load cell (full scale 50 N) was used to record the generated force in either flexion or abduction of the thumb. EMG signals were acquired with a linear array of 16 electrodes with 2.5 mm interelectrode distance. The protocol consisted of contractions lasting five seconds at different percentages (10%, 20%, 30%, 40% and 50%) of the maximal voluntary contraction (MVC) to assess the motor unit recruitment with respect to the contraction level. Further, one endurance contraction at 80% MVC was recorded to study the myoelectric manifestations of fatigue.

Results: Patients were, in general, unable to properly complete the protocol, in both muscles and for all the contraction levels. The interference patterns recorded from symptomatic subjects appear very different with respect to the control group: signals are characterized by separated motor unit activation bursts and low amplitude. Force values and initial values of conduction velocity (CV) were found, both in the flexor and in the abductor muscle, greater in the control group than in the CTS group ($p<0.05$ Mann Whitney U test). EMG signal spectrum mean frequency (MNF) initial values from the flexor muscle were found to be greater in the control group than in the CTS group ($p<0.05$ Mann Whitney U test). Normalized slopes of CV and MNF from the flexor muscle were found greater in the control group than in the CTS group ($p<0.05$ Mann Whitney U test). CV distributions (obtained from the CV estimates for each motor unit action potential pooled together within each group of subjects) were found different in both muscles and in all contraction levels (Kolmogorov-Smirnov test, always $p<0.001$). CV distributions mean values were found greater in the healthy group than in the symptomatic subjects in both muscles and in all contraction levels (Mann Whitney U test, always $p<0.0001$).

Discussion: According to needle EMG observations, chronic pathology seems to affect the motor unit pool recruitment strategy, determining a shift toward slow motor units characterized by lower CV, MNF and force levels in both flexor pollicis brevis and abductor pollicis brevis muscles. It is possible to conclude that the surface EMG technique is able to distinguish the CTS condition with respect to the healthy one. Further studies should investigate it as a tool to monitor different levels of CTS severity and subject exposed to occupational risks.

464 - Seats Padded With Gel Reduce the Activity of Back Muscles During Sitting

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Introduction: Foam is commonly used for padding surfaces that come in contact with the body for extended periods of time. The foam surface is compliant in the direction of the force and consequently conforms to the shape of the body surface, increasing the contact surface and reducing pressure points on the body surface. This distribution of pressure provides a more comfortable sensation and potentially modifies the activity level of muscles that maintain the body surface in the required posture. Gels, unlike foams, have the property of displacing in two dimensions; in the direction of the force and in the orthogonal direction. Thus, gels have the potential of providing a more conformable interface between the body surface and the support surface. This study was designed to investigate the hypothesis that a more conformable interface has the potential of reducing the necessary muscle activity, and therefore the force, required for stabilizing the back during seating.

Methods: Twelve healthy subjects, 7 females and 5 males (age range 20-34, weight 51-87 kg., height 158-182 cm) were tested. Four of the subjects were tested twice for reliability assessment. Two identical office chairs (Freedom^{TM} task chair, Humanscale Cop.) were used. One was equipped with a padding of standard polyurethane foam (36 mm thick); the other with padding of Technogel$^{®)}$ plasticizer-free gel, 24 mm thick fused to 12 mm of foam. Seat and back supports were adjusted to accommodate differences in subject size. Each subject was tested in both chairs during the same session. Subjects were required to sit quietly during a sequence of 5 sitting positions: 1) full back support, both feet on the ground; 2) full back support, one leg crossed over the other; 3) no back support, both feet on the ground; 4) no back support, one leg crossed over the other; and 5) leaning forward with both arms supported on a table. The positions were maintained for 20 minutes (positions 1 & 2), 5 minutes (positions 3 & 4), and 10 minutes (position 5). Six surface EMG electrodes were placed bilaterally over the Longissimus-L1, Iliocostalis-L2, and Multifidus-L5 muscles using an eight-channel EMG system (Bagnoli-8, DelSys Inc.). The sampling rate was set at 1000 Hz. Overall muscle activity was measured by calculating the Average Rectified Value (ARV) over the duration of the test. Variation in muscle activity was measured by the Coefficient of Variation (COV). A repeated measures ANOVA was performed to compare mean differences in these EMG parameters for the two test conditions (foam vs. gel).

Results: The data showed some definitive trends. In all three seating positions with no back support, all three muscles tested were activated to a lesser level when the subjects sat on the gel cushion as compared to the foam cushion. (In two of these positions, the Longissimus and Iliocostalis muscles were activated at a significantly ($p<0.07$) lesser level.) When the subjects sat with their backs against the back support and with both feet on the ground, the Longissimus muscle produced significantly ($p<0.04$) greater EMG signals when seated on the gel cushion. The COV was not different for the two cushion conditions. Reliability results for ARV and COV demonstrated no significant difference between the test and re-test conditions.

Conclusions/Suggestions: Preliminary results indicate that when subjects are seated with no back support, the lower back muscles are less active with the gel cushion than with the foam cushion. (The unsupported back position is the normal sitting position). One possible explanation is that the greater conformity of the gel cushion provides a more stable support for the pelvis which, in turn, requires less activity from the back muscles for stability. Whereas, the increased activity from the Longissimus muscle when the back was supported may be due to the requirement for contouring the surface of the back to the shape of the back support.

481 - Evaluation of a Cart for the Transportinon of Meals in a Hospital

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Moving loads is one of the most ubiquitous tasks in a hospital. Rarely the designer of means of transportation thinks on the effort the worker has to do to move. A hospital has asked us to evaluate a design for a cart to transport the meals.

METHODS. We obtained the characteristics of the cart from the designers. We defined that the following task could affect health: 1-Prepare the meal trays and introduce them in the cart as well as putting them back in the washing tunnel. 2-Transport the cart back and forth from the kitchen to the beds. We calculated the weight that the workers move with the trays by multiplying the unit weight of the tray by the number of trays moved, before and after eating. We used the NIOSH formula for recommended weight to evaluate the risk. The largest effort in moving the cart is the initial force for pushing or pulling needed to overcome the rolling friction. It was calculated using the formula F= (ro *weight)/ r. Where ro is the coefficient of rolling friction, w is weight of the cart and r is the radius of the wheel. The ro for initial force was obtained from Al-Eisawj. As their experiments did not included the radius of the proposed cart, we did linear interpolation form the data published. The acceptability of the initial force was based in the Snook and Ciriello tables.

RESULTS. A full loaded tray weights 4.5 kilos. The maximum acceptable weight that the fifth percentile worker could manage in the given conditions is also 4.5 kilos. A full loaded cart weights 265 k. and the wheel radio is the 75 mm. The initial force for pushing a tray with a wheel radio of 55 mm in tile floor is 11.2 Kp. For a wheel of 153 mm the initial force can be calculated to be 40% smaller in concrete floor. Applying this reduction, we obtain 6.7 Kp, within limits of tolerability.

DISCUSION. We could simulate the conditions of a new work implement and learnt that it is safe concerning loads. However, we could see that several characteristics could pose risk for the workers because of the design, namely, the lack of vision when the cart is loaded and the lack of passive brakes. We recommended to modify these issues

493 - Lumbar Load for Flight Attendants during Trolley Handling aboard Aircraft

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Introduction. In the context of service activities during short flights of commercial aircraft, flight attendants report on increased physical load and musculoskeletal complaints, in particular, with respect to the lower back, resulting from trolley handling during the ascent and descent flight phases. As musculoskeletal load was assessed hitherto only theoretically on the basis of container mass, friction, cabin inclination, and other task conditions, an interdisciplinary experimental study was conducted. Frequency and performance properties were determined aboard aircraft, postures and pull-or-push forces during trolley handling was measured in the laboratory. Evaluating the working capacity of the subjects participating in the laboratory experiments and of a larger group of German male and female flight attendants, the maximum isometric strength was measured for approx. 500 persons adopting various postures. In the paper on hand, the corresponding analyses on lumbar load during pushing and pulling the trolleys are described.

Methods. For quantifying mechanical indicators of lumbar load, such as bending and torsional moments of force or compressive and shear forces at the lumbosacral disc, calculations were performed applying a spatial dynamic multi-segmental biomechanical model (‘The Dortmunder’). Computer simulations were based on the measured data on subjects’ movements, using the 3-D dynamic CUELA system with several goniometers, torsiometers, and inclinometers, as well as on bilateral triaxial handforce recordings at the grip points. In total, 25 flight attendants (22 female, 3 male) participated in the laboratory measurements of pushing and pulling the trolleys on an adjustable floor of 12 m length under various task conditions assuming 4 inclination angles (0°, 2°, 5°, 8°), 3 container loadings (empty, medium, full), 2 trolley types (halfsize / fullsize), and 2 handling directions (pull / push), i.e. approx. 1200 sets of data were totally gathered.

Results. Analysing nearly 500 load situations, the results with respect to lumbosacral compressive force and sagittal bending moment as adequate indicators of the (bio-) mechanical load on the lumbar spine are summarized as follows: Lumbar load, in general, increases with increasing trolley weight and, for pushing only, increases with floor inclination. Comparison of handling types reveals that lumbar load is higher for pushing than for pulling of fullsize trolleys, whereas it is higher in case of pulling halfsize trolleys due to supplementary vertical handforces needed for stabilization the small containers. Comparing the trolley types, lumbar load is higher for the large containers than for the smaller ones in case of pushing, whereas viceversa effects were found for halfsize trolleys. The disc compression reach up to approx. 3 kN, the sagittal bending moment up to approx. 130 Nm.

Conclusion. Applying assessment criteria of literature in order to identify risky working situations (age-and-gender related ‘Dortmund Recommendations’ for maximum lumbar disc compression, based on the lumbar spine’s load-bearing capacity, or torque classification according to Tichauer, respectively), shows that potential spinal overloading must be pressumed for pushing heavy large trolleys on considerably inclined floors and for pulling the small containers performed by one person only.

494 - Electromyographical Investigation on Muscular Strain and Fatigue at Office Work

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Introduction During office work persons often complain of muscular pain in spite of relatively low forces produced by the respective muscles. Such complaints may result from long-term activation of the muscles needed for stabilizing the posture. Long-term electromyographical studies performed during total shifts represent an adequate method for the documentation and analysis of such long-lasting activities.

Methods Studies on muscular activity were performed during 13 full working days on persons working in an office of the German tax authority. In the shoulder/arm region surface electromyograms (EMG) were derived from the trapezius muscle (pars descendens), deltoideus muscle (pars acromialis and pars clavicularis), and from the hand extensor (m. extensor carpi ulnaris). The actual activity of the persons was documented using a coding procedure. For this purpose the subjects were accompanied during the total working time by an observer, who uses a numerical keyboard to encode the actual activity according to a predefined code list. An electrical code signal was recorded together with the EMGs; in data evaluation it was used to select from the EMG signals all sections belonging to a certain type of activity. Furthermore, the occurrence and localization of actual complaints was documented using a questionnaire four times during the day.

Results From the temporal distribution of the code signal the activities of the subjects were evaluated; the main activities are related to paper work (about 40 % of the working time) and data exchange with the computer system using the mouse (12%) and keyboard (16%). During paper work the highest EMG amplitudes were observed in the shoulder muscles and during mouse application in the forearm. Temporal changes in the EMGs were analyzed and used as indicators of muscle fatigue. For about half of the persons an increase in the EMG amplitude over time was found for the trapezius muscle during paper work and for the hand extensor during the use of the keyboard. For the same muscles and activities for about 2/3 of the persons a change in the frequency spectrum to lower values was observed. From the corresponding questionnaire it was determined that complaints also occur in the shoulder and forearm regions with increasing frequency in the course of the working day.

Discussion Paper work represents the main activity of the subjects (about 40%). Due to the widespread use of data processing systems in today's tax authority the secondary activity is related to computer interactions via keyboard and mouse (about 30%). Temporal changes of the EMG amplitude and spectrum demonstrate the occurrence of muscular fatigue, in particular in the shoulder and forearm, for the majority of the persons. An increasing number of complaints was documented for the same body segments; therefore at office work the shoulder and forearm should be considered as regions with an increased risk for muscular overload.

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002 - EMG Analysis of the Superior and Inferior Fascicles of the Orbicularis Oris Muscle on Deaf Individuals

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Introduction: Electromyography (EMG) has been used to study the performance of the peribuccal musculature in mastication, swallowing and speech and is an important tool for the analysis of physiopathological changes affecting this musculature. There are many studies with patients with auditory and speech deficiency, but no one has evaluated the musculature responsible for the speech. The present work aims to compare the electromyographical measures of the superior and inferior fascicles of the orbicularis oris muscle in patients with profound bilateral neuro-sensorial hearing deficiency (deaf) and healthy volunteers.

Methods: An Electromyography K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA) with eight channels was used. Applied electrodes were duotrodes, silver-chloride surface, disposable, diameter of 10 mm, and inter-electrode distance of 21 mm. EMG analysis was performed on recording from twenty individuals matched for gender and age. Subjects were divided into two groups: ten deaf individuals and ten healthy volunteers. Five clinical conditions including suction, blowing, lip projection and compression, and the production of the syllable "Pa", were evaluated.

Results and Discussion: Statistical analysis was performed using the SPSS software version 10.0 (Chicago, IL). Continuous data with normal distribution were analyzed by univariate analysis of variance (ANOVA). During all clinical conditions the orbicularis oris muscle of deaf individuals showed higher EMG levels than healthy volunteers, with statistical significant difference during blowing, lip compression and pronunciation of the syllable "PA" ($F = 6.74$, $p < 0.01$). Also, the inferior fascicle of the orbicularis oris muscle showed higher EMG levels than the superior fascicle in all clinical conditions ($F = 6.33$, $df = 1$, $p = 0.02$).

It was found that deaf patients presented with muscle hyperactivity in all clinical conditions, and that the inferior fascicle of the orbicularis oris muscle showed the highest rates of activity.

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004 - EMG Analysis of the Orbicularis Oris Muscle in Deaf Individuals, In Mandibular Rest Position, Compared To Hearers

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Introduction: Mandibular rest position is know as that in which the jaw is involuntarily suspended by the reciprocal coordination of mastication muscles and depressor muscles group, with both superior and inferior teeth slightly outlying. Electomyographic silence is characteristic to this relaxed position, which characterizes an inactive muscular condition, namely a passive stability position, controlled by gravity and muscle's elastic forces associated to other tissuesThis study had the aim to analyze electromyographically, the upper and lower fascicles of the orbicularis oris muscle in bilingual, oralist deaf individuals, comparing them with clinically healthy volunteers in mandibular rest position.

Methods: This was performed in 50 patients of both sexes with an average age of 18.5 years, divided into 4 groups: 1. Ten deaf, bilingual, nasal-breathing patients; 2. Ten deaf, bilingual, buccal-breathing patients; 3.Ten deaf, oralist, nasal-breathing patients; 4.Twenty healthy volunteers, nasal-breathing patients. An electromyograph K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA) of eight channels was used. The electrodes applied were duotrodes, silver-chloride surface, disposable.

Results and Discussion: Statistical analysis was performed using the SPSS software version 10.0 (Chicago, IL). Continuos data with normal distribution were analyzed by univariate analysis of variance (ANOVA). The level of significance was set at $\alpha = 0.01$. Comparing the EMG activity of the orbicularis oris muscle made it possible to verify that, during clinical mandibular rest position, all four groups presented various levels of electromyographic (EMG) activity with statistically significant differences ($F = 8.81$, $p < 0.01$). Based this study's data, it was possible to conclude that the electromyography analysis of the orbicularis oris muscle in deaf individuals showed that deaf individuals presented higher levels of EMG activity of the orbicularis oris muscle than normal controls during mandibular rest position.

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005 - EMG Analysis of the Orbicularis Oculi Muscle in Normal and in Individuals Indicated to Receive Eye Prosthesis

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To analyse comparatively through electromyography (EMG) the orbicularis oculi muscle from normal patients and those indicated to receive eye prosthesis (treated patients), it was studied 24 male patients with mean age of 32.5 years old, who were divided into 2 groups as follows: 12 individuals with absence of the left eyeball and indicated to receive prosthesis (treated); 12 normal individuals (control). The work was performed in 4 different clinical conditions: initial resting; normal opening and closure of eyelids; forced opening and closure of the eyelids and final resting, before and after placement of eye prosthesis. The exams were made using an Electromyograph K6-I Light Channel and Surface Electrodes. By the results obtained under the work conditions, we can conclude that: the use of eye prosthesis did not interfere in the clinical conditions of opening and closure of the eyelid; the loss of eyeball increases the EMG activity of the orbicularis oculi muscle; the use of eye prosthesis for a period of 7 days, was not enough to diminish the muscular activity, even its perfect adaptation been evidenced clinically.

010 - Electromyographic Analysis Of The Masseter And Temporal Muscles In Oralized Deaf Individuals

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Introduction: Deaf individuals show a number of difficulties related to the functionality of the stomatognathic system, mainly by reason of the little or no use of facial musculature during speech either due to the use of sign language or to the difficulty that these individuals have in articulating words.

Methods: This study aimed to assess, by means of computerized bilateral electromyography (EMG), masseter and temporal muscles of oralized deaf individuals in clinical activities that involve part of this masticatory musculature and compare this system's functionality with that of normal listening individuals, performing the same activities. An 8-channel K6-I EMG Light Channel Surface Electromyography device was used, in addition to disposable double electrodes covered with silver chloride containing a conductor gel.

Results and Discussion: The statistical analysis confirmed that there were any significant differences between the groups, clinical activities, and muscles, and also effects of interaction among them. The analysis made use of Variance Analysis (ANOVA). Significant differences ($p<0.01$) for both muscles were found among the clinical conditions, with deaf individuals showing greater electromyographic activity for both muscles for the clinical activity protrusion. Deaf individuals showed a lower muscular activity for clinical activities that demanded a greater masseter and temporal muscular activity such as mastication, mouth opening and closing, and dental compression. Greater electromyographic values were found for both deaf individuals and healthy controls during clinical activities of mastication and dental compression. Based on the obtained data, we concluded that deaf individuals showed a lower activity of the masticatory musculature than healthy individuals; the differences were significant at the level of $p<0.01$ between the performed clinical activities; and all deaf individuals and healthy controls showed greater electromyographic values for mastication and dental compression.

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017 - Electromyographic Crosstalk in the Measurement Of Pelvic Floor Muscle Activation

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Introduction: We investigated the interaction between pelvic floor muscle (PFM) activation and vaginal pressure generation to study muscle crosstalk in continent females, because other researchers have not delineated whether enhanced electromyographic (EMG) activity recorded from the PFM is due to synergistic activation or crosstalk1-4.

Methods: Eight women, mean 27.63 years (+ 4.14), performed a series of maximal PFM contractions alone and then with static contractions of the gluteal, hip adductor, hip external rotator, rectus abdominis, and transversus abdominis muscles, while EMG activity and then vaginal pressure were recorded. Signals were acquired at 1000Hz using Bortec AMT-8 amplifiers and LabviewTM software. The FemiscanTM vaginal probe was used to record surface EMG and vaginal pressure was measured using a PeritronTM Perineometer. For each data set, a moving window of 100 ms was used to find the maximum root mean square (RMS). Resting RMS values were subtracted from all recordings. A Kruskal-Wallis test (= 0.05) was used to compare each combination of contractions. The EMG and pressure data were analyzed separately. Crosstalk was suspected if increased EMG activation amplitude was seen for a combination of contractions without increased vaginal pressure.

Results: No significant differences between PFM contractions performed alone or with other contractions were found in either the EMG (p=0.285) or pressure (p=0.131) measurements. Overall, there was no evidence of crosstalk, but two individuals demonstrated patterns of crosstalk.

Conclusion: From our sample we determined that crosstalk is generally not a problem, however activity from the abdominals and external rotators may be a problem in certain individuals and under certain experimental paradigms.

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039 - Arm-Trunk Compensations for Beyond-The-Reach Movements in Adults With Chronic Stroke

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By integrating multiple degrees of freedom of the body, the nervous system is able to produce invariant hand trajectories when pointing movements with or without trunk displacement are made. In movement beyond the reach, Rossi et al. (2001) have shown that the initial contribution of the trunk movement to hand displacement is neutralized by appropriate compensatory rotations at the shoulder and elbow. Trunk movement begins to contribute to hand displacement only after the peak velocity of the hand. After a stroke, control of movement in specific joint ranges is limited and the trunk contributes to hand transport from the movement onset (Levin et al., 2000; 2001). We hypothesized that the damaged nervous system also lacks the ability to make appropriate compensatory adjustments of the arm joints to maintain the hand trajectory when trunk movement is involved in reaching. This was tested by comparing interjoint and intersegment coordination during beyond-the-reach pointing movements involving the trunk to targets placed in the ipsilateral and contralateral workspace of the arm, in 10 healthy subjects and in 10 individuals with mild chronic unilateral hemispheric stroke. Arm and trunk movement kinematics during 60 reaches to each target were recorded (8 markers, Optotrak, 120 Hz). In 30% of randomly chosen trials, the trunk movement was unexpectedly prevented by an electromagnet. Hand trajectories and elbow-shoulder interjoint coordina-tion were compared in free-trunk and arrested-trunk trials. In contrast to neurologically intact individuals, trunk movement contributed from the start of the hand displacement. When the trunk was arrested, the hand trajectory changed while the elbow-shoulder coordination did not change in the early part of the reach in participants with stroke. This suggests that the damaged nervous system was unable to make rapid adjustments to movement perturbations. This deficit may be partly responsible for the lack of dexterity of the arm even in well-recovered patients.

043 - Changes in Foot Contact and EMG Occur After Botulinum Toxin Type A Injection and Physical Therapy in a Child with a Diagnosis of Idiopathic Toe Walking- A Case Study

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Introduction: Idiopathic toe walking (ITW) is a diagnosis of exclusion in which children walk with a toe-toe gait pattern due to the early onset of gastrocnemius (GA) activity. Over time a gastrocnemius/soleus contracture may develop resulting in a significant loss of dorsiflexion range. Early treatment may prevent a fixed equinus contracture that often results in musculoskeletal changes. However, conservative treatment approaches are often not successful and surgery remains the only option. We used Botulinum Toxin Type A (BTA), a known inhibitor of the release of acetylcholine, to inhibit GA. It was hypothesized that this would allow normal tibialis anterior activity (TA) and promote a normal gait pattern.

Methods: The 3 year old child was tested prior to and 3 weeks after BTA injection of the GA and at regular intervals for 3 years. Physical therapy was initiated at 3 weeks after BTA and concentrated on activities that promoted controlled foot contact pattern including strengthening of the TA, treadmill training as well as facilitation of balance strategies. Foot contact patterns and the onset and duration of GA and TA EMG activity were monitored. Foot contact patterns were described as heel-strike, flat foot, forefoot (heel just off the ground) or digitigrade. The EMG signals were band-pass filtered (20Hz to 4 KHz) (Therapeutics Unlimited, Iowa City, Iowa) and sampled at 1000Hz. The timing of the EMG was referenced to ground contact on a force plate.

Results: Before treatment, when 68% of foot contacts were digitigrade; 22% of foot contacts were forefoot, the onset timing of the GA for stance phase was about 80 ms before foot contact and TA duration for swing phase was very short (250 ms). After treatment, the improvement of foot contact was in a gradual manner-at 3 weeks post injection, 19% of foot contacts were either forefoot or digitigrade where 81% were flat foot; at one year post injection, the child had 88% heel contact pattern during walking. EMG data paralleled the change in foot contact patterns- GA onset was changed to appear after foot contact immediately after injection; TA duration gradually increased from 250ms to 416ms and its offset time was now at least 20ms after foot contact. These data were similar at three years post treatment.

Conclusion: In this case study, BTA combined with PT treatment normalized the ankle EMG and gait patterns of the child with ITW. The GA activity was inhibited initially after injection, thus allowing the TA to be re-educated through physical therapy. The long-term effects of this novel treatment approach for ITW suggests that it may be an alternative to traditional conservative approaches and thus prevent surgery.

045 - The Effects of Circumferential Air-splint Pressure on Flexor Carpi Radialis H-reflex in Subjects With and Without Neurological Deficits

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Introduction: The purpose of this study was to investigate the effects of circumferential pressure (CP) on flexor carpi radialis (FCR) H-reflex in subjects without neuromuscular deficits, ($S_{ND),}$ subjects after cerebral vascular accident ($S_{CVA)}$ and subjects following complete spinal cord injury (S_{SCI}).

Methods: Forty-four S_{ND} , 7 S_{CVA} and one S_{SCI} were included in this study. FCR H-reflex was assessed by measuring the peak-to-peak amplitude change before, during and after CP was applied to the forearm. Twelve H-reflexes (H/M ratio = mean 25 %; SD 14) were recorded before pressure application to obtain a baseline value ($H_{baseline}$) to which all data were compared. A pneumatic 34 cm air splint inflated to 51-60mmHg provided the pressure around the forearm. H-reflex recordings were taken at 1, 3 and 5 minutes during ($H_{pressure}$) and after pressure application. A sham study was conducted on 5 subjects to ensure that changes in reflex amplitudes were not a result of cutaneous effects. Two, one-way analysis of variance (ANOVA) tests with repeated measures were used to analyze change from baseline in the average ratio of H/M amplitudes at 1, 3 & 5 minutes of pressure application for S_{ND} and $S_{CVA,}$ respectively. Multiple comparison procedures were performed using Tukey tests at $p<0.05$. A forward stepwise regression analysis was performed on the data from S_{ND} only. The regression analysis looked at four independent measures as predictor variables (M_{max}, H_{max}, H_{max} /M_{max}, $H_{baseline}$).

Results: Two types of responses were observed in the FCR H-reflex following pressure application in S_{ND}. Group 1 significantly increased in H-reflex amplitude ($p <. 05$) while Group 2 decreased in H-reflex amplitude ($p<.05$) when compared to $H_{baseline}$. A forward stepwise regression found that H_{max} explained 37.2% of the variance when controlling for $H_{baseline}$. Subjects with larger H_{max} showed an increased in $H_{pressure}$ while subjects with lower H_{max} demonstrated decreases in $H_{pressure}$ For S_{CVA}, H-reflex amplitudes decreased at 1, 3 & 5 min in all subjected tested ($p=0.004$). Descriptive statistics performed on the S_{SCI} demonstrated similar results to the S_{CVA}. The Sham study revealed no differences in H-reflex amplitude from baseline values.

Conclusion: Circumferential pressure to the forearm had variable results on H-reflex amplitude in S_{ND}. This dichotomous result is unclear, however, we suggest the correlation of H_{max} to $H_{pressure}$ was likely due to the type of motor units involved in FCR H-reflex generation. Fast twitch muscle fibers innervated by larger motoneurons (MN) may respond to pressure differently than slow twitch muscle fibers with smaller MN. FCR does vary in structure among subjects. This may explain why in analogous soleus studies, H-reflex amplitude decreased in all subjects tested. For S_{CVA} and S_{SCI}, pressure application decreased the H-reflex in all subjects. Released from higher CNS control, reflex arcs may become more stereotypical and presumably more one-dimensional in function. Therefore, the MN response to pressure may become less variable. The discrepancy between S_{ND} and S_{CVA} and S_{SCI} , however, can not be explained from our results. Our study does suggest air splints may be used in the UE to temporarily reduce muscle activity associated with neurological dysfunction.

051 - Reliability of Flexor Carpi Radialis Hoffmann Reflex Measures

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Introduction: Investigators have reported difficulty in evoking the Hoffmann reflex (H-reflex) in the flexor carpi radialis (FCR) without facilitation (2). Recent research has shown recordings of the H-reflex from the soleus to be reliable (1), but these results may not be extended to the FCR due to difficulties in evoking the response. The purpose of this study was, therefore, to evaluate the reliability of H-reflex recordings from the FCR.

Methods: Thirty-seven volunteers completed 4 test sessions. Ten trials for the maximal M-wave (Mmax) and the H-reflex at a stimulus intensity corresponding to 5% of Mmax (H5%) were recorded during each of the four test sessions. The total number of trials used for analysis was forty. The peak-to-peak amplitude of these responses and the latency of the H-reflex response were determined. The stability of the recordings across days and trials was assessed using a fully nested repeated measures analysis of variance. The consistency of the measures was evaluated with the intraclass correlation coefficient (ICC).

Results: Recordings of the H-reflex were obtained from all participants, without facilitation. There were no significant differences within subjects across days for any of the measures (P's>0.05). The ICC for Mmax was 0.97, attesting to careful methodological controls. The latency and amplitude of the H-reflex were also reliable, with ICC values of 0.89 and 0.93, respectively.

Conclusions: Contrary to previous studies, it was demonstrated that the H-reflex could be evoked in the FCR without facilitation. It was shown that the H-reflex can be reliably recorded from the FCR. This has important implications in clinical settings for testing and diagnostic procedures in the upper limb.

Supported by NSERC.

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060 - Evaluation of the Biofeedback-EMG in the Treatment of Enforcement Genuine Incontinence

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Introduction: The stress genuine incontinence is the involuntary urine loss by the urethra. About 10 to 30% of women show loss of urine in some phase of life. Many conditions can cause or contribute to an urinary loss, and some are reversible. The purpose of this clinical trial was to evaluate the effectiveness of biofeedback-EMG to the treatment of stress genuine incontinence in women.

Methods: Forty women aged between 24 and 68 years old, which had urodinamically proved the stress genuine incontinence have participated of this clinical prospective controlled study, conduced to treatment in the physiotherapy department. The control group received a 6-month treatment program of the pelvic floor, using only kinesiotherapy, while the other treatment group received, additionally, biofeedback-EMG (vaginal electrode, being the signal amplified with a 1000-times gain and a rejection common mode of 80dB; the signal amplitude was set to express the values in Kgf, presenting a linearity of 97,3%). The primary measuring was the quantity of urine loss determinated by a pad test, and subjective evaluation of the patients.

Results: A total of 37 women have completed the study and from this data bank it were used to evaluate the effect in voluntaries who have received treatment; 61% were subjectively presenting increase and cure, and 64% had a reduction of 75% or more in urine loss in the pad test. There were no statistically significant difference of measures in both groups. But, the higher percentage of volunteers with meaningful increases and subjective cures (80%) an by pad test (80%) were in the vaginal biofeedback-EMG group (n=20).

Conclusion: Exercise and Biofeedback alone are an effective treatment to stress genuine incontinence. Women with a long history of symptoms or previous inefficient incontinence surgery can be benefited by vaginal biofeedback-EMG.

061 - Neuromuscular Changes with Aging: Implications for Knee Stability

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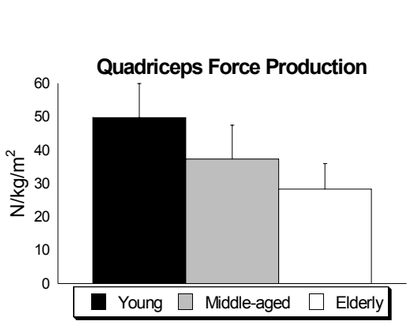
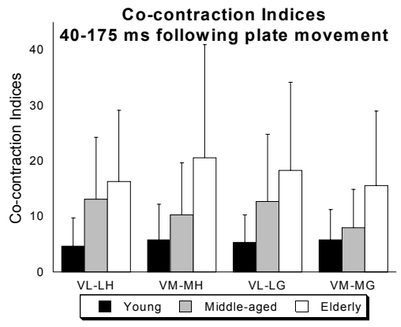
Introduction: Aging is associated with neuromuscular changes, including decreased muscle force production and reduced afferent information, which may lead to diminished muscle responses that are important for joint stability and protection. Individuals with medial knee osteoarthritis (OA) also demonstrate changes in muscle function and global muscle activation for stabilization. The purposes of this study were to: 1. investigate how aging alters muscle responses to a perturbation at the knee and 2. determine if age-related changes in muscle function are similar to changes previously reported in persons with medial knee OA.

Methods: Fifteen young (19-25 years), 17 middle-aged (40-57 years) and 15 elderly (60-80 years) participated. All subjects reported no previous lower extremity injuries or joint dysfunction. Quadriceps isometric force output and central activation ratio were measured. Kinematic, ground reaction force and EMG data were collected while subjects stood with one lower extremity on a moveable platform that delivered a rapid valgus movement at the knee. Knee joint excursion and muscle activation patterns (onset latency, integral of activation, co-contraction) before and in response to the perturbation, were compared between the age groups.

Results: Quadriceps force output diminished with age ($p<0.05$), but there were differences in CAR ($p>0.05$). In response to the perturbation, the valgus knee motion and muscle onset latencies were no different ($p>0.05$). The elderly demonstrated significantly greater magnitude of muscle activation following plate movement compared with the young ($p<0.05$). Greater muscle co-contraction about the knee was measured among middle-aged and elderly individuals before ($p<0.05$) and in response to ($p<0.05$) plate movement.





Discussion: The higher muscle co-contraction observed in the elderly subjects both before and after the valgus perturbation suggests that the older subjects attempt to preset the muscles to stabilize the knee prior to a perturbation and demonstrate global stabilization strategy in response to the perturbation. Greater co-contraction may contribute to greater compressive loading that, coupled with other age-related neuromuscular changes could lead to articular degeneration over time.

062 - Electromyographic Assessment of Upper Limb Proprioceptive Exercises In Closed Kinetic Chain With Medicine Ball

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The purpose of this study was to evaluate the normalized RMS values of bench-press, push-up and wall-press with 90° and 45° shoulder forward flexion exercises with medicine ball. This study evaluated 12 healthy volunteers men (mean age 23 ±7 years). Medicine ball with 55 centimetres diameter was suitably calibrated. Surface EMG was recorded from the long head of biceps brachii, anterior portion of deltoid, clavicular portion of pectoralis major, trapezius upper fibres and serratus anterior muscles using surface differential electrodes (silvers bars 10mm apart, 10mm long, 2mm wide, gain of 20x, input impedance of 10GΩ and CMRR of 130dB). The EMG signals were analogically amplified with gain of 100x, filtered (10-1500Hz band-pass) and sampled by 12 bits A/D covert board with a 2KHz frequency. The signals were digitally band-pass filtered (10-500Hz). The maximal voluntary isometric contractions RMS values were used to normalize each studied muscle EMG amplitude. The differences among the muscle amplitude data were analysed by the ANOVA for each exercise tested. The results showed that all investigated muscles are active during the exercises with medicine ball. Biceps mean normalized RMS values were lower than serratus muscle ($p<0.05$) in bench-press and wall-press with 90° and 45° shoulder forward flexion exercises. There are no differences among the normalized RMS values of deltoid, pectoralis major, trapezius and serratus muscles ($p>0.05$) in bench-press and wall-press with 90° and 45° shoulder forward flexion exercises. The mean normalized RMS values of the serratus were similar to pectoral ($p>0.05$), but they were higher than deltoid, biceps and trapezius muscles ($p<0.05$) in the push-up exercise. The results showed a cocontraction of the studies muscles during upper limb proprioceptive exercises in closed kinetic chain with medicine ball. The serratus anterior showed greater activation amplitude than other studied muscles, in these experimental conditions.

078 - Soleus H-Reflex Modulation During Hip And Knee Joint Passive Movement In Spastic Stroke Patients

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Introduction: In the stroke patients, changes in the soleus H-reflex during ankle joint movements have been studied, but changes in the soleus H-reflex during the movements of other leg joints (hip and knee) have not been studied. In the previous study of normal participants, we measured the soleus H-reflex during hip and knee joint movement with the ankle immobilized, which prevented, direct stretching of the soleus, and found that the soleus H-reflex was decreased by passive movement of the hip and knee joints (1). This decrease occurred when the hip and knee joints were flexed rapidly. The present study measured the effects of the same passive movement on soleus H-reflex in stroke patients.

Method Five stroke patients participated in the study. All patients were right hemiplegia. A passive-movement machine (TEM, Yaskawa Electric Corp., Japan) was used. The participant was directed to lie supine on the TEM bed and relax the extremities. Soleus H-waves of the right leg were recorded. The knee and hip were passively flexed and extended simultaneously. The angle of movement ranged from 0˚ to 120˚. Two movement velocities were used (fast movement 16 deg/s and slow movement 8 deg/s) to investigate the effects of movement velocity. Electric stimulation was delivered from a personal computer. An anode was placed on the top of the patella, and a cathode was on the skin of the popliteal region. Soleus M-waves and H-reflexes were measured after delivery of a 1 ms square electric wave pulse to the tibial nerve in the right knee. Stimulus intensity was so adjusted that H-reflex amplitude at rest was 30%Mmax with each participant (2). Soleus H-waves were measured 200 times for each participant.

Results: For both the fast and slow movement, H/Mmax decreased in the middle flexion phase. In contrast, H/Mmax increased in the middle extension phase. There were no significantly different results in the two velocities.

Conclusion: These results demonstrate different effects of soleus H-reflex modulation in stroke patients when compared with normal participants. Although preliminary, results may suggest that the effects of hip and knee joint angles cause the changes of soleus H-reflex in stroke patients.

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090 - Wrist Muscle Activity Patterns Change with Use of a Haptic Mouse

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Introduction While it has been shown that force-feedback haptic computer mouse change the human-machine interface performance, few studies have examined the changes of motor control. We hypothesize that both wrist kinematics and the wrist muscle activity patterns change with the presence of force-feedback during a simple Fitts like point-and-click task.

Methods Fourteen subjects completed a Fitts Law like task utilizing a force-feedback computer mouse (Logitech™ Wingman Mouse). Two circular targets, 30 pixels in diameter 500 pixels apart horizontally were presented on the screen. Subjects were instructed to click on the highlighted target, which would alternate between the two, as fast as possible. Three force-feedback conditions were tested: 1) No force feedback, 2) an attractive basin around the desired target, and 3) an attractive basin with twelve distracting basins placed in three rows of four between the two targets. The attractive basins created force fields that would draw the mouse to the center of the target and would act 30 pixels from the target center. The distractors were evenly spaced 100 pixels apart allowing for areas with no force-fields. Bipolar surface EMG electrodes measured the muscle activity of the wrist four prime muscles:flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), and extensor carpi ulnaris (ECU). Electrogoniometers measured wrist posture and software loaded on the computer measured the cursor movements.

Results: Movement times (MT) improved in the tasks with force-feedback; however, improvements were not significant in the force-feedback condition with distracters. Peak velocities of the cursor and wrist were 50% higher for the distracter condition compared to the no-force and one attractive basin condition. Muscle activity was the greatest for the force-feedback condition with distracters and the lowest for the force-feedback or the no-force condition. Changes in the muscle patterns were also observed. The modified Fitts task parameters, the effective target width (W_e) and effective index of performance (IP_e) changed significantly with the addition of the force-field.

Conclusion: These results suggest that the force-field developed by the haptic interface changed the task and hence the required motor control.

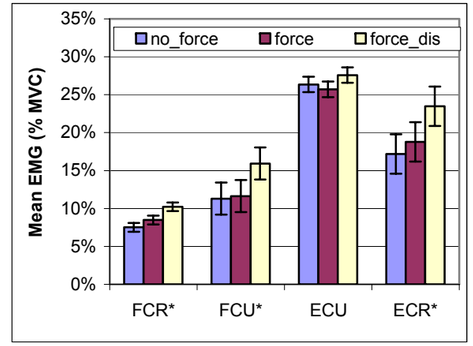

Figure 1: Muscle activity increases for the force with distracters conditions (* $p < 0.05$).

091 - Evaluation of the Thoracic Curve through the Cifolordometer

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Introduction: The present study had as purpose to establish criterious to evaluate the thoracic curve through the cifolordometer, as well as verifying the presence or not of existent correlations between this method and the Cobb's method, accomplished through the x-ray exam.

Methods: To evaluate the thoracic convexity two different methods were used: radiographic exam and the evaluation accomplished in the cifolordometer. Each individual was submitted to an x-ray of the thoracic spine, incidence profile, and the same curve was measured in the cifolordometer. The evaluation of the thoracic curve in the cifolordometer consisted of three successive measures, accomplished with the aim of verifying the validity intraobserver of this method.

Results: It was observed that there is a positive and significant correlation between the two approached methods. A clear methodology was established to evaluate the thoracic curve in the cifolordometer, and through the analysis of the three measures accomplished in each element of the sample, the validity intraobserver of this method was confirmed

Discussion: The results of this study showed the cifolordometer as a reliable method, of easy access, high reproduction and great effectiveness in the thoracic curve measure.

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092 - Shoulder Movement Range Assessment in Mastectomized Women Through Computerized Biophotogrammetry

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Introduction: The purpose of this research was to evaluate quantitatively the range of movement (ROM) of the shoulder (flexion, extension, abduction) in mastectomized women comparing with the counter lateral side to the surgery, to verify if there is significant limitation of the shoulder movements.

Methods: Twenty-nine mastectomized women were analyzed with age ranging from 33 to 80 years. There were 6 months between the operation and the examination at least. All the patients were in follow up in the mastology clinic of the Department of Gynec and Obstetric of the Universidade Federal de Uberlândia. The data was collected in the Laboratory of Analysis of the Movement of the Centro Universitário do Triângulo and analyzed by an instrument of range of movement quantification named Computerized Biophotogrammetry. The images of the movements were registered as described above quantified at a program named ALCImage® 2.1.

Results: The Wilcoxon Test for statistical analysis was significant (0,05) in a bilateral trial. According to the results, it was found significant differences in the flexion movements of the shoulder homolateral to the mastectomy when compared with the counter lateral side.

Discussion: Significant decrease was verified in the flexion movement of the homolateral shoulder to the mastectomy. The range of movement was committed even after 6 months of surgery.

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107 - Initial Feasibility of Wavelet Analysis of Gait in Children with Cerebral Palsy

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Introduction: Surface electromyography (sEMG) has been demonstrated to be useful in understanding neuromuscular function in cerebral palsy (CP). For example, sEMG analysis has been used to the determine muscle onset and offset timing [1], and for examination of amplitude changes during movement [2]. Frequency analysis, in contrast, has been little studied even though it has the potential of providing insight into neuromuscular function [3]. Recent studies have demonstrated the potential of using the continuous wavelet transform (CWT) for a time-frequency analysis of dynamic sEMG during gait [4] in able-bodied adults. This could have applicability to the analysis of gait in CP if the feasibility of the method can be determined.

Methods: A retrospective study was conducted with three children. Subject A was of typical development (TD); Subject B was diagnosed with right, spastic hemiplegic CP; Subject C was diagnosed with spastic diplegic CP. The EMG signals were recorded from five select lower extremity muscles during walks at a self-selected pace. For each subject, ten gait cycles for the right and left sides were extracted and the CWT scalogram was calculated. The ten scalograms for each muscle were averaged, and a representative curve for the averaged scalogram was calculated using the instantaneous mean frequency (IMNF). A root mean squared (RMS) algorithm was employed to determine onset and offset times for comparison to the IMNF. Intra subject variability of the ten IMNF curves was determined through the calculation of the coefficient of variability (CV). Inter subject comparisons were done using bivariate correlation coefficients between the averaged IMNF curves for each muscle in each subject.

Results: The IMNF demonstrated low intra subject variability within a muscle (CV < 5%), and a good comparison to the more traditional RMS method for EMG timing. Inter subject comparisons demonstrated a corresponding drop in the correlation coefficients in comparison of the children with CP to the child with TD. This was evidenced though timing and frequency differences. The less involved (left) side for the child with spastic hemiplegia demonstrated good correlation for all the muscles as compared to the child with TD. On the more involved (right) side, the subject with spastic hemiplegia demonstrated decreased correlations in the ankle musculature in comparison to the subject with TD, agreeing with the clinical assessment of foot drop in this subject.

Conclusion: CWT can provide a new method of examining the EMG signal in the child with CP. The IMNF extracted from the CWT analysis preserved EMG timing information in relation to the gait cycle, and demonstrated intra subject repeatability. It also appears to be possible to use this method to quantify walking ability, which may be useful in clinical assessment and rehabilitation outcome measures.

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110 - Neuromuscular Properties of the Quadriceps Femoris After Knee Surgery Evaluated By Muscle fMRI and EMG

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Introduction: It is well known that dysfunction of the quadriceps femoris (QF) is induced by knee surgery. To investigate neuromuscular activation, surface electromyography (EMG) has been frequently used in numerous previous studies. Recently, muscle functional magnetic resonance imaging (mfMRI) has been developing to acquire neuromuscular properties during exercise. The purpose of this study was to investigate neuromuscular properties of the QF after arthroscopic knee surgery using mfMRI and EMG.

Methods: The subjects of this study were 13 arthroscopically treated patients with meniscus lesions (men: 6, women: 6, mean age 46 years). All measurements were performed 5.2 ± 3.8 months after the surgery. For injured and non-injured limbs, maximum voluntary contraction (MVC) during isometric knee extension, cross-sectional area (CSA) of the mid-thigh by MRI, mfMRI and EMG during fatiguing knee extension exercise were measured. mfMRI was taken before and immediately after submaximum fatiguing isotonic knee extension exercise. This exercise consisted of 5 sets of 10 repetitions with 1 min rest between sets, load equalled to 28 to 33% MVC for each injured and non-injured limb. During this knee extension task, EMG signal of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) was also acquired.

Results: The MVC of the injured limb was lower than that of the non-injured limb (370 ± 207 and 511 ± 216 N, respectively, $P < 0.0001$). The CSA of the QF of the injured limb was significant lower than that of the non-injured limb (42.7 ± 10.6 and 47.7 ± 8.5 cm2, respectively, $P < 0.01$), but there was no significant difference in the CSA of the hamstring and adductor muscle group between the injured and non-injured limb. Resting mfMRI signal (i.e. T2) of the injured QF was significantly higher than that of the non-injured QF (36.7 ± 2.3 and 38.3 ± 3.0 msec, respectively, $P < 0.01$). Exercise-induced mfMRI signal change (delta change from rest) was not different between the injured QF and non-injured QF (2.0 ± 1.2 and 1.4 ± 1.2 msec, respectively, $P = 0.067$). EMG activity of the RF, VL, and VM during fatiguing isotonic knee extension was not significant difference between the injured and non-injured limbs ($P = 0.10$).

Discussion: The main result of this study was that arthroscopic knee surgery induced decrease of muscle force and size of the QF, however CSA of the hamstring and adductor muscle group was preserved. In submaximum fatiguing exercise test, we did not find any significant change in neuromuscular properties of the QF between injured and non-injured limbs from mfMRI and EMG observation. These results suggest that maximum force generating capacity of the QF impaired, but submaximum fatigue resistance capacity of the QF did not alter after arthroscopic knee surgery evaluated by mfMRI and EMG.

113 - Electromyographic Activities During Repetitive Neck Motions in Asymptomatic Young and Middle-Aged Adults

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Introduction: The control of neck movements required highly coordinative contraction of the superficial neck muscles to execute motions. Previous studies have emphasized the neuromuscular change with age during gait. Whether the activation patterns of neck superficial muscles changes with age is unknown. The purpose of this cross-sectional quantitative investigation was to compare the electromyographic (EMG) active pattern of bilateral superficial paravertebral muscles (PARA, mainly the splenius capitis and semispinalis capitis muscles) and ventral sternocleidomastoid (SCM) neck muscles between asymptomatic young and middle-aged adults during repetitive neck motion in three cardinal planes (extension/flexion, left/right rotation, and left/right side-bending).

Methods: Eleven asymptomatic young volunteer (age = 24.0 ± 4.4 yrs) and 17 middle-aged adults (age= 55.6 ± 5.0 yrs) performed repetitively neck motions with surface EMG recording (Gould polygraph) in three cardinal planes. Movements were divided into two phases: moving toward the maximal ranges and moving toward the neutral head position from maximal ranges for each direction of motion. The normalized average integrated electromyographic activity (NAIEMG) for each phase was normalized by maximal voluntary isometric contraction (MVIC) at neutral position for each investigated muscle. Analysis of Variance with repeated measures (ANOVA, group* direction) was used to analyze the main effect of age and the interaction between groups and directions.

Results: No significant interaction was found between groups and directions ($p>0.05$). The main effect of age indicated that middle-aged asymptomatic adults recruited significant higher ($p<0.05$) level of bilateral SCMs (36.4±3.8% and 32.3±2.1% MVIC for left and right respectively) and PARAs (44.2±3.6% and 41.3±3.0%) than young adults (29.6±4.7% and 27.5±2.6% for SCMs; 33.7±4.5% and 31.3±3.7% for PARAs) during movement toward the maximal range. During moving toward the neutral position from maximal position, bilateral SCMs of middle-aged adults was also recruited at higher levels ($p<0.05$, 15.9±1.2% and 14.8±1.2%) than young adults (9.4±1.4% and 10.0±1.5%), but PARAs of middle-aged adults were not.

Discussions and Conclusions: Higher recruitment of the PARAs and SCMs indicated over-activation of superficial neck muscles during functional neck movement in the middle-aged adults. Whether this over-activation played a role in the neuromuscular compensatory mechanism that led to the development of neck pain required further investigation.

134 - Influence of Treadmill Walking Speed on Plantar Flexor EMG Pattern

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Introduction: In order to walk efficiently, proper synchronization of plantar flexor muscle activity must necessarily be relearned by many patients with upper motor neuron lesion (e.g., stroke and traumatic brain injury). Despite the significant role of plantar flexors on walking efficiency, the literature provides conflicting data on their firing patterns in able-bodied subjects at different speeds — particularly at the slow speeds (0.08–0.84 m/s) characteristic of these patients.

Methods: Thus, we studied the electromyogram (EMG) profile — including ON, OFF and peak timing locations — of the plantar flexor muscle group over a wide range of walking speeds (0.5–2.1 m/s) in healthy young adults. A surface EMG electrode was placed over the lateral head of the gastrocnemius muscle and recorded in 15 healthy subjects ambulating on a treadmill at their normal walking speed and three paced walking speeds (0.5, 1.8 and 2.1 m/s). Initial contact to pre-swing was determined from a force sensitive resistor sensor secured to the skin over the calcaneous. Ensemble plantar flexor (gastrocnemius) EMG patterns were determined for each patient at each walking speed.

RESULTS and DISCUSSION: For all speeds, the plantar flexor EMG firing pattern was characterized by a main peak occurring 40–45% into the gait cycle, whose amplitude increased with walking speed. Speeds greater than or equal to 1.3 m/s maintained a common timing pattern (relative to stride duration) for the onset and offset of this peak. However, at a walking speed of 0.5 m/s — typical of an individual who has had a stroke or TBI — cessation of plantar flexor firing was prolonged by 10.8% of the gait cycle ($p<0.004$) compared to all other speeds examined. Given the importance of appropriate plantar flexor firing patterns to maximize walking efficiency, understanding the speed-related changes in gastrocnemius firing patterns may be essential when retraining the gait patterns of patients who have suffered upper motor neuron lesions.

151 - Visualizing and Testing Spasticity

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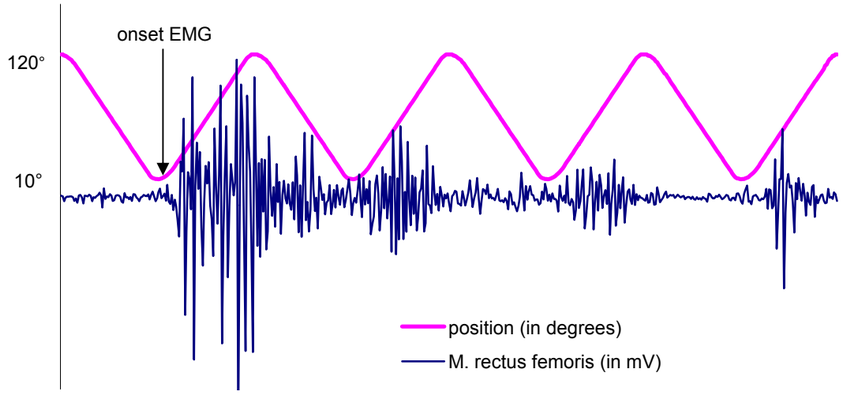
Introduction: Spasticity is difficult to test. However, when we test the subject at the same time of the day, in the same position and we passively move his limbs with the same preset, machine-given speed within the same range of motion (ROM), the spasticity in spinal cord injured (SCI) subjects seems to vary not very much (Kakebeeke et al. 2002). Apart from the elicited torque that is measured in our earlier work, the EMG of the muscles is recorded simultaneously. This enables us to determine whether there is a contribution of the reflex-mediated force (spasticity) to the measured torque.

Methods: The lower leg of the patient is passively moved with different speeds within the same ROM. The movements with the slow speed (10 degrees per s) inform us about the resistance of the structures around the knee (i.e. stretching of connective tissue, relaxed muscle fibers and intrinsic properties of the muscle), especially at the end of the ROM. With the fast speed (120 degrees per s) we elicit spasticity. The torque, the RMS of the tested muscle over the whole trajectory and the onset of the EMG (concerning the angle; see graph) are recorded.

Results/Discussion: The excitability of the neuromuscular system in the SCI subject can be tested by eliciting the stretch reflex. However, not only the size of the torque also its timely occurrence may influence the patient's self-report on spasticity. By measuring both the torque and the onset of the EMG during a passive movement that is standardized, we have gathered an objective measurement of the spasticity in the SCI subject. This method enables us to test the effect of therapies against spasticity. As testing can take place immediately before and after an intervention, electrodes can stay fixed on the skin and thus repositioning and test criteria are easily met.



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171 - Assessment of Proprioceptive Reflexes in Patients with Spasticty After Stroke

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Introduction. The aim of this study was to estimate the contribution of proprioceptive reflexes to the joint stiffness around the shoulder in patients with spasticity after stroke using a recently developed method for quantifying reflex gains in vivo (Van der Helm et al. 2002, De Vlugt et al. 2002).

Methods. Random force perturbations (bandwidth 0.5-20 Hz) were applied to the shoulder via the handle of a linear manipulator. Seven patients in the chronic phase after stroke had to counteract the perturbations, while external damping was varied from zero to a damping of 200 Ns/m. From the measured position of the manipulator's handle and the force applied by the subject, the joint admittance (ratio of position and force per frequency) was estimated in the frequency domain. From the recorded EMG of agonist and antagonist shoulder muscles and the position of the handle the reflexive impedance (ratio of muscle activation and position per frequency) was simultaneously estimated, representing the reflex gain per frequency. Level of co-contraction was estimated from integrated rectified EMG, normalised to force of lumped agonist and antagonist muscles. Data were compared to a control group.

Results. In patients, reduced joint admittance for the lower perturbation frequencies was found, indicating decreased joint stiffness. High oscillatory peaks around the eigenfrequency indicated reduced stability and likely resulted from high reflexive levels as for the lower frequencies the reflexive impedance was relatively higher. The reflexive impedance was lower for the higher frequencies indicating a decreased velocity feedback gain. The phase of the reflexive impedance showed two distinct differences 1) a phase of zero degrees for the lowest frequencies indicating substantial position feedback (in contrast to velocity feedback for controls) and 2) a phase lag for higher frequencies that was substantially larger indicating domination of the reflexive response by medium latency reflexes (in contrast to short latency, or spinal reflexes). Levels of co-contraction were generally higher in patients

Conclusion. Reflexive gains can be assessed in stroke patients using the applied methodology. The current data indicate changes in the reflexive feedback loop and supraspinal control in stroke patients in the sense that there are indications that velocity feedback is blocked at a spinal level (Ia afferents) and medium latency position feedback gain dominates the reflexive feedback. Reduced stability around the eigenfrequency is explained by enhanced (position) feedback gains and larger time delays. Co-contraction may be a salvation mechanism to counteract the negative influences on stability.

In a following study the reflex gains for position and velocity will be quantified, together with the neural time delay and the visco-elasticity of the muscles by fitting a neuro- muscular model simultaneously to both joint admittance and reflexive impedance.

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192 - Analysis of the Paraspinal Muscles Activity in Patients with Duchene Muscular Dystrophy

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Introduction: Approximately 80% of patients with Duchene muscular dystrophy (DMD) will develop scoliosis. Our goal is to detect muscular characteristics that might be susceptible to induce scoliosis. For this purpose, the electromyographic (EMG) activity of their paraspinal muscles on both sides of the spine was studied.

Methods: The subject was in a sitting position and he (all patients are boys) was asked to produce an isometric and isotonic force with his trunk. A steel cable, attached to the floor was linked to a non-stretchable harness that the patient was wearing at their shoulder level. The force produced (measured with a strain gauge) corresponded to 70% - 85% of his maximum voluntary contraction level. Three contractions were made in extension. Diodes were placed on their back and a motion analysis system was used to ascertain that they did not move during the task. EMG activity of the iliocostalis and longissimus muscles was collected with 10 pairs of surface electrodes placed bilaterally on the back at T10, L1 and L5 level. Besides EMG acquisition, imaging of the back from T12 to L5 levels was done with magnetic resonance (MR).

Results: Seven patients have been tested so far. Among them, 3 did not have spinal deformation and no difference in the left and right EMG activity of their paraspinal muscles was observed. Three other patients showed a beginning of scoliosis (<10° of Cobb angle) and the EMG level was found larger (≈ 52%) on the concave side of the deformation but the difference was not statistically significant ($p<0.05$) for such a small sample. As for the seventh patient with a larger Cobb angle (15°), muscular activity was found ≈ 2.5 times higher on the convex side of the curve. Following segmentation of the MR images, no difference in the cross sectional area of the paraspinal muscles nor on the fat thickness on either side of the spine at the EMG electrode levels was observed for those 7 patients.

Conclusions: Preliminary results with DMD patients seem to indicate that an initial larger muscular activity on one side of the spine could induce a bending of the spine on the opposite side. It would appear that beyond a Cobb angle of 10°, above which a patient is considered to be scoliotic, a higher muscular activity is found on the convex side. Such a result was reported with scoliotic patients and was associated with a mechanism that could prevent further development of the deformation [1]. Since no difference in the cross sectional area of the paraspinal muscle, in the fat infiltration in those muscles nor in the fat thickness at the electrodes recording position, an uneven nervous activity on left and right sides of the spine can be at play. Imbalanced neural input was also considered to have a pathogenic importance in the etiology of adolescent idiopathic scoliosis by Avikainen et al. [2]

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201 - Assessment of Stretching and Resistive Exercise on Muscle Oxygenation in Poststroke Hemiplegic Patients Using Near-Infrared Spectroscopy

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Introduction: Individual muscle stretching and resistive exercise has been an accepted approach for poststroke hemiplegic patients. However, it is difficult to assess the effects of stretching and exercise in the physical therapy field. Near-infrared spectroscopy (NIRS) has been used to measure the muscle oxygenation and hemodynamics. Some investigators assessed muscle oxygenation in patients using NIRS [1,2]. The aim of this study was to investigate effects of stretching and resistive exercise on local muscle oxygenation in poststroke hemiplegic patients by use of NIRS.

Methods: Three poststroke hemiplegic patients (age 62.3 yr, height 157.7 cm, weight 61.0kg; mean, Brunnstrom stage IV) participated in this study. The subject sat down in a comfortable position before the examination. Relative changes in concentrations of deoxygenated hemoglobin/myoglobin (□deoxy(Hb+Mb)) and total hemoglobin (□tHb) accumulation were measured from gastrocnemius muscle on unaffected side during 5-min recovery periods from walking (Rec1), walking after individual muscle stretching (ID stretching; Rec2), and walking after resistive exercise (4th level of Manual Muscle Testing; Rec3) continuously. Oxygen saturation (SpO2) and pulse rate at third finger were also recorded. The walking distance was 10m and the subject walked at free speed. This study was approved by the ethics committee of Fujimoto Hayasuzu Hospital, and all subjects gave their written, informed consent.

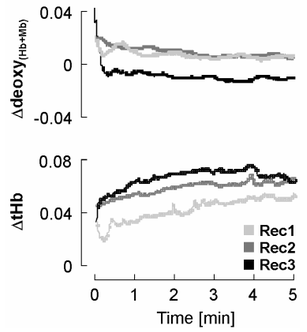

Fig.1. *A comparison of three conditions in Δdeoxy$_{(Hb+Mb)}$ and ΔtHb (Sub.C).*

Table 1. *P values between three conditions in each subject.*

	Sub.A	Sub.B	Sub.C
Δdeoxy$_{(Hb+Mb)}$			
Rec1 vs. Rec2	$P < 0.01$	$P < 0.01$	$P = 0.41$
Rec1 vs. Rec3	$P < 0.01$	$P < 0.01$	$P < 0.01$
Rec2 vs. Rec3	$P = 0.77$	$P < 0.01$	$P < 0.01$
ΔtHb			
Rec1 vs. Rec2	$P < 0.01$	$P = 0.97$	$P < 0.01$
Rec1 vs. Rec3	$P < 0.01$	$P < 0.01$	$P < 0.01$
Rec2 vs. Rec3	$P < 0.01$	$P < 0.01$	$P < 0.01$

Results: There were no net changes of SpO2 and pulse rate during the periods of walking and recovery. Walking speed at Rec2 and 3 were faster than at Rec1 at all of subjects. Rec 3 was lower in the □deoxy(Hb+Mb) compared with the other conditions except at the beginning of the period (Fig.1). This result showed that resistive exercise increase □deoxy(Hb+Mb) and then Hb and Mb were more oxygenated than the other conditions. □tHb was increased at all of conditions, and significantly highest □tHb appeared at Rec3 (Table 1). Note that these results were found in all of subjects. This increment of □tHb suggested that blood flow was increased at Rec3.

Conclusion: Our results showed that resistive exercise more increase blood flow in local muscle compare with ID stretching. We believe that NIRS method is a useful tool to assess the effects of rehabilitation.

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230 - Analysis of Anterior Tibial Translation and Quadríceps - Hamstrings EMG Ratio during Isometric Quadriceps Contractions in ACL – Deficient Individuals

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Introduction : There is a concern between physical therapists when working with patients that have recently undergone anterior cruciate ligament (ACL) injury or reconstruction, which is to restore quadriceps strength while protecting the reconstructed or injured ACL and patellofemoral joint from excessive stresses. The aim of this study is twofold: 1- to investigate the correlation between quadriceps/hamstring ratio EMG activity on anterior tibial translation (ATT) during a maximum voluntary isometric quadriceps contraction (MVIQC) at 30, 60 and 90 degrees of knee flexion in the injured and non injured side; 2 – to compare the amount of ATT at 30º, 60º and 90º in a (MVIQC) between the injured and non injured side.

Methods: Ten male subjects with ages ranging from 18 to 40 years and with unilateral ACL injury were voluntary to participate in the study.The uninjured side of the ten subjects were used as a control group. The electrical activity of 5 muscle (vastus medialis obliquos, vastus lateralis, rectus femoris, semitendinosus and bíceps femoral) was recorded by a EMG system and bipolar surface electrodes while performing three (MIVQC) at 30, 60 and 90 degrees of knee flexion in a Biodex Isokinetic Dynamometer. The measurements of the amount of ATT and side-to-side differences at each angle was recorded simultaneously with the EMG activity by a arthrometer KT 2000 during the MIVCs. Correlation between quadriceps/hamstrings EMG ratio and ATT were calculated using a matrix of Pearson Correlation Coefficients. The Mann-Whitney U-test was used to compare the quadriceps/hamstrings EMG ratio and the amount of ATT at each angle between the injured and non injured side. The analysis of variance (ANOVA) was used to compare the amount of ATT at each angle. All significance was determined at a level of $p \leq 0.05$.

Results: Results showed no statistically differences of quadriceps/hamstrings EMG ratio between injured and non injured side at 30º (p=0.85), 60º (p=0.85) and 90º of knee flexion (p=0,48). No significant correlation was found between quadriceps/hamstrings EMG ratio and ATT in the injured and non injured side. The average amount of ATT in the injured side was 11,40mm ±2,7 at 30º, 10,22mm ±2,6 at 60º and -1,05mm ±2,4 at 90º, respectively. In the non injured side was 6,90 mm ±1,72 at 30º, 5,47 mm ±1,69 at 60º and - 1,85 ±1,68 at 90º of knee flexion. Statistically difference was found in the amount of ATT between the injured and non injured side at 30º (p=0,00013) and 60º (p=0,0003) of knee flexion. No differences was found in ATT at 90º of knee flexion (p=0,85)

Discussion: The quadriceps/hamstrings EMG activity was not statistically different between injured and non injured side at the three angles tested suggesting that the greater amount of anterior tibial translation at 30º and 60º compared to 90º is due to lack of compressive load at the tibiofemural joint, low hamstrings EMG activity to restrain the ATT at 30º and 60º and greater anterior shear forces produced by quadríceps contraction at the range 60º to 30º. This study also shows that the amount of ATT in acl deficient individual is statistically greater than the contralateral knee at 60º and 30º of knee flexion despite the no statistically difference quad/hams ratio between non injured and injured side. **Conclusion:** We conclude that prescribing isometric knee extension between 60º to 30º of knee flexion may cause excessive strain on the injured or reconstructed ACL during the healing phase.

245 - EMG Analysis of the Biceps Brachii Muscle in Deaf Individuals, Compared To Hearers

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Introduction: It is well known that deaf individuals who use signal language usually maintain a muscle overload during their communication, mainly in superior limbs. This study aimed to analyse and to compare the biceps brachii muscle functional electromyographic characteristics in deaf individuals who use LIBRAS (Brazilian signal language) with healthy speaker controls.

Methods: Electromyographic recording of biceps brachii muscle were used to evaluate muscle activity during the rest position and maximal voluntary contraction (MVC). The EMG signal were obtained by surface differential electrodes (silvers bars 10mm apart, 10mm long, 2mm wide, 20x gain, input impedance 10GΩ and 130dB CMRR). The EMG signal were analogically amplified with gain of 200x and sampled by 12 bits A/D covert board with a 2KHz frequency. Two groups were used, matched according to gender and age: Group 1, consisted of twenty four bilingual deaf and Group 2, consisted of twenty four healthy speaker controls.

Results and Discussion: Statistical analysis was performed using the SPSS software version 10.0 (Chicago, IL). Continuous data with normal distribution were analyzed by unvaried analysis of variance (ANOVA). Comparing the EMG activity of the biceps brachii muscle it was possible to verify that there were no significant differences between deaf and speaker controls during clinical rest position (F=0.31, p = 0.57) and the comparison regarding MVC showed higher EMG values for the deaf and significance differences (F=4.0, p=0.05). There were no significant differences between the groups when considering sex or age. Based on the data from this work, it is possible to conclude that, although deaf individual presented higher levels of EMG activity of the biceps brachii muscle than healthy volunteers during the rest position, these differences were not statistically significant, but when the muscle is in function, the hyperactivity may cause overuse and future problems for these individuals.

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250 - Effects of Myofascial Release on Heart Rate Variability in Healthy Subjects

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Introduction Its is possible to explore the functioning of the autonomic nervous system (ANS) based on the heart rate variability (HRV), which can be measured in R-R intervals between two electrocardiogram consecutives R waves.

The sympathetic activity plays an important role in myofascial trigger point (TP) activity regulation. However, until the present study only one research has used the myofascial TP massage therapy to the head, neck and shoulder areas to examine its effects in HRV.

Aim (of the study) To evaluate quantitatively (in time-domain - TD and frequency-domain – FD parameters of HRV analysis) the myofascial release (MR) influence to the head, neck and shoulder areas in heart autonomic modulation.

Method The electrocardiogram data were obtained with 26 healthy volunteers (17 in MR group and 9 in control group, aged 27,2 ± 6,72 years, mean ± standard error), in supine, breathing in natural frequency, during 30-minutes, imediately before, during and after a MR 20-minutes session. Autonomic function was measured using time and frequency domain analysis of heart rate variability.

Results The control group did not present significant differences ($p < 0.01$) in none of the analysed parameters, both in TD and FD. Neverthless, the MR group, in TD, showed a significant decreasing ($p < 0.01$) in heart rate and a statistically significant increasing ($p < 0.01$) in HRV, during and after the MR session. In the FD the MR group, showed significant diferences ($p < 0.01$), only during myofascial TP massage therapy.

Discussion In normal subjects the MR to the head, neck and shoulders areas is effective to increase the HRV and decrease the heart rate, indicating an increasing in the cardiac parasympathetic activity.

Keywords: heart rate variability, sympathetic, parasympathetic, spectral analisys, myofascial trigger point.

252 - Electromyographic Activity of Shoulder Muscles During Land and Water Proprioceptive Neuromuscular Facilitation Exercises

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Introduction: Shoulder musculoskeletal disorders affecting individuals today is common in the outpatient care setting. Most of the treatments focus on reducing pain and restoring range of motion as well as strength of the rotator cuff, the scapular pivoters, the humeral positioners, and the propellers muscles groups. Treatment protocols include the proprioceptive neuromuscular facilitation (PNF) exercises and can be employed not only on land but also in water environment. The purpose of this study was to compare the electromyographic activity of the middle deltoid and pectoralis major (sternal head) muscles during the PNF exercises performed on land (Diagonal 2) and in the water (Bad Ragaz Concept – Diagonal 301).

Methods: Eight male subjects (21-23 yr) without history of shoulder dysfunction participated in the study and were oriented how to perform the two exercises. A portable, dual surface electromyography system was used to record muscle activity (middle deltoid and pectoralis major) as well as during maximum voluntary isometric contraction for normalization (MVIC) purposes. The unit used DeLuca disposable electrodes and the electromyographic data were sampled at 1000Hz, and band-pass filtered (20-500Hz). Before electrode placement, the skin was thoroughly cleaned with an alcohol pad. For the water procedures, the electrodes were covered with a bio-occlusive, water-resistant dressing and the exit port for the lead from under the water-resistant dressing was set petroleum jelly to prevent splash or immersion interference. Subjects were instructed on how to perform the Diagonal 2 (from extension- adduction-internal rotation to flexion-abduction-external rotation) on land as well as the Diagonal 301 (same movement pattern) in the water. The exercises were performed with three repetitions with the dominant arm. To determine differences in electromyographic activity of muscles during the two exercises, a two-tailed paired t-Test was performed.

Results: There was significantly greater electromyographic activity of the pectoralis major (sternal head) muscle done on land (Diagonal 2) compared with water environment (Diagonal 301) ($p<0.05$). There was no difference in electromyographic activity between the performance of middle deltoid muscle done on land (Diagonal 2) compared with water environment (Diagonal 301). The electromyographic intensity for the pectoralis major was 76% and 43% of MVIC for the land and the water exercise respectively. For the middle deltoid was 35% and 39%.

Discussion: Although aquatic physical therapy has received a refinement in the last years, few studies have documented the differences between land and aquatic exercises. One of goals in shoulder musculoskeletal disorders is to strength muscles groups involved, but there is no consensus if the aquatic exercises can have the same effect of the land exercise. The findings of this study provided some insight into the role of two muscles while performing the PNF exercises. It is suggested that the level of activity required for a strengthening effect must exceed 66% of MVIC (1). In our results, only the exercise performed on land by the pectoralis major achieved this level. Care must be taken because our sample are healthy subjects, there were only two muscles assessed and we do not have statistic power (due to small sample) to detect real difference. The electromyographic activity of two shoulder muscles was compared during land and water PNF exercises and provided a step in quantifying the use of EMG in an aquatic environment.

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256 - The Effects of Hand Vibration on Motor Evoked Potentials In Hemiparetic Individuals

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Introduction: In healthy subjects, muscle vibration (<12s duration) has been reported to facilitate motor evoked potentials (MEPs) produced by transcranial magnetic stimulation (TMS) (Kossev et al., 2001; Rosenkranz et al., 2003). The aim of this pilot study was to evaluate the effect of vibration at rest on the MEP responses of individuals with chronic hemiparesis (44±11 months following a CVA). Our goal was to study the persistence of these effects in time and their relationship with motor function (Fugl Meyer score for the upper limb), as well as to compare the vibration effects between control and hemiparetic individuals.

Methods: MEPs were recorded in the first dorsal interosseus muscle before, during and up to 9 minutes after hand vibration (80Hz; 1mm amplitude, 60s duration) in 12 patients (43±14 years) and in 16 healthy control subjects (41±14 years). The patients had mild-to-severe hand paresis (Chedoke McMaster hand score 2-7) and preserved vibration sensibility (≥ 5s with 128 Hz tuning fork). The hand motor cortex was stimulated (Magstim 200, 1.2 x MT, 15s interstimulus interval) over the affected hemisphere or the dominant hand area of the control subjects with a 70 mm double coned coil. MEPs were evoked at rest to prevent fatigue. ANOVA and non-parametric tests (Mann-Whitney and Wilcoxon) were used, respectively, to compare MEP latencies and amplitudes.

Results: At rest, MEPs could be generated in all control subjects but were absent in 5 of the 12 hemiparetic individuals at a stimulation intensity of 70% of the maximal stimulator's output. MEPs could not be evoked in patients with a Fugl Meyer score below 50/66. Only 2 of these 5 patients were unable to produce a MEP response with vibration. In the 7 other patients, motor thresholds (40±8%) were not significantly different from those of the control subjects (37±6%) but their MEP latencies (mean 24.5 ± 0.4 ms) were longer ($p<0.035$) than the control values (mean 22.6 ± 0.3 ms). Latencies were not affected by vibration in either group. At rest, although patients' MEP amplitudes did not reach values (mean ± SD: 423±287 µv) as high as those in the control subjects (mean ± SD: 806±1058µv), there was no difference between the groups ($p=0.820$) because of the large inter-subject variability. However, while vibration had a strong tendency ($p=0.063$) to increase MEP amplitudes in control subjects (mean ± SD: 1101±1135µv), it also significantly increased ($p=0.018$) it in the patients (mean ± SD: 1014±813µv) to a level similar to that of the control subjects. These effects did not last beyond the duration of the vibration.

Conclusion: Our results show that vibration could be used to increase the motor response generated with a descending cortical drive in hemiparetic subjects. Vibration procedures, different than the ones we used, need to be tested in order to evaluate if these effects could persist after the duration of the vibration. Vibration could also be used for prognostic purposes when additional input is needed to reveal motor responses.

265 - Atypical Shoulder Muscle Activation Parameters in Subjects with Multidirectional Instability

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Introduction: Multidirectional instability (MDI) of the shoulder is a complex form of glenohumeral instability characterized by capsular laxity and instability in more than one direction. MDI can occur traumatically, atraumatically, unilaterally, bilaterally and with or without generalized joint laxity. Glenohumeral stability occurs as the result of passive capsuloligamentous restraint and the proprioceptively mediated, coordinated activation of shoulder girdle muscles, in particular the rotator cuff. Although deficient proprioception has been implicated as a factor in the pathophysiology of MDI, the muscle activation patterns associated with this condition have not been investigated. Consequently, the purpose of this study was to compare the activity of selected shoulder girdle muscles in patients with MDI to subjects with normal, healthy shoulders using quantitative surface and intramuscular fine-wire electromyography (EMG).

Methods: Seven subjects with MDI and 11 controls performed 10 continuous concentric isotonic (50 N) repetitions of shoulder abduction/adduction, flexion/extension and internal/external rotation on an isokinetic dynamometer. Double-differential surface electrodes (SE) were used to record activity from the deltoid (anterior, middle and posterior portions), latissimus dorsi and pectoralis major (sternal head) muscles. Single-needle, bipolar intramuscular fine-wire electrodes (IFWE) were used to record activity from the infraspinatus and supraspinatus muscles. SE and IFWE data were sampled at 2500 Hz and band-pass filtered at 10-500 Hz and 30-750 Hz, respectively. Integrated EMG (IE), normalized (% of peak) average amplitude (AMP), contraction duration (DUR), burst onset (ONST) and termination (TERM) parameters were investigated. A two-way (group x movement) ANOVA with repeated measures (repetition) was used to compare EMG parameter values for each muscle. Bonferroni post-hoc tests were used to identify significant main or interaction effects.

Results: Significant differences ($p < 0.05$) between MDI and control subjects for both amplitude (IE & AMP) and phase based (DUR, ONST & TERM) parameters were found for 5 out of the 7 muscles tested (middle and posterior deltoid, pectoralis major, infraspinatus and supraspinatus). Several group parameter differences were movement specific while others were not. Most importantly, IE, AMP and DUR parameters for the infraspinatus and supraspinatus muscles in subjects with MDI were significantly lower than controls, particularly when performing internal/external rotation.

Discussion: This preliminary investigation demonstrated atypical shoulder muscle activation in subjects with MDI during the performance of controlled, planar shoulder movements. The results agree with previous findings of diminished supraspinatus EMG activity in subjects with anterior instability (McMahon et al., 1996). The identification of movement specific reduced rotator cuff activation has important implications for the development of physical rehabilitation programs in the treatment of MDI.

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267 - Application of the Electromyographics Biofeedback in the Treatment of Anal Incontinence

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Introduction: The biofeedback electromyographic is considered an effective treatment for anal incontinence, but a substantial proportion of patients fails to improve. he purpose of this study was to verify the efficiency of the application of EMG in the study of the anal incontinence as well as to verify the fidelity as quantification instrument during the treatment.

Methods: The signs were captured by an electromyography composed of bipolar anal electrode with pré-amplification of 20 times, amplifier with factor 1000 times, filters with band of frequency 20 to 1000 Hz, way common of rejection of 120 dB, converter A/D of 12 bits and sampling frequency 2000 Hz. In all of the procedures of the sign EMG, were following the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK) relative to the job of the electromyographic. The treatment of the sign was constituted in rectification by wave completes, lineal wrapper through filter Butterworth of 4th order, cut frequency of of 5Hz, normalized in the base of time and of the intensity, and the intensity was normalized by the average. The variability of the intensity of the sign EMG was calculated through the variability coefficient (CV). The comparison among the signs of EMG of the different studied patients was made through the test-t for parallel samples, and the level of adopted significance was of 0,05 . We retrospectively analyzed the clinical and physiologic data of 20 patients consecutively treated in our unit for anal incontinence by electromyographics biofeedback end Clinical evaluation was performed by means of a structured questionnaire that included previous history, symptoms of incontinence, and bowel habit. Anorectal evaluation measured anal pressure profiles and registration of the EMG signs, defecatory dynamics, rectal compliance, and rectal sensitivity. Biofeedback treatment was performed by a manometric technique with reinforcement sessions scheduled every three months and daily exercising at home.

Results: Of 20 patients (20 female; age range, 50+ 10 years) with at least three-month follow-up, 84 percent had a good response to treatment. By univariate analysis, several factors, such as age, history of constipation, abnormal defecatory maneuver, and rectal compliance, were significantly related to treatment response, but by multivariate logistic regression only age and defecatory maneuver were independent predictors of the response. The association of both factors provided the best sensitivity and specificity; 48 percent of patients younger than age 55 years and with abnormal defecatory maneuver had negative response to treatment, whereas 96 percent of patients age 55 years or older with normal defecatory maneuver had a positive response.

Conclusion: In patients with anal incontinence scheduled for electromyographic biofeedback treatment, potential alterations of defecation should be first searched for and corrected, particularly in younger patients. Biofeedback training improves continence in patients not only during treatment and within the first two years but also for several years after therapy. The employment of biofeedback training to obtain improvement of the threshold of rectal sensibility (minimal volume of endoluminal distension to produce the sensation of imminent defecation and external anal sphincter contraction) has proved useful in the rehabilitation of incontinent patients.

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275 - The Effects of Functional Electrical Stimulation Gait Training on Joint Coordination and Muscle Activation in the Child with Cerebral Palsy

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Introduction: Children with cerebral palsy (CP) often lack the ability to produce appropriate muscle activation patterns for effective joint coordination and efficient ambulation. We assessed the effects of functional electrical stimulation (FES) applied to the ankle musculature while walking on lower limb coordination and on muscle activation (electromyography or EMG) in a child with CP when walking without FES.

Methods: A nine-year-old female with left spastic hemiplegic CP underwent gait training with surface stimulation of the left tibialis anterior (TA) to produce dorsiflexion while walking. The subject practiced at home twice daily for 30 minutes, five days a week. This was done for 20 weeks with a 2-week break between weeks 6 and 8. Motion analysis and surface EMG data were collected before and after the training. Three trials were selected for full analysis. Sagittal-plane joint angle and joint angular velocity data were calculated for the ankle, knee and hip. EMG data from ten lower extremity muscles was processed using a continuous wavelet transform (CWT) to derive the instantaneous mean frequency (IMNF).

Results

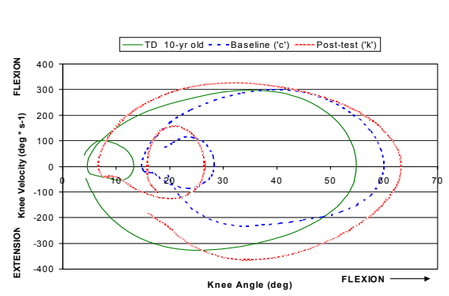

Figure 1. Relative phase plane portraits of th left knee before and after the gait training Data for an aged matched child of typica development (TD) is also shown. Simila shifts were observed in the ankle phase plan portraits.

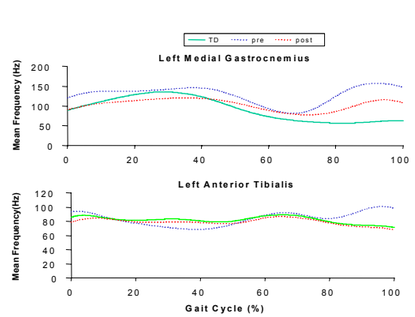

Figure 2. IMNF curves for the left ankle musculature before and after the gait training. Data for an aged matched child of typical development (TD) is also shown.

Discussion: Gait training with FES appears to have influenced the joint coordination of the knee and ankle of the more affected side as evidenced by the shift in the relative phase plane plots towards a more typical profile. In addition, the IMNF curves demonstrate a downward shift in the frequency characteristics of the left gastrocnemius (GA) and a shift towards a more typical profile. Possible reasons for this frequency shift could be related to changes in joint position, muscle activation, timing or muscle selectivity. This may, in part, also explain some of the improvement in knee joint coordination as the GA crosses the knee joint and influences knee joint mechanics. Interestingly, the IMNF curves of the TA demonstrate similar frequency characteristics for both pre- and post-training. This may suggest that changes are incurred in the antagonistic muscle when FES is applied, and therefore may have important implications for future training programs with FES.

282 - The Effects of Scapular Taping on the Surface EMG Activity of Shoulder Girdle Muscles During Upper Extremity Elevation in Individuals With Shoulder Impingement Syndrome

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Introduction: Subacromial (shoulder) impingement syndrome is considered to be accompanied by abnormally increased activity of the upper trapezius and inhibition of other shoulder muscles active during upper extremity (UE) elevation. Scapular taping is commonly used by physical therapists in the rehabilitation of people with shoulder impingement syndrome to enhance control of scapular motion and normalize shoulder biomechanics. Firm application of a specific type of tape, perpendicular to the fibres of the upper trapezius muscle, is theorized to normalize activity of the shoulder girdle muscles by decreasing activity of the upper trapezius and increasing the activity of the lower trapezius. Activity of other muscles may also be affected. Theories regarding the effects of scapular taping have yet to be adequately tested. The purpose of this study is to investigate the acute effects of scapular taping on the magnitude of surface EMG activity of selected shoulder girdle muscles during activities involving UE elevation in individuals with impairments consistent with shoulder impingement syndrome.

Methods: Twenty volunteers with shoulder pain and positive Neer's and/or Hawkins-Kennedy tests have participated to date. Each participant performed five repetitions of the following two UE elevation activities, both with and without the application of scapular taping: 1) "scaption" (elevating and lowering the UE in the scapular plane); 2) a functional task comprising placing and removing a 0.5 –kg water bottle onto and off of an overhead shelf (i.e., raising and lowering the UE both with and without the bottle). The timing of the movements was kept consistent among participants using a metronome at a pace of 40 beats/min. The possible testing orders for the two activities with and without tape were randomised, then applied in succession as participants entered the study, to minimize test order effects. Surface electrodes were applied over the upper trapezius, lower trapezius, serratus anterior, and infraspinatus muscles. The ground electrode was applied over the manubrium. The characteristics of the Noraxon□ data acquisition and processing system were: bandwidth10 Hz ±10% cutoff to 500 Hz 1% cutoff; sampling frequency 1000 Hz; CMRR >100 dB; gain 1000; baseline noise < 1 μV rms; input impedance > 100 M□. The surface EMG signal was obtained during maximum voluntary isometric contractions elicited for each muscle, and the RMS was derived. The surface EMG signal was then obtained for each muscle in each component of each activity. The RMS was then derived and normalized to the RMS for the maximum contraction, then divided by the contraction duration of each movement component (which varied slightly among the trial repetitions within and between participants), to yield the "area" variable that was used in the statistical tests comparing the tape versus no-tape conditions. Data analysis was performed using SPSS software. Dependent t-tests were used to compare the tape versus no-tape conditions. The alpha level was 0.05.

Results: Upper trapezius muscle activity was significantly lower for the tape condition for elevation during scaption ($p=0.015$), and for functional shelf task components of elevation with ($p=0.02$) and without ($p=0.015$) the bottle and lowering the UE while holding the bottle ($p=0.018$). Upper trapezius activity while lowering during scaption and lowering without the bottle during the functional task were not significantly lower in the tape condition ($p>0.05$). No other significant differences were found between the tape and no tape conditions for the other muscles and component motions ($p>0.05$).

Conclusion: Scapular taping appears to significantly decrease surface EMG activity of the upper trapezius during UE elevation, but there does not appear to be an associated significant increase in activity of the lower trapezius, serratus anterior, and infraspinatus muscles.

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287 - EMG Activities of Shoulder Joint Muscles while Standing on One Leg with a Crutch

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Introduction: There have been several reports of the motion analysis while locomotion with a crutch[1, 2)]. However, the EMG activity of the upper limb muscles while standing with a crutch could not be clarified. The purpose of this study was to investigate EMG activities of the shoulder joint muscles while standing on one leg with three kinds of crutches.

SUBJECTS AND Methods: Eight healthy volunteers (8 males, aged from 19 to 31) participated in this study after obtaining their informed consent. One leg of each subject was assumed to be an affected limb. All subjects used three kinds of crutches such as T-cane (T), Quadripod cane (Q), and Lofstrand crutch (L) with an upper limb of sound side while standing. They kept their 20% partial body weight bearing (20%PWB) on a crutch. In this condition, the crutch and the affected leg were on the floor while standing for 5.0 seconds. EMG activities were detected from biceps brachii, triceps brachii, deltoid (anterior medial posterior), pectoralis major and latissimus dorsi with bipolar surface electrodes. Each electrode distance was set at 1.0 cm. EMG signals were digitized at a sampling rate of 1KHz, filtered using a bandwidth ranging from 10Hz to 500Hz and integrated (IEMG). IEMG values of the upper limb muscles while standing were normalized by the value at the maximum voluntary isometric contraction (MVC). MVC was performed at the shoulder joint abduction of 10°and the elbow joint flexion of 30° in supine.

RESULTS AND DISCUSSION: Figure 1 showed that the normalized IEMG value of biceps brachii, triceps brachii, deltoid (medial posterior), and latissimus dorsi while standing were significantly larger in T and Q than in L ($P<0.05$). The normalized IEMG value of pectoralis major was significantly larger in Q than in L ($P<0.01$). The normalized IEMG values of deltoid (anterior) was no significant difference among three crutches ($P>0.3$). These findings indicated that L was capable of over 20%PWB. This result is one of the indicators when we recommend an adequate crutch for each patient.

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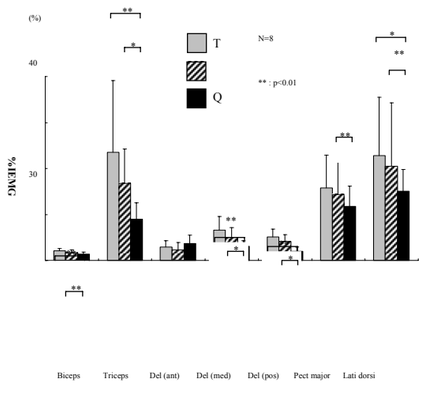

Figure 1 %IEMG of the shoulder joint muscles while standing with three kinds of crutches

293 - Changes in Muscle Coalitions in the Upper Extremities in Patients with a Cervical Spinal Cord Injury

H.A.M. Seelen, Y.J.M. Janssen-Potten, C. Pons

Introduction: In cervical spinal cord injured (c-SCI) patients arm-hand function (AHF) is impaired. New coalitions in muscle activation must be acquired by these patients during rehabilitation. In some cases muscle transpositions are performed to improve function. Aim of this study was to quantify changes in muscle co-ordination in the upper extremity in c-SCI patients.

Methods: During standardised upper extremity task performance (moving a small object over approx. 25 cm in medio-lateral direction) activity of 21 muscles of the trunk, shoulder girdle, upper arm and forearm was recorded using surface EMG in a group of high c-SCI (n=10), low c-SCI (n=10) and non-SCI subjects (n=10) (study A). Eight trials were recorded per subject. Time to perform the task was normalised to the movement cycle. Intra-class correlation coefficients (ICC) indicating EMG signal reproducibility was calculated. A similar protocol was presented to a c-SCI patient who was scheduled for forearm muscle transposition (study B).

Results: The vast majority of ICC values ranging from 0.86 to 0.99 in both studies. Clear differences in timing of dominant muscle activity during task execution were observed between all groups in study A. In study B before the operation dominant activity in most muscles occurred between 60-95% of the movement cycle, i.e. near the end. In contrast, after the operation the temporal pattern of main muscle activity was more differentiated across the whole movement as was also visible in non-SCI subjects in study A.

Discussion: Both within and between subject EMG reproducibility was good. Results show that our test is well standardised and may be useful to assess changes in muscle co-ordination in c-SCI. Data from study B indicate that a very localised (muscular) intervention has profound consequences for the total complex of intermuscular co-ordination of the shoulder and arm.

323 - Activity of Lower Limb Muscles During Driving a Cycling Chair In Hemiparetic Stroke Patients

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Introduction: We developed a cycling chair with a steering system to control a front wheel by one hand and investigated if the patients with severe hemiparesis can drive it by both legs pedalling. Furthermore, we studied the relation between the muscle activities on both paretic and non-paretic lower limbs and the pedalling torque generated during driving.

Methods: Three healthy adults (26~45 years) and four non-ambulatory hemiparetic stroke patients (69~81 years) participated in this study. The level of hemiparesis evaluated by Brunnstrom's stage was I in the two patients and II in other two patients. The surface electrodes to record EMG were put on the following muscles: gluteus maximus (GM), rectus femoris (RF), vastus medialis (VM), medial hamstrings (MH), tibialis anterior (TA), and soleus (Sol) in both sides. The EMG was recorded by using a telemetry system during isometric muscle contraction with total flexion and extension in each leg and during driving the cycling chair straightforward with maximum effort in 13m distances. According to the forward movement of the left pedal from the top position, the rotation cycle of the pedal was divided into 4 phases (P1~P4) every 90 degrees. The pedalling torque was shown by a sine curve and it indicated minus values when the left pedal moved from top to bottom. The mean values of integrated EMG in each phase were compared statistically with Sheffe's method.

Results: All the patients could drive the cycling chair in a straight line and the mean driving speed was 49.5 (42.8~55.8) m/min. The integrated pedalling torque showed minus values in P1and P2 and plus values in P3 and P4 in all subjects. In the healthy subjects, VM, MH and Sol in left side and RF and TA in right side were significantly active in P1 and P2. In P3 and P4, the muscle activities in each side reversed. GM of both sides showed no significant activities in all phases. In the patients, the pattern of muscle activity in the non-paretic lower limb was similar to that of the healthy subjects, but MH tended to be active together with RF and TA, and the two patients showed significant activity of GM in P1. While no clear signals of EMG were detected from the paretic muscles when performing isometric contraction, some periodic EMG signals appeared during driving and the integrated EMG of several paretic muscles showed significant differences among 4 phases. However, those tended to make co-contraction with the homologous muscles in the non-paretic side at the same phase.

Conclusion: All the patients could drive the cycling chair with excellent manner. Since the mean driving speed was more than the level of practical speed for indoor walking, it is suspected that the cycling chair can provide a chance of practical locomotion for the non-ambulatory hemiparetic patients. According to the muscle activities in the healthy subjects, VM, MH and Sol move a pedal downward and generate the torque to propel the cycling chair, while RF and TA assist another pedal moving upward. In the patients, however, this reciprocal pedalling pattern disappeared. MH in the non-paretic lower limb may act to assist a pedal moving from bottom to top by co-contracting with RF and TA. GM, that is inactive in the healthy subjects, will participate in the phase for pushing a pedal forward cooperatively with Sol in some patients. The muscles in the paretic lower limb showed significant activities during pedalling compared to isometric voluntary contraction. This result indicates driving the cycling chair can induce some activities in the paretic leg muscles even in the patients with severe hemiparesis.

342 - Comparative EMG Analysis of the Pain and the Conscription of Ascending Staple Fibres of the Trapezius, After Application of Techniques TENS and PRT – Positional Release Therapy

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Introduction: Science looks for ways to improve and develop therapeutical techniques through the use of complementary and non-invasive therapies, such as TENS. We also find an increased interest in the use of manual therapies, such as Positional Release Therapy (PRT), which is also a non-invasive method that does not compromise the gastrointestinal system. The PRT is used to assist in the treatment of tender points located in definitive detectable anatomical regions through the hands: one of the advantages of this technique when compared with TENS is that it diminishes the degree of pain to palpation with application of 90 seconds, while TENS has its peak effectiveness between 15-40 minutes. The aim of this study is: 1.Establish a comparative analysis through the use of surface EMG of the conscription of ascending staple fibres of the trapeze in the isometric voluntary contraction after the use of TENS and the Positional Release Therapy. 2.Establish a comparative analysis of the reduction of pain through an analogical visual scale, in ascending staple fibres of the trapeze after the use of TENS and the Positional Release Therapy.

Methods: The collection of data was carried carried out in 21 female students between the ages of 18 - 25 years presenting pain above a level 5 in the Visual Analogl Scale after the palpation of tender point in ascending staple fibres of the trapezius muscle. All the subjects had been randomized in three groups with seven volunteers assigned to each group.

Results: It was clearly that both the techniques, TENS and the PRT, demonstrated effectiveness in the reduction of pain and the exerted muscular tension in ascending staple fibres of the trapezius. With the application of the PRT, there was a decrease of 60%, while with the use of TENS this decrease was 24%. In the data collected with the use of the surface EMG, we observed that in the voluntary isometric contraction, the PRT demonstrated in 85% of the samples an improved organization of the conscription of ascending staple fibres of the trapeze, whileTENS only resulted in 28.6% improvement. In the data collected with the use of surface EMG, the TENS group and the PRT group had reduction of the average of the activity during marches, however, in the group of TENS, 57% had shown this reduction while that in group PRT, 100% of the samples they had demonstrated a reduction of the muscular activity during marches.

Conclusions: We have, as a result of these findings, found that the technique of positional release therapy demonstrated to be more effective with respect to the organization of the conscription of muscular staple fibres as well as for the reduction of pain.

344 - Electromyographic Analyses of Infra-Spinal Muscle Fiber Recruitment during a PNF Pattern and a Bad Ragaz Pattern – An Effectiveness Comparison Between Dry Land and Water.

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UniFMU- Brazil

Introduction: It is not commom to find research which compares muscle recruitment in dry land and in water. Inspite of being a new field of study and because of it´s importance in movement rehabilitation, the aim of this study was to analyze the effectiveness of Bad Ragaz and Proprioceptive Neuromuscular Facilitation (PNF) methods in recruitment of infra-spinal muscular fibers during the proposed motion for each method throughout Surface Electromyography (SEMG).

Methods: We selected 9 individuals, without any shoulder pathology, with the same characteristics (per age, weight, and frequency of sports practice per week). These subjects were assessed for infra-spinal muscle recruitment through a surface electromyographic evaluation. The first measurement was taken during voluntary isometric maximum contraction for lateral rotation in dry land. The surface electrodes were placed over each subject's infra-spinal muscle and the Maximal Isometric Voluntary Contraction (MIVC) was solicitated. Afterwards, the ground-based PNF standard was done in a lateral position (not to cause cross-talk) and then, the electrodes were "waterproofed" with a protective adhesive disk for the Bad Ragaz standard execution in water. The SEMG data of the three tests were recorded and processed for statistical analysis.

Results: After the calculations, based on the average of maximal values of each test and standard deviation, and considering MIVC as 100% of infra-spinal muscular recruitment capacity, it was realized that PNF recruits 81,65% of infra-spinal and Bad Ragaz Method, only 20,76%. These results were confirmed by statistical significance index.

Conclusion: The PNF method was more effective than the Bad Ragaz method in recruitment of infra-spinal muscle fibers. This information is very useful for physiotherapists, because, it is difficult to know exactly which method is better in treating a patient in water or on dry land. Thus, the performance of these methods in physical therapy practice can be elucidated based on evidence. It becomes obvious that it is necessary for more research on this field to establish efficacy of physiotherapy techniques based on real evidence.

345 - Electromyographic Analysis of the Quadriceps Femoris Muscular Group after Application of Short-Wave Continuous Diathermy

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Introduction: Short-wave continuous Diathermy are electromagnetic radiations responsible for promoting tissue heating of the superficial musculature as well as deep musculature, in such a way that their effects could lead to further modifications in the nervous excitability and maximal voluntary contraction. The purpose of this study was to verify whether the use of short-wave continuous Diathermy can modify the recruitment of motor units through surface electromyographic recordings of the quadriceps femoris muscle.

Methods: Seven women were recruited in this study: two Africans and five Caucasians, age range 20 to 24 years and without any pathological conditions. They underwent a surface electromyographic evaluation in which they placed in a sitting position and made knee extension by means of one resistance of equal intensity during three isometric maximal voluntary contractions for intervals of five seconds duration. The measurements were recorded through a four channels surface electromyography system consisting of silver chloride surfaced electrodes. Afterward, a continuous short-wave Diathermy was applied in transversal position, directly into the quadriceps femoris muscle for 20 minutes. Following this, the electromyographic recording was repeated, under the same position and resistance.

Results: There was a reduction of the electromyographic signal in all the muscles studied for subjects 1, 4 and 5; an increase of the signal for all the muscles of subject 2; a reduction of the rectus femoris (RF) and vastus medialis (VM) and increase of the vastus lateralis (VL) for subject 3; an increase of RF and VL and reduction of the VM for subject 6 and an increase of the RF and VM and reduction of VL for subject 7. An important reduction of 98% of the signal in muscle VM was achieved; so were a significant increase of 57.14% in muscle VL and a significant reduction of 57,14% for muscle RT. This can be justified due the volunteer's differences of race and sensibility, the bad location of the electrodes and the proximity of the origin and insertion of these muscles to the electrodes location.

Conclusion: Therefore, the conclusion is that had as much an increase how much a reduction have taken place in the recruiting of motor units right after the application of the short waves continuous, but more researches are necessary to complement the results achieved so far.

346 - Analysis of the Muscular Recruitment of the Anterior Tibial, Lateral and Medial Gastrocnêmius During Gait in Individuals with Concave and Plane Foot, Through the Surface Electromyography (Semg)

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Introduction: The bones and their support through ligaments and muscles form two longitudinal arches and a transverse arch, which make it possible to sustain weight and promote lever movement. A foot under load tends to increase its surface area absorbing the impact of the force of the weight of the body. The alterations in those plantar arches can cause abnormalities in the feet and consequently in the muscles used to move them. In the planar foot we observed a flattening of the vaults of the foot, and in the concave foot the longitudinal arch has curvature above the normal. The aim of this study is, through the surface electromyography, to analyze and to quantify the individuals' muscle recruitment with plane and concave foot during gait, preventing possible future alterations in the normal functional kinematics.

METHODOLOGY: Postural assessments were made for 6 individuals (3 with planar foot and 3 with concave foot), all were female between 18 and 25 years of age. Analysis of the feet were made through a plantígrafo. With circular electrode of silver chloride positioned between the motor point and the muscular insertion of the studied muscles, the individuals walked at 2 miles per hour for 3 minutes in the electric mat by NordicTrack Apex - 6100xi and the data were acquired through the surface eletromyography and biofeedback device, a Pathway NMR 400 with 4 channels.

RESULTS: The averages of the muscle recruitments were larger in the individuals with plane foot. For the medial gastrocnemius muscle the average of the activity during the gait was of 88,5 mV in the individuals with concave foot and 101,7 mv of plane foot. This same way, the activity of the lateral gastrocnemius was of 51,0 mV in the concave feet and 65,5 mV in the plane feet. This difference was also observed in the muscle tibialles anterior, where it presented an average of activity of 69,2 mV in the individuals with concave foot and 80,8 mV in the individuals with plane foot.

CONCLUSION: The analysis of data showed that the averages of the muscle recruitment of the medial gastrocnemius, lateral gastrocnemius and of tibialles anterior of the individuals with plane foot were statistically significantly larger than the averages of muscular recruitment in individuals with concave foot. This finding can be explained by considering that during the gait of the individuals with plane foot they need a larger muscular recruitment of the segment studied than the individuals with concave foot, which can unchain alterations in the normal functional kinematics in some cases.

348 - Electromyography Analyses of Infra-Spinal Muscle Recruitment During the Use of Two Different Resistance Water Devices - An Effectiveness Comparison Between Resistances In Water

Figueiredo, F.L.Moraes; Fernandes, S. Mary; Torriani, Camila; Cyrillo, F. Navarro
UniFMU- Brazil

Introduction: It is not commom to find researchs which compares muscle recruitment in dry land and in water. Inspite of being a new field of study and because of it´s importance in movement rehabilitation, the aim of this study is to compare the conscription of muscle staple fibres of infra spinal, through the use of two different resistances devices (Aquatoner®, to palmar of E.V.A), in aquatic environment, through the use of Surface Electromyography. The purpose of this study was to show which one of the most used water devices in acquatic rehabilitation is the best in muscle recruitment of infra-spinal muscles.

Methods: Nine individuals volunteered for this study, without any sholder pathology, with the same characteristics (as age, weight, frequency of sports practice per week). These subjects had been submitted to the infra-espinal muscle recruitment through the electromyography surface evaluation. The first measurement was voluntary isometric maximum contraction for lateral rotation in dry land. In the water in a sitting position with C7 immersion it was measured for the lateral rotation of the shoulder with the use of two electrical resistances: Aquatoner® and Palmar of EVA). All the data had been sent for statistics analysis.

Results: It was possible to verify that there were significant difference between the two resistances devices, in accordance with value calculated F = 18,46 were greater than of critical F (4,49). So, it was evident that the Aquatoner® demonstrated more muscle recruitment of infra-spinal than the Palmar of EVA. This fact probably happened because the contact surface of Aquatoner® is bigger than Palmar EVA, which shows the importance of use and knowledge of water physiologic principles during acquatic activities.

Conclusion: It was possible to conclude that the muscular conscription of the infra spinal muscles, were statistically significantly different in the use of the Aquatoner®, when compared with the Palmar of E.V.A. In the initial phase of rehabilitation treatment, palmar of E.V.A. may be more indicated because its resistance is not strong and can prevent lesions or pain during exercises. During the therapeutic water process, the Aquatoner® can be used in a more advanced stage of treatment, because its resistance provides more recruitment than the other one. The Electromyography showed to be a very useful device of muscle assessment during therapeutic exercises, because it can be important to physiotherapist decision during physiotherapeutic intervention. . It becomes obvious that it is necessary to conduct more research in this field to establish physiotherapy based on real evidences.

382 - Knee Adduction and Abduction Moment Patterns during Normal Walking and Tai Chi Exercise: Application for Osteoarthritis Rehabilitation

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Introduction: Musculoskeletal disease, including osteoarthritis (OA), is the leading cause of physical activity limitation for adults in the United States. The knee joint is the most frequently affected joint by OA. Mechanical joint loading is believed to contribute to the development of OA. , Increase in kKnee adduction moment during stance phase of normal gait can effectively generate large loads on the medial side of knee, which may increase the rate of progression of medial tibiofemoral OA. Recently, alternative approaches have been employed in the treatment of OA, attempting to decrease pain and stiffness. One approach, Tai Chi Chuan (TCC) has begun to draw more attention. For specific groups such as patients with OA, Tai Chi Chuan may provide unique benefits of improved function and decreased pain as compared to regular exercise walking programs. In order to understand the mechanisms of how TCC may be beneficial to persons with arthritis,. Iit is important to look at the loading demands TCC exercise places on the knee joint, specifically knee abduction/adduction moments. The purpose of this case study is to assess the knee abduction/adduction moments during normal walking and TCC exercise.

Methods: One subject (Age: 47 years, 10 years experience as a TCC instructor) walked across a level 5 m walkway at a self-selected pace and performed TCC stepping while motion detecting sensors attached to their trunk, thigh, shank, and foot of each limb. Optotrack® motion analysis system (Northern Digital Inc. Ontario, Canada), recorded three-dimensional kinematics of left lower extremity at 100Hz sampling rate (Figure 1). An AMTI (AMTI, Watertown, MA, USA) force platform recorded ground reaction forces (GRF) during the stance phase of gait and the TCC step. Knee abduction/adduction moments were calculated during the stance phase of each task using an inverse dynamics approach during the stance phase of each task.

Results: The pattern of knee abduction/adduction moment during normal walking and TCC stepping is shown in Figure 2. It is demonstrated that during the stance phase, although the peak abduction moment is similar in the tasks, TCC walking and normal gait generally showed similar peak magnitude of abduction knee moment, with the exception of during the 0% to 40% of stance phas has lower abduction moment during early stance and shows a large adduction e, TCC walking showed a higher knee abduction moment compared to normal walkingmoment in the 50%-80% stance phase..

Discussion: The current analysis of knee abduction/adduction moment during normal walking and Tai Chi stepping suggests that practicing Tai Chi exercise may increase the knee adduction moment that, potentially may increasing medial knee joint loading. This pilot study is a first step in understanding the impact of Tai Chi exercise for OA patient. It may be indicated that Ppeople with OA may need supervision to assist with modifyied TCC form to reduce chances of increasing adduction moments. This pilot study is a first step in understanding the impact of Tai Chi exercise for OA patient.

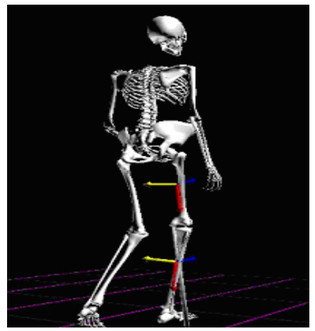

Figure 1: Musculosar Skeletonal Model

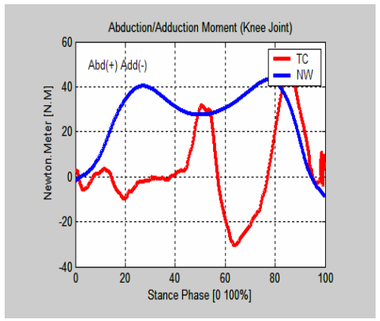

Figure 2: Knee Abduction(+)/Adduction(-) Moment

387 - Electromyographic and Radiological Evaluation, Pre Treatment and Post Treatment, Through the Maitland Method in the Cervical Spine, on Patient with Neurological Lesion: a Case Report

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Objective: The aim of this study was to evaluate the pre and post physiotherapeutic treatment through the Maitland method, in a patient with incomplete medullar lesion.

Methods: One patient, 36 years old, female, with sequels of spastic tetraparesis due to a medullar astrocytoma level C_2 - C_3, surgically extracted in May of 1999, participated in this experiment. The clinical evaluation of the patient showed a situation of asymmetrical spasticity of the cervical spine, adopting a predominant posture in rotation and lateroflexion to the left side. As a measuring instrument, a global postural physical evaluation was done through the observation and photographic register and electromyograph evaluation of the sternocleidomastoid and scalene muscles bilaterally, in addition to radiological exams. After this evaluation, the patient was submitted to 3 weekly sessions for 4 weeks, therapeutic focus exclusively on the cervical spine. The chosen treatment was the Maitland method. The patient was evaluated before and immediately after each session. This way, considering the electromyograph evaluation, the recordings were done before and after the first session, as well as before and after the last session. The radiological measurement was done before and after the total end of the proposed therapeutic intervention.

Results and Discussions: This study showed the improvement of the cervical control, demonstrated by the electromyographic exam and the photographic register. Besides that, an improvement in the cervical posture was observed through radiological exam done at the end of the 4 weeks, observing an alignment of the spinous processes of C_3-C_4-C_5 and better space between C_2-C_3.

Conclusion: It was verified that, through the Maitland Method, significant improvement in the amplitude of the cervical movements was revealed, making their control easier and improving their vertebral realignment. From this study it is necessary to go deeper into this line of research.

389 - Electromyographic Analysis of Knee Muscles During Normal Walking and Tai-Chi Step in Health Adults

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Tai-Chi exercise has been used to improve muscle strength, flexibility, cardiopulmonary function, and balance in healthy adults and elders. In an effort to understand the uniqueness of Tai-Chi exercise one strategy is to assess muscle activation profiles of Tai-Chi practitioners. The purpose of this pilot study was to compare selected knee muscle activity during normal walking and Tai-Chi gait in healthy adults experienced in Tai-Chi for a minimum of six months.

Methods: Nine healthy adults performed Tai-Chi exercise and normal walking while electromyography (EMG) in four knee muscles: vastus lateralis (VL), vastus medialis (VM), long head of bicep femoris (BF), and medial head of gastrocnemius (GA) were recorded. An eight-channel EMG system with bandpass of 10-1000Hz, (CCRR 90dB @ 60 Hz) (Myopac Jr., Run Tech., Laguna Hills, CA) recorded muscle activity using surface electrodes (30mm inter-electrode distance, Blue Sensor, Medicotest, Denmark) at 1000Hz. Two force platforms (AMTI, Newton, MA) marked the stance phase in both conditions. Paired t-test ($p \leq 0.05$) was used to compare the difference in peak root-mean-square (RMS) amplitudes in each muscle group during the stance phase of normal walking and the stance phase of the Tai-Chi step, Co-contraction was also assessed as the sum of activity of hamstring (BF) plus quadriceps (VL or VM) during the tasks.

Results: No significant difference between normal walking and Tai-Chi step was found for the average of peak RMS or co-contraction in any of the muscles (Tables 1&2).

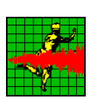
Discussion: Preliminary results demonstrated that Tai-Chi exercise produced low-level muscle activity similar to normal walking although the stance phase was longer duration. These results are consistent with an earlier study of EMG profiles shown in a single case report (Chan et al 2003) Tai-Chi exercise has low muscle activity demands particularly in gastrocnemius and hamstring muscles. However, the current findings are opposite to findings in a study that showed higher EMG activities in inexperienced practitioners during Tai-Chi stepping compared to normal walking. Results of this study possibly indicate that experienced practitioners are better able to perform the exercise of Tai-Chi with less muscle activation.

Table 1. Mean peak values and standard deviations (SD) of normalized RMS (nRMS)

	Normal walking (n=9)	Tai-Chi step (n=9)	
Muscle	Mean% + SD	Mean% □ SD	P
Vastus Lateralis	46.86 □ 11.29	60.10 □ 34.75	0.34
Vastus Medialis	44.92 □ 22.29	50.50 □ 15.93	0.58
Bicep Femoris	67.23 □ 47.70	45.98 □ 22.14	0.12
Gastrocnemius	116.43 □ 102.42	69.55 □ 31.79	0.12

Table 2. Co-contraction of Hamstring and Quadriceps -Mean and standard deviations (SD)

	Normal walking (n=9)	Tai-Chi step (n=9)



Muscle combination	Mean% □ SD	Mean% □ SD	P
VL and BF	114.09 □ 73.35	106.08 □ 46.10	0.63
VM and BF	112.16 □ 57.96	96.47 □ 30.25	0.32

403 - Quantitative Measurement of the Muscular Recruitment of a Bearer of Cerebral Paralysis with Scoliosis during Therapeutic Activity of Balance Reaction

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Introduction: In clinical practice of pediatric physiotherapy, it is very common to find patients bearers of Cerebral Paralysis of the type spastic hemiparesis that develop, with time, structured scoliosis. There is no doubt that a scoliosis, when established, harms the execution of some motor functions and it hinders physiotherapeutic intervention. For the treatment of cerebral paralysis, the physiotherapist uses, as therapeutic proposal, the reactions of balance in several postures and with the therapeutic aid of different materials. One of the therapeutic materials used is the therapy roll (rigid cylindrical structure covered with foam and antiskid lining), with which it is possible to propose different activities for the patient. However, few works present quantitative results effected with the use of this material. In this way, the objective of this work was the measuring, through the use of the surface electromyograph, the muscular recruitment of the lumbar spine erecting and of the straight abdominal of a hemiparetic patient with scoliosis, during activities of displacement of the center of gravity with use of a rigid roll.

Methodology: The subject selected for analysis was a bearer of cerebral paralysis of the type spastic hemiparesis with lower limb prevalence and presented a scoliosis with right convexity. The muscular analysis was accomplished bilaterally through a surface electromyograph in the lumbar muscles and straight erecting muscle abdominal. The subject was positioned seated on a rigid balance roll in the vertical position and displacements antecedent and posterior of the center of gravity were accomplished. The electric activity was registered in microvolts during these displacements.

Results: It was observed that during the vertical to posterior displacement on the roll the electric activity of the spinal erecting muscle on the right side was 157*mv* and on the left side of 43*mv*, while the activity of the straight abdominals on the right side was 25.5*mv* and on the left side was 28.3*mv*. During the vertical to antecedent displacement on the roll the electrical activity of the spinal erecting muscle was 238*mv* on the right side and 136*mv* on the left side, while the activity of the straight abdominals was 17.4*mv* on the right side and 28.9*mv* on the left side.

Conclusion: It was possible to conclude that during antecedent displacement on the roll, there was larger recruitment of the spinal erecting muscles than during posterior displacement on the roll. In addition, it was possible to observe that the side of convexity presented larger muscular recruitment in the antecedent displacement and in the posterior displacement on the roll. Moreover, the activation of the straight abdominals was greater during the posterior displacement on the roll, when compared to the antecedent displacement. This work was accomplished with one patient, being important to encourage other works with a larger number of patients seeking to explain the possibilities of the use of the roll as support material in the physiotherapeutic intervention of the bearer of cerebral paralysis with scoliosis.

408 - Maximal Recruitment of the Knee Musculature in Moderate Osteoarthritis: Implications For Management

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Introduction: Neuromuscular impairments of the knee musculature have been observed in the presence of knee osteoarthritis (OA). Whether sensory motor dysfunction is a precipitator to the pathologic process of knee OA or a consequence of it is not clear.1 It is hypothesized that neuromuscular impairments can be modulated by therapeutic exercise interventions to impede progression of OA joint damage. Therefore, there is a need to understand what deficits in muscular recruitment exist in those with early-stage OA so that appropriate interventions can be prescribed. The purpose of this study was to determine whether differences exist in maximal activation amplitudes between medial and lateral knee muscle pairs and between those with moderate OA and healthy controls during maximal static efforts.

Methods: Thirty (15 OA and 15 controls) participants were matched for BMI and sex. Both groups completed the WOMAC Osteoarthritis Index. The OA group was classified as mild to moderate severity based on Kellgren Lawrence radiographic assessment scores of ≤ 3. Thigh and calf circumference measurements were taken in bilateral standing. After skin preparation Ag/AgCl electrodes (10 mm2) were placed in a bipolar configuration over the vastus lateralis (VL), VM, rectus femoris (RF), lateral (LH) and medial hamstring (MH) and lateral (LG) and medial gastrocnemius (MG) muscles of the affected limb for the OA subjects and a random leg for the controls. Subjects performed a series of seven exercises: knee extension and flexion at 15° and 45°, knee flexion in prone lying at 55°, plantar flexion against a Cybex II dynamometer and a standing resisted plantar flexor exercise in an attempt to elicit maximal voluntary isometric contractions (MVIC) for the seven muscle sites examined. Each exercise was repeated twice. EMG signals were amplified (AMT-8, Bortec Inc, Canada) and sampled at 1000Hz. A root-mean-square (RMS) amplitude was calculated for a 100 ms moving window and the maximum RMS value, regardless of the exercise, was recorded as the maximal activity. A two factor (muscle by group) ANOVA model was used to test differences between groups, among muscles and group by muscle interactions. A ratio of lateral to medial sites was calculated for each muscle pair. T-Tests were used to test for differences between groups for age, BMI and thigh and calf circumferences and for the muscle pair ratios.

Results: The mean WOMAC score for the OA group was (31+/-17). There were no differences in age, BMI or thigh and calf circumferences between groups ($p>0.05$). There was a significant muscle by group interaction ($p<0.05$). Bonferroni post hoc analysis revealed a significant difference between groups for the LG muscle only which was higher for the OA group ($p=0.007$). The VL (294+/-204 μV) and VM (147+/-83 μV) amplitudes were different for the OA group only ($p=0.002$). The OA VL/VM ratio was 2.2+/-1.1, and for the controls it was 1.6+/-0.6.

Conclusion: These findings support a VM inhibition in the early OA subjects, although the control subjects did not have a 1:1 ratio between the two vasti muscles either. The hamstrings and gastrocnemius activity was not compromised in the OA subjects and in fact the LG recruitment amplitudes were significantly higher. These results show that in this sample of subjects with moderate knee OA, the ability to maximally recruit the muscles surrounding the knee joint was not compromised during static efforts. Although maximal muscle recruitment was not compromised, the differences between the vasti muscles and the higher LG for the OA group highlight the importance of evaluating muscle pairs. These results do not support sensory motor dysfunction as a precipitator of the pathologic process.

References:

1. Hurley MV (1999). Rheum Dis Clin North Am. 25(2):283-98.

Acknowledgements for funding: Canadian Institute of Health Research

409 - Comparative Analysis of the Recruitment of the Muscle Tibial Anterior with Two Resistance Resources In Relation to Voluntary Isometric Contraction Maximum (CIVM), Through EMGs

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Introduction: It is difficult for the physiotherapist to choose the most effectiveness resource so much, as to determine the quantitative percentage of resistance in relation to maximum capacity of contraction of a muscular group. Like this, the aim of this study is analyzes the muscular recruitment of the tibial anterior in different resistance situations, such as the Voluntary Isometric Contraction Maximum (CIVM) and with the use of the thera band and thera tubbing. Among the available resources for the muscular evaluation, the surface electromyography can be outstanding.

Methods: The selected subjects should fill out the inclusion criteria (feminine sex, entre18 and 24 years, height between 1,45 and 1,75, until 70 kg and no-athletes) and exclusion (presence of any muscular lesion, to articulate or bone in knee or ankle, antecedents of surgical process in knee or ankle, practice of superior sport to 4 times a week). As the placement of the electrodes was chosen the place between the area of insert distal and the motor point. Each subject stayed in rest 5 minutes before accomplishing the collection of data. The subjects were positioned seating in the stretcher with the leaning feet in a chair, in order to guarantee flexing of 90° of knees and hip. Soon afterwards the tests of CIVM were accomplished, being this done by an single examiner, the test with the thera band and to proceed with the thera tubbing, all in three series sustained by 5 seconds and with intervals of 5 seconds amongst themselves, requesting of the subject the dorsiflexion movement.

Results: The initial study was proposed with 42 subjects, but only 37 completed the tests, tends as average of age 20,3 years. The average of the values obtained in were: CIVM 219,8mv representing like this the 100%; thera band with average of 185,5mv, representing 84,4%; and the thera tubbing with average of 181,9mv, representing 82,7%.

Conclusion: As for the resources that supply resistance and that intend to the muscular invigoration, it fits to emphasize that the different types of materials found in the market and the tension supplied by the material and graduate for the physiotherapist they will determine the offered resistance and the necessary muscle recruitment to win such resistance. It was observed that the resource that supplied larger resistance, demanding larger muscular recruitment and producing larger picks in Mv, it was the thera band. However, the purpose of this study didn't establish the comparative analysis among these two resources, but the quantification in percentage of the thera band and thera tubbing with CIMV, what translates more interesting results for the physiotherapeutic clinical practice. It is important to emphasize the importance of the establishment of such comparisons with CIMV due to great need of resistance quantification that offers to the patient in the different phases of the treatment process, as well as in the explanation of the resistance percentage offered by the resource in comparison with the potential considered maximum of that muscular group. This way, the thera band promoted average of recruitment of 84,4% of CIMV and the thera tubbing promoted 82,7%, what suggests that there is no significant difference among the resources.

414 - Comparative Evaluation Case Study of the Abdominal Musculature Between Pregnant And Non-Pregnant Women During Isometric Movement Through Surface Electromyography

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Introduction: The posture and biomechanic changes suffered during gestation result in, possibly, alterations in the dynamics of the contraction of the abdominal muscles. In this way, it becomes important to establish the recruitment of the abdominal musculature quantitatively, through its electric activity in pregnant and non-pregnant woman and to establish correlations between those two states. Due to the shortage of work published in this area, this study has as objective to evaluate the recruitment of the muscular fibers of the right and left straight abdominal muscles and of the right and left external oblique muscle in pregnant and non-pregnant women, using surface electromyography.

Methods: Selected randomly within the students of the United Metropolitan University College, a 20 year-old pregnant patient, 39 weeks of gestation, realizing prenatal and a control subject of 20 years, physically active, both being of the same physical level. The patients were evaluated during the movements of trunk flexing, trunk flexing with rotation to the right and trunk flexing with rotation to the left in a series of isometric contractions sustained for 20 seconds. The electrodes were put on the straight abdominal muscle two centimeters from the umbilical scar and on the external oblique muscle three centimeters and 45 degrees from the antero-superior ilíacspine.

Results: After the evaluation, it could be observed that the values of muscular recruitment realized during the movements were larger in the control subject, in other words, in the non-pregnant subject. The values obtained in the pregnant subject in the external oblique muscles right and left and straight abdominal right and left were, respectively: 10,5*mv*; 9,9*mv*; 23,3*mv*; 32,7*mv*. In the non-pregnant subject, the obtained values were: 60,1*mv*; 49,6*mv*; 142*mv*; 107*mv* in the measurement of the same movements.

Conclusion: During the trunk flexing, in both patients, the straight abdominal muscle presented larger electric activity than the external oblique for what was already expected due to biomechanic action of such musculature. However, during both the trunk flexing with rotation to the right and the trunk flexing with rotation for the left, along with the external oblique right as well as left, the pregnant subject had higher values. Such a fact, not keeping with the literature due to the biomechanic action of this musculature, whose function is rotation of the trunk to the opposite side. But what can actually be observed is that surface electromyography is a very useful evaluation resource in that it was possible to notice differences in the pregnant subject's muscular recruitment and of the non-pregnant subject's, making possible to affirm that the pregnant subject presents a lesser muscular recruitment when compared to the non-pregnant subject. More research in this area is necessary in seeking to explain the mechanism of gradual loss of abdominal muscular recruitment during gestation, as well as its recovery after childbirth.

430 – Comparison of the Activity of the Paravertebrals Ridge Muscles, During Posture Maintenance in Dry Land and Immerged, Through Surface Electromyography

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Introduction: Many of the skeletal muscle disorders are derived from muscle tensions from daily activities such as heavy workload, professional and personal demands, and inappropriate physical activities among other overwhelming factors. Successfully, the water therapy has been used for the treatment of these disorders. Based on the physics principles of thrust, hydrostatic pressure and temperature this treatment seeks the reduction of muscle tension. Therefore the use of the surface Electromyography (equipment which measures the quantitative and qualitative muscle function) was essential to verify the reduction in muscle tension until C7 in the therapeutic swimming pool.

Methods: To perform this study, a group of 5 health individuals were chosen based on questionnaires and postural evaluation: sedentary women with no apparent posture disorder and physiotherapy major students of the Faculdade Cidade de São Paulo. They took part of muscle function evaluation for five minutes, monitored by Surface Electroyography signal reception of the paravertebrals ridge muscles, muscles that are largely active on gravity posture maintenance; outside (ground level) and inside of the swimming pool in sitting position.

RESULTS: During 5 minutes a median of 9,34mV on the right side and 6,84 mV on the left; and 5,59 mV on the right side and 3,12 mV on the left of muscle activity was detected outside of the pool and inside respectively. These changes are equivalent to a 27% reduction of muscle activity on the right side and 44% decrease on the left side. Analysis of the Electromyography activities mean were also completed during the last 30 seconds of the signal reception evaluation, the results were as follows: 8,66 mV on the right side and 6,15mV on the left, and 4,18mV on the right side and 2,99mV on the left, on ground level and inside the swimming pool respectively. There was a 52% decrease in muscle activity on the right side and 51%on the left when submerged (inside the pool).

CONCLUSION: As a result of this study, the paravertebrals muscle when submerged in therapeutic swimming pool reduces its activity; the longer the period of submersion the grater the reduction in muscle activity. This results support the acquatic rehabilitation in cases of pain and muscle tension.

443 - Reliability of Voluntary Step Execution Behaviour Under Single And Dual Task Conditions in Healthy Young and Elderly Individuals

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In a recent study we have demonstrated statistically significant differences between healthy young and old individuals in the ability to quickly step following a tactile stimulus under single and dual task conditions (modified Stroop task). In the current study we investigated the reliability of these step execution measures. Eight healthy young (26.4±1.0 years) and 12 older adults (73.8±6.0 years) performed a voluntary rapid step execution following a light tap on their heel while standing on a force platform, under either single (motor task only) or dual task (motor and cognitive Stroop task) conditions. Each subject completed 12 step execution trials (six single and six dual task trials) on three different occasions. The first two tests were performed 30 minutes apart by two different testers followed by a third test a week later performed by the first tester. Ground reaction force data were analyzed to determine the following three phases; step initiation (stimulus to first mediolateral deviation of center of pressure); preparation (end of step initiation to foot-off time) and swing (end of preparation to foot-contact of stepping leg). Young subjects were significantly faster than elderly subjects across all parameters, under both single and dual task conditions ($p < 0.05$). Intra-class correlation coefficient (ICC) values were calculated for the pooled population (N=20) to assess reliability within and between observers. ICC values were highly statistically significant ($p<0.01$). Inter-tester ICC values were somewhat higher under single than dual task conditions (0.78–0.94 vs. 0.58–0.93, respectively) with the lowest values seen for the swing phase parameter (0.78 and 0.58 for single and dual task, respectively). ICCs for the remaining parameters ranged 0.83–0.95 and 0.78–0.89 for single and dual task, respectively. Similarly, excellent ICC values were found for intra-test reliability with the lowest values seen for the swing phase (0.71 and 0.66 for single and dual task, respectively) with remaining ICCs ranging 0.84-0.95. A simple voluntary step execution test, performed under single and dual task conditions, appears to be a reliable outcome measure that can be used to assess dynamic postural function in clinical trials.

446 - Effect of Type of Practice on Arm Motor Recovery in Chronic Stroke Patients

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The effects of two types (guided vs non-guided) of long-term constant practice of a pointing movement on kinematics of the paretic arm were evaluated. Three groups of chronic stroke patients participated (2 experimental and 1 control). Patients from both experimental groups practised 75 pointing movements/day, 5 days/week for two weeks. Movements were made from an initial target located beside the body ipsilateral to the trunk to a final target located in the contralateral workspace, in front of the subjects. One experimental group had non-guided practice (knowledge of results) and the other had guided practice (knowledge of performance). The control group practiced a variety of unrelated motor tasks with the paretic arm following the same training schedule as the experimental groups. A retention test (1 month after training) and a transfer task were also recorded. Arm and trunk kinematic data were analysed. After practice, both experimental groups made faster and smoother movements. In addition, in the non-guided practice movements were more precise while in the guided-practice group, movements were less variable. The control group improved only the movement time. In all those who improved, motor gains were retained at the one-month follow-up but only in the guided-practice group did improvements transfer to another motor task. Improvements were accomplished differently depending on the type of practice. Some patients in the non-guided practice group, the majority of patients in the guided practice group and very few patients in the control group improved active joint range of motion and interjoint coordination. Only the patients in the guided group significantly decreased the excessive trunk movement during reaching. Our results suggest that significant improvements in movement patterns and function of the arm can occur even in patients with chronic hemiparesis when practice focussing on movement quality rather than outcome is provided.

Supported by CIHR, FCAR-FRSQ, Canadian Stroke Network and Foundation of the IRM.

451 - Electromyographic Analysis of Abdominal Muscle in Chronic Obstructive Pulmonary Disease Patients During Slow Vital Capacity Maneuver

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Introduction: Chronic obstrutive pulmonar disease (COPD) is considered an important problem of public health. It is the fourth cause of chronic morbidity and mortality around the world as a global impact pathology, according to the World Health Organization \ World Bank. The air inspired and expired from the lungs can be measured with respirometry during slow respiration or during forced expiratory movements, in order to classify the COPD degree. Electromyography is becoming a tool to evaluate the respiratory musculature due to the changes in respiratory mechanics and muscular respiratory weariness, because it is more comfortable to the patient, avoiding bigger overloads to each individual's body, imposed by espirometry.

Objective: This study's objective was to compare the electromyographic activity of right and left superior abdominiais muscles in individuals with COPD and in healthy individuals when performing the slow vital capacity movement.

Methods: 20 volunteers of both sexes with 55 + 10 years old mean age were divided in two groups : A group (Control), individuals with normal respirometrics performance, having VEF1 (forced respiratory flux during the first second) 80% above forecasted; and B group (COPD), individuals with respirometrics performance compatible with moderate to severe obstruction, having VEF1 60% below forecasted. Once identified the two groups, the recording of the electromiographic activity of right and left superior abdominiais muscles took place, in orthostatic position (standing), during the making of the slow vital capacity maneuver (expired gas volume after maximum inspiration, in a slow way). Electromyographic signal acquisition (EMG) was performed by an electromyograph composed of a 12 bits A/D converter, amplifier with 2000 times gain and 20 to 1000 Hz band pass filter. A differential bipolar electrode was used in the sampling, with 20 times pre-amplification, 25 mm2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. All applicable recomendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures.

The results were analysed using independent t student test ($p<0.05$).

Results: No statistically significant difference was observed when comparing the RMS (Root Mean Square) values taken for right and left superior abdominiais muscles of all volunteers from groups A and B, during the making of the slow vital capacity maneuver.

Conclusion: The electromyographic records in both groups did not show alterations between them, since in COPD group, the expiration is no longer passive due to the alterations in the respiratory mechanics, making these patients to use actively the abdominal musculature.

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452 - Study of Inspiratory Capacity in COPD Through Surface Electromyography

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Introduction: Chronic obstrutive pulmonary disease (COPD) is considered an important problem of public health. It is the fourth cause of chronic morbidity and mortality around the world, especially in the United States, and may reach the fifth position in 2020, as a global impact pathology according to the World Health Organization \ World Bank. The air inspired and expired from the lungs can be measured with espirometry during slow respiration or during forced expiratory movements, in order to classify the COPD degree. Electromyography is becoming a tool to evaluate the respiratory musculature due to the changes in respiratory mechanics and muscular respiratory weariness, because it is more comfortable to the patient, avoiding bigger overloads to each individual's body, imposed by espirometry.

Objective: This study's objective was to evaluate the inspiratory capacity in COPD through surface electromyography of superior and inferior abdominiais muscles.

Methodology: 10 volunteers of both sexes with age between 42 to 73 years old were divided in two groups : A group (Control), individuals with normal espirometrics performance, having VEF1 80% above forecasted; and B group (COPD), individuals with espirometrics performance compatible with moderate to severe obstruction, having VEF1 60% below forecasted. Once identified the two groups, the recording of the electromyographic activity of superior and inferior abdominiais muscles took place, in orthostatic position (standing), during the inspiratory capacity.

Results: No statistically significant difference was observed when comparing the RMS (Root Mean Square) values taken for the superior and inferior abdominiais muscles of all volunteers from groups A and B, during the inspiratory capacity.

Conclusion: The electromyographic records in both groups did not show alterations between them during inspiratory capacity, since in (CPOD) group, the expiration is no longer passive due to the alterations in the respiratory mechanics, resulting in a paradoxal respiration which makes the patients use actively the abdominal musculature.

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457 - Electromyographic Analysis Of Extensor Carpi Radialis Longus, Flexor Carpis Ulnaris And 2nd Dorsal Ulnaris Muscles During Objects Grasping Movement For Daily Life Activities (DLA).

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Introduction: The increasing incidence of musculoskeletal disturbances that affect the distal regions of superior members, constitutes one of the most important public health problems nowadays. A great number of persons presents musculoskeletal pain, reduction of grasping force, directly interfering in hands' functionality . Daily life activities are practical details that constitute a person's day to day tasks. The movements and muscular activity necessary to perform such activities go unnoticed until a wound or sickness interrupts the individual's ability to perform them in a normal way. The rehabilitation expert when meeting a patient with reduced functional capacity must count on appraisal instruments that give an acceptable degree of objectivity, regarding musculoskeletal structures, to guide in a safe way, the most adequate occupational therapeutic prescription to the patient. This research's objective was to analyse the simultaneous electromyographic activity of extensor carpi radialis longus, flexor carpis ulnaris and 2nd dorsal ulnaris muscles, during objects manipulation in daily life activities.

Methods: The electromyographic record of the muscles under study was made with 10 healthy volunteers, right handed, 3 women and 7 men, from 25 up to 39 years old. All volunteers signed an agreement term, after explanations about the procedures to be performed. Electrodes' placement was made with the individual seated, after skin cleaning to reduce the resistance and gel application between the electrode and skin to improve electric signal conductivity. The volunteers were kept seated, shrunk shoulders, 90 degrees elbow bending, wrists and hands in neutral position. Movements were then performed according to pre defined protocols. EMG signals during the movement of grasping a cup on the table, taking it to the mouth and then returning to the starting point were recorded. Electromyographic signals were acquired by an electromyograph composed of 12 bits A/D converter, amplifier with 2000 times gain and 20 to 1000 Hz band pass filter. A differential bipolar electrode was used in the sampling, with 20 times pre-amplification, 25 mm2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. All applicable recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures.

Results: The results show that during the cup's grasping movement the extensor carpi radialis longus muscle, responsible for the wrist extension in isolated action and elbow bending in combined action, has greater electric activity when compared to the flexor carpis ulnaris, confirming the results found in literature, while dorsal interossio muscle showed gretaer values than flexor carpis ulnaris, and close to extensor carpi radialis longus muscle, because it performs bending and abduction in relationship to the mean finger during objects' grasping movement.

Conclusion: Electromyography is an efficient tool in the study of superior members, and can be used in the clinical appraisal of patients with muscleskelectic lesions, as well as in physioteraphy, occupational therapy for a better understanding of biomechanical movement.

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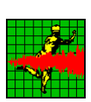

490 - Functional Electrical Stimulation (FES) of Gastrocnemius-Soleus (G-S) Improves Gait Patterns by Addressing the Changed Dynamic Resources of Children with Spastic Cerebral Palsy (CP)

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Introduction: The purpose of this study is to evaluate the effect of FES on dynamic resources (impulse and stiffness) and the corresponding changes in spatio-temporal parameters (stride length and frequency). Children with spastic CP demonstrate decreased power production, decreased calf muscle strength, changed timing and sequencing of muscle activity, decreased speed, and increased stride frequency with decreased stride length during walking. Rehabilitation procedures are usually based on the goal of correcting atypical patterns and have met with limited success. An alternative approach is to address the changed dynamic resources that result from the disease. Holt et al. [1] demonstrated that children with spastic hemiplegic CP had increased stiffness and decreased impulse of the affected limb. Carmick [2] and a later study [3] addressed the changed dynamic resources of children with spastic CP and found that paradoxically a more typical heel strike pattern was obtained. The preliminary results suggest that by addressing the changed dynamic resources, more typical patterns may emerge. This study investigated this hypothesis in a randomized control trial.

Methods: A crossover design with NoES and FES conditions was implemented. Nine children with spastic CP were included and randomly assigned to one of the two groups that received FES and NoES in reverse order. Six typically developing children (TD) were investigated without FES. FES was triggered by a footswitch system at initial contact with ground, remained on during the stance phase, and turned off when the stance foot lost contact with the ground. Stride length and stride frequency were measured using the position data collected by Optotrak 3020 system. Impulse and stiffness were estimated using an abstract biomechanical model, the escapement-driven inverted pendulum with spring (EDIPS) model [1]. To compare between NoES and FES conditions and between TD and children with CP, dimensional analysis and speed-normalization procedures were used [4]. Intrasubject means were used to generate group means for NoES and FES conditions and for TD. Mean differences between NoES and FES conditions and the 90% confidence intervals were calculated.

Results: FES increased mean speed-normalized dimensionless impulse significantly for the nine children with CP from 9.47 to 16.50. The mean speed-normalized dimensionless stiffness was unchanged. The results of spatio-temporal parameters were dependent on the order of receiving FES. The group that received FES first (n=4) had higher mean speed-normalized dimensionless stride length and lower mean speed-normalized dimensionless stride frequency than the group that received FES second (n=5) due to the effects of FES and the order of receiving it.

Conclusion: FES is effective in increasing impulse during walking but not in decreasing stiffness. FES effects on spatio-temporal parameters are dependent on the order of receiving FES.

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496 - Modulation of Cortical and Spinal Excitability During Stretching of the Rectus Femoris Muscle

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Objective: To measure the modulation of the cortical and spinal excitability during prolonged passive stretching of the rectus femoris muscle (RF).

Subjects: 16 healthy volunteers' subjects (mean= 23.4±0.5) (6F and 10M) participated in the study. Two were dropped. The 14 remaining subjects were later divided into two groups: stiff (n=9) and flexible (n=5) as determined by the modified Thomas test.

Methodology: Surface EMG activity of the RF was measured after electrical stimulation of the femoral nerve just below the inguinal ligament (Hoffmann's reflex and M response) and after magnetic stimulation over the vertex with a double coil (Motor evoked potentials [MEPs]). These measures were taken after a 30s stretch of the RF, with the patient in the "rectus femoris contracture test (Modified Thomas test)" position. The measures were repeated at 0% (pre), 25%, 50%, 75%, 100% and at 0% (post) of the maximal stretching position (max knee PROM). For each position, the degree of stretch felt by the subject was assessed with a 10 centimetre visual analog scale (VAS).

Analysis: Multiple comparisons of each condition were analysed using a repeated measure ANOVA with Dunnett's post-test. When correlations were calculated, Spearman's coefficient was used.

Results: When compared with pre-test condition (0%), MEPs of the RF were increased by 103±35% ($p<0.05$) at the maximal stretching condition (100%). At post-test, MEPs were back to their pre-test values. This facilitation was more evident within the stiff group (174±30% increase). The flexible group followed the opposite tendency showing an inhibition (44±10%). A positive correlation ($r_s = 0.56$, $p<0.01$) between VAS (stretching sensation) and MEPs amplitude was also observed. Regarding the H reflexes, a 51±18% ($p<0.001$) decrease was observed at the maximal stretching condition (100%), when compared with pre-test values. No significant difference was noted between the two groups. When measured at post-test, H reflexes equalled their pre-test values. Finally, the M responses remained quite stable with only a 16±10% decrease at the 100% condition.

Discussion: The maximal stretching condition showed reciprocal inverse results. Stretching of the RF decreased spinal excitability and increased cortical excitability, mainly on stiff subjects. The diminution of the spinal excitability observed in the flexible group could be explained by the pre-synaptic inhibition instigated by the muscle spindles. The same phenomenon was observed by Guissard et al. (2001) with passive stretching of the soleus muscle. On the other hand, the MEPs' facilitation measured within the stiff group at the maximal stretching condition could be explained by an increase in the discharge coming from the muscle spindles. Also, the cutaneous receptors located over the RF could participate in the MEPs' facilitation by stimulating the motor cortex via the sensitive cortex. Since there is a positive correlation between VAS and MEPs, another explanation could simply be that stiff subjects have difficulty to relax during maximal stretching. By being tensed, the motor cortex would be facilitated.

Conclusion: On a clinical basis, the effect of short-term stretching therapy (30s) is regulated by the neural system and not exclusively by tissue stiffness. Furthermore, diminishing the cortical and spinal excitability related to the RF muscle could increase the efficacy of passive stretching for that muscle. As examples, electrical stimulation or volitional contraction of the antagonist muscle could play this role. Finally, one could suggest that the reciprocal behaviour of the cortical and spinal excitability related to the RF is an adaptive plastic phenomenon.

Posture

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014 - Balance Control: Gender and Age Differences in 9 to 16 Year Olds

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Introduction: Age-related changes in indicators of balance control have been frequently measured in children up to 9-10 years old. What happens to the development of balance from this age, and whether girls and boys develop at a similar rate has not been fully explored.

Methods: Children of 9-10, 13-14 and 15-16 years of age (n=180, 90 girls and 90 boys) were randomly selected from schools in Sweden. Ground reaction force data, using a force platform sampled at 40 Hz for 60 s, were collected during a) bipedal stance eyes open, b) bipedal stance eyes closed and c) standing on 1 leg, eyes open (1LEO). Summary sway parameters of the centre of pressure (COP), frequency content, and stabilogram diffusion analysis parameters (Collins and De Luca, 1993), using the equations of Chiari et al. (2000), were calculated in the anteroposterior and mediolateral directions from the ground reaction force data. Statistical analysis was used to determine any effects of age, gender, and balance condition. Children who lost their balance during 1LEO were classified as 'steppers' (n=37) and were statistically compared to an age- and gender-matched group of 'non-steppers'. The significance level was set at $p<0.05$ with trends in the data indicated by $0.05\leq p<0.1$.

Results and Discussion: Gender differences at 9-10 years of age were apparent. Boys exhibited greater values than girls for selected parameters including sway velocity, RMS, total path length, total power and long-term diffusion coefficient. While few age differences were seen in girls, 9-10 year old boys exhibited greater values in sway velocity, RMS, total path length, total power, and short- and long-term diffusion coefficients than older boys. These results may be indicative of 9-10 year old boys using an open-loop, high velocity, large corrections of COP movements (Kirshenbaum et al., 2001). Since these parameter values were lower in 15-16 year old boys, a progression to an adult-like integrated open- and closed loop strategy may be indicated. As the girls in this study showed few age-related differences, they may be close to an adult-like control strategy at 9-10 years old. On closing the eyes, few parameters increased, thus an adult-like visual control strategy was not being used (Riach and Hayes, 1987). Either these parameters are not able to detect subtle changes in the development of visual control, or some aspects of visual control are still developing at 15-16 years. The 'steppers' had a greater short-term scaling exponent, with a trend towards a greater long-term scaling exponent than 'non-steppers'. This indicates that in the long-term region, 'steppers' are more likely to continue moving their COP in a particular direction. If that direction is moving away from equilibrium, the COP may continue to drift, possibly indicating instability.

Conclusion: Age-related 'improvements' in the calculated balance parameters occurred mostly in boys, thus there is a need to study genders separately when measuring balance in children. As little age-related difference was seen in girls, boys may lag behind somewhat in terms of developing postural control.

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055 - Effects of a Single Soleus Muscle Twitch on the Posture of a Standing Subject Studied With a Force Platform and Electromyography

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Introduction: Several experimental protocols have been used to study the mechanisms involved in postural control. In our experiments the standing posture was perturbed by a twitch of the soleus muscle. The objectives are *i* the study of the biomechanical and electromyographic (EMG) responses and their putative mechanisms *ii* the search for representative mean response waveforms for a population of normal subjects that could be used as a reference when testing neurologic patients with this technique.

Methods: Eight healthy subjects were studied (5 female and 3 male), 24 years old average. Two experimental conditions were used: *i* electrical stimulation of the Tibial Nerve to evoke an H reflex amplitude equal to 10% of the maximum M wave, *ii* percussion of the Achilles tendon using a clinical hammer provided with an accelerometer. Signals from the force platform and from the soleus, tibialis anterior, ventro-medialis and biceps femoralis muscles were acquired for later analysis.

Results: The most reproducible variables (coefficients of variation CV<0.05 for the normalized 1st peak), were: COP-ap, My and Fx (center of pressure in the anterior-posterior direction, moment along a perpendicular to the ap direction and force along the ap direction). The COP-ap had similar behaviors for the two types of perturbations, but not the COP-ml (medio-lateral). The population averages of the rectified and lowpass filtered EMGs were relatively similar for the two types of stimuli. To relatively similar COP-ap time courses corresponded different muscle activation patterns, which fell in two categories. In the first a more distal strategy prevailed and in the other a more proximal was found. The latter seemed to be associated with a higher period spent to achieve balance compared to the use of a more distal strategy.

Discussion: The data suggest that the subjects presented two different muscle activation patterns in response to similar perturbations, one more proximal than the other. Some of the biomechanical signals showed good reproducibility among the subjects and could be potentially useful for the study of neurologic patients together with the two main EMG profiles found in this research.

065 - Biomechanical Analyses of Postural Responses to an Unexpected Slip During Gait In Healthy Young Adults.

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Introduction: Slip-related injuries pose serious problems for elderly people in our society. Understanding recovery responses to slips during gait is important in developing more effective interventions for preventing slip-and-fall accidents. The purpose of this study was to biomechanically examine postural responses to an unexpected slip during gait.

Methods: Fifteen healthy males (20-30 years of age) participated in this study. None of them had a history of otological, orthopedic, or neurological problems. Subjects walked on a walkway (5 m long × 1.2 m wide) with an in built movable platform that induced an unexpected forward slip. The platform translated 15 cm anteriorly at an average speed of 75 cm/s when a subject's fourth step landed on it. Whole body motions were recorded using a 3D motion analysis system (Vicon motion system, Oxford Metrics Ltd.). Temporal-spatial and kinematic variables were examined.

Results: All subjects were able to regain their balance in all slip trials, and no falls occurred. In the slip trials, prolonged stance duration and increased angles of knee flexion and ankle dorsiflexion of the perturbed limb were observed. Decreased swing duration and shortened step length of the swing limb was noted in 13 of the 15 subjects, indicating that they rapidly landed their swing limbs on the ground following the platform movement. At the trunk, an increased angle of the trunk flexion was noted following the trunk extension induced by the platform movement. Further, a forward elevation movement of the upper arms on both sides was frequently observed after the slip.

Discussion: These results suggest that the dynamic equilibrium may be maintained by re-establishing the base of support and shifting the body's centre of mass anteriorly to avoid a backward fall due to a slip during gait.

093 - Static Postural Equilibrium Assessment of Normal Subjects Through Computerized Biophotogrammetry And Oscillometry

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Introduction: The balance is the maintenance of the body in position where the center of mass is found within a base of support (feet) out of meaningless oscillations, that is, up to the stability limits. For the maintenance of the balance, is needed the anatomical and functional elements be inviolate. This way, the aim of this study was the aim of study was quantify the static postural equilibrium of young women, as well as verifying the presence or not of existent correlations between the methods, computerized biophotogrammetry and oscillometer.

Methods: The study was conducted with 100 female subjects, ages ranging from 18 to 26, weight 50 to 75 Kg and height 1.50 to 1.75m. Having made the static balance experiment through computerized biophotogrammetry and through oscillometer, making use of Romberg test which was adapted into 30 seconds in which the subject is placed in body sway with joint and paralleled feet and eyes closed. It is verified, from it, the sagittal and lateral plane.

Results: The result revealed significant difference between the compared measures, having the assessed women with a variation of postero-right. Also, it was noticed the correlation between both methods.

Discussion: The results of this study showed the oscillometer as a reliable method, of easy access, high reproduction and great effectiveness in the balance measure.

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094 - Postural Evaluation Of Individuals Congenitally Totally Blind Using Computerized Biophotogrammetry

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Introduction: The aim of study was to evaluate the occurrence of postural asymmetry in individuals congenitally totally blind. The postural evaluation was undertaken using computerized biophotogrammetry.

Methods: The study was performed in a group of 44 individuals, being 22 congenitally blind and 22 sighted controls. The cases were selected following clinical ophthalmologic examination and an enrollment protocol and the controls following clinical ophthalmologic, visual acuity testing using Snellen charts and an enrollment protocol. White reflexive cylinders were used to mark the body anatomic parts previously selected and then, the images were registered in the anterior, posterior and left and right lateral views. The registered images were analyzed using the software ALCimage® 2.1, where 10 angles related to the corporal posture were measured: head, pelvic, knee, and maleolar symmetries, vertebral line, shoulder symmetry, relationship between head and shoulder symmetries and pelvic anteriority.

Results: Mann-Whitney U test was used in the comparison of the analyzed angles, age, and stature and body weight. Wilcoxon text was used for comparison of the left and right profiles and chi-square test was applied to verify the occurrence of significant trends in relation to the deviation laterality. According to the results obtained, the congenitally sightless individuals presented statistically significant postural alterations when compared to the controls: head/shoulder symmetry, more evident in the left lateral view. Significant difference was found in the knee symmetry in the female subjects when compared to the male subjects, as well as significant difference in the shoulder symmetry in male subjects as compared to the control females. It was noted a trend to the left laterality of the postural deviations in the control group, which was not present in the cases. A trend to obesity was not observed. The height of congenitally blind women was smaller than the women in the control group.

Discussion: the present study shows occurrence of postural asymmetries in congenitally sightless individuals and that in the absence of vision, the sensory-motor system, which orients the acquisition of visual information and directs the body positioning in the space is indispensable for posture regulation. In the majority of the comparisons between the anatomic points, only head and shoulder and knee symmetries were significantly different, which demonstrates the compensatory mechanisms act in order to compensate the vision loss.

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098 - Study of Elder's Static Balance and Its Correlation with Falls

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Introduction: The fall is one of the main problems of the senior population, being responsible for the increase in the morbidity, mortality and high social costs indexes. Different methods and instruments so much qualitative as quantitative, it has been developed to measure the corporal balance, flocking the seniors with has tendency to fall, so that it is possible to intervene in the face of the occurrence of the event. The purpose of this study was to quantify the body sway in seniors, in the sagittal and frontal plane through the Romberg test that was adapted being used as instrument the computerized biophotogrammetry, as well as the correlation verification among the oscillations of the static postural equilibrium with the falls.

Methods: Images of the oscillations were captured in both plans of 68 individuals of the feminine gender, with the age ranging from 65 to 84 years. After that, the images were selected and quantified by the software ALCimage® 2.1.

Results: The results exhibited oscillations of the body in the frontal plane (8,87 + 5,51) to the right side and (10,81 + 5,61) to the left side. In the sagittal plane the anterior sways (19,00 + 9,58) and the posterior ones (12,42 + 7, 07).

Discussion: We concluded that the body sway can be quantified individually in the plans of movement of the body, being possible to establish a minimum degree starting from which senior is in a fall risk.

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109 - Static Postural Equilibrium Assessment in Pregnancy Through Computerized Biophotogrammetry

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Introduction: The purpose of this study was to assess static postural equilibrium in pregnant women using the adapted Romberg test, comparing the body sway between two different moments of pregnancy.

Methods: Each subject was filmed, in the frontal and sagittal plane, and assessed frame to frame to select the greater body sways. The selected images were quantified through AlCimage® 2.1 software. A sample of 27 subjects, before the 17 weeks pregnancy and 15 after the 27 weeks pregnancy, was analyzed.

Results: The results showed mean differences between anterior and the right sway during all pregnancy moments with higher levels to the anterior direction. Moreover differences were observed between the anterior and posterior sway and anterior and on the left, only in pregnant women with more than 27 weeks pregnancy with anterior higher levels in all cases.

When compared the value of the oscillations between the two studied moments, was recorded a significant difference found through the Wilcoxon test. The higher values referred to the subjects after the 27 week gestation.

Discussion: These data indicates that pregnant women are likely to oscillate anteriorly. In later pregnancy the oscillation tend to increase considerably implying a progressive trend to anterior sway.

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114 - Individuals with Medial Compartment Knee Osteoarthritis Have an Altered Neuromuscular Response to a Rapid Valgus Perturbation at the Knee in Standing

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Introduction: Individuals with genu varum and medial compartment knee osteoarthritis (OA) can develop dynamic instability due to the presence of excessive frontal plane knee joint laxity that is localized to the medial compartment. Excessive joint laxity may negatively influence the latency of muscle responses because larger joint excursions are required to stimulate high-threshold mechanoreceptors. Increased latency may indicate diminished joint protection that necessitates larger magnitude neuromuscular responses to stabilize the knee. Increased muscle activity, however, may lead to excessive joint compression that could contribute to the progressive destruction of articular cartilage. Such a stabilization strategy would propagate a progressive cycle of joint destruction that involves cartilage erosion followed by laxity and dynamic instability, requiring greater muscular activity leading to excessive joint compression. The purpose of this study was to determine the manner in which individuals with medial compartment knee OA respond to a rapid valgus perturbation to the knee during standing.

Methods: Sixteen subjects with medial compartment knee OA and genu varum along with 16 age- and gender-matched healthy control subjects were tested. All subjects had stress radiographs taken to measure frontal plane knee joint laxity. Evaluation of the neuromuscular response of the muscles around the knee was performed with subjects standing with the tested foot on a custom designed movable platform placed flush with the floor. Straps stabilized the thigh while the plate translated laterally 5.8cm at a velocity of 40cm/sec, inducing a rapid valgus motion of the knee. Electromyographic (EMG) activity of the sartorius, gracilis, and medial and lateral portions of the quadriceps, hamstrings and gastrocnemius was assessed before, during, and after plate movement. Onset latency, EMG magnitude and level of co-contraction were determined during a 40-175msec window following the initiation of plate movement, which is consistent with a long loop reflexive response.

Results: The OA subjects had significantly greater medial laxity than the control group ($p=0.010$). No difference existed between the OA (2.3±0.7°) and control (2.6±0.6°) groups' valgus excursion ($p=0.313$), although the OA group ended in significantly less valgus (3.7±5.1°) than the control group (9.9±4.7°) ($p=0.001$). The medial gastrocnemius latency was longer in the OA subjects (114±24msec) compared to the control subjects (100±15msec) ($p=0.068$). The OA subjects had greater medial than lateral muscle activity ($p=0.026$) and greater medial than lateral co-contraction compared to the control subjects ($p=0.001$). In addition, the OA subjects took a longer time to shift the weight off of the test limb ($p=0.045$).

Discussion: The presence of greater medial than lateral muscle activity in the OA group indicates a less selective muscle stabilization strategy than that of the control subjects. This more global muscle activation strategy may be detrimental to articular cartilage as greater compressive loads are transmitted through the joint. The delayed medial gastrocnemius activation could be particularly harmful due to its role in minimizing frontal plane laxity during functional activities, such as gait. Through appropriate rehabilitation programs, it may be possible to modify the muscular responses to those that can stabilize the joint while minimizing additional joint damage.

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120 - Age-Related Postural Change During Gait: The Influence of Musculoskeletal Functions and the Experience of Falls

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Introduction: Age-related postural change, with rounding of the trunk with hip and knee flexed, is often observed in elderly people. The flexed posture appears to require more muscular effort; muscle strength, however, tends to decrease due to the aging process. As such, the question as to why elderly people tend to stoop, even though it requires more muscular effort, must be addressed. On the other hand, fear of falling has been associated with changing gait parameters in older adults. The aim of the present study was to compare the influence of musculoskeletal function to that of experiences of fall in forward trunk lean during walking.

Methods: A total of 20 elderly subjects aged between 61 and 86 years participated. A degree of thoracic kyphosis, lower-extremity range of motion, knee extension, and hip flexion isometric strength were measured as a musculoskeletal function. Subjects were questioned regarding their experiences of fall and whether they had any experienced injurious falls within a 1-year period. For gait analysis, subjects were asked to walk along a 10-m walkway at a comfortable speed. To represent the trunk lean during gait, the angle of the trunk segments in the sagittal plane were used to determine the relative angle between the vertical line and the neck-hip line. To clarify the effects of posture during gait, subjects were categorized according to the degree of trunk lean and their experiences of fall.

Results: No significant differences were found between the moderately bent group and the erect group with respect to the degree of thoracic kyphosis, nor in any of the lower-extremity ranges of motion or in muscle-strength values in terms of knee flexion and hip flexion. All fallers (n = 4) belonged to the moderately bent group. The mean trunk lean angle of fallers was significantly greater than that of the nonfallers (0.2 ± 1.7 degrees vs. –2.6 ± 1.7 degrees; P = 0.01).

Discussion: A forward trunk lean was found to be independent of the musculoskeletal evaluations carried out in this study. Only the experience of fall was associated with the forward trunk lean. Though the fear of falling was considered as one factor in gait changes, the experience of fall may also elicit postural changes during walking.

196 - The Effect of Sandal Straps on Standing Posture Control

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Introduction: To compare standing posture control using slippers with a thong between the first and second toes (traditional Japanese-style) and slippers without the thong by quantitatively evaluating the wearers' dynamic standing balance. This research provides information, important in the field of Kinematics, on the best footwear for fall prevention.

SUBJECTS: The subjects were 43 healthy university students (mean age: 21.4 years, average height:160.6 cm, 10 males and 33 females).

Methods: Dynamic balance was quantitatively evaluated in the Motor Control Test using Equi-Test system (NeuroCom). Turbulent movement of the platform was achieved by forward horizontal movements and backward horizontal movements of the force plate. The parameters were latency (ms) and strength (pounds). The height of the heel was matched to the area of the forefoot of the slippers in order to minimize experimental errors. Slippers were worn at random.

ANALYSES: Statistical analyses was performed using StatView package (ver 5.0). Because the data was non-parametric, the Wilcoxon rank-sum test was used.

RESULTS: Latency (ms); As for slippers without the thong, the latencies in backward horizontal movement and forward horizontal movement were longer ($p<0.0001$, $p=0.0003$, respectively) compared with slippers with the thong.

Strength(pound); As for slippers with the thong, the strength during backward horizontal movement and forward horizontal movement was decreased ($p=0.0177$, $p<0.0001$, respectively) compared with slippers without the thong.

DISCUSSION: As for slippers with a thong between the first and second toes, the latency was shorter and the strength was decreased compared with slippers without a thong. Therefore, slippers in the traditional Japanese, that is with the thong, provide better stability and consequently are better suited for fall prevention.

197 - Effect of Vision and Imposed Inclined Surface During Quiet Stance On Postural Sway

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Introduction. Postural sway is studied here in different ramp inclinations with open and closed eyes, with the objective of inferring how ankle joint muscles contribute to postural control with different proprioceptor and visual inputs.

Methods. Nine healthy subjects stood over a force platform in three inclinations: +14º (dorsiflexion) termed D; -14º (plantarflexion) (P) and 0º (horizontal plane) (H), with eyes opened (O) and closed (C). EMGs from the soleus (SO) and tibialis anterior (TA) muscles and the signals from the force platform were acquired for posterior cross-covariance analysis. The standard deviation (STD) of the center of pressure in the anterior-posterior direction (CoP_ap) and the area of an ellipse (obtained by a principal component analysis technique) which cover 85% of the CoP values (in both directions) were used as a measure of postural sway.

Results. In all cases, there was a clear tendency for higher sway for closed eyes. Both sway measures, area and STD, showed significant differences for the DC condition (higher sway) compared to HO ($p<0,05$). There was a small, but statistically significant, positive cross-covariance peak between SO and CoP_ap for all conditions, with the EMG preceding the CoP by about 250ms. Similarly, there was a small, but statistically significant, crosscovariance peak between TA and CoP_ap, negative in condition D, but positive in condition P, at similar delays (around 250ms). There was no correlation between TA and CoP_ap in condition H.

Discussion. In the overall, there was little sway difference between conditions H and P, but an increase in sway when the subjects were in condition D. The crosscovariance data suggest that in the latter condition there would be some degree of alternated modulation in the TA and SO activations. On the other hand, the presence of a positive peak in the cross-covariances between TA or SO and CoP_ap, in condition P, suggests an increase in ankle joint stiffness that could contribute to a decrease in postural sway. Vision did not affect the cross-covariance peaks in any of the three platform angles. On the other hand, postural sway, measured either in area or STD, tended to increase in all closed eyes conditions.

200 - Prediction of Different Muscle Activity Patterns between Soleus and Gastrocnemius during Standing in Humans: Preferred Direction Approach

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Introduction: According to the single inverted pendulum model of human bipedal standing, whole triceps surae muscles are considered to counteract the gravitational torque around ankle joint. However, there is a considerable difference in activity pattern among them: soleus (Sol) activity is tonic, while medial head of gastrocnemius (mGas) activity is rather phasic (see Fig.2). Here we try to explain this phenomenon rationally by focussing the functional difference between mono- (Sol) and bi-articular (mGas) muscles.

Methods: Six healthy subjects were asked either to maintain quiet standing (QS) or to stand swaying voluntarily at 0.2 Hz (Vol) for 30 s on a force plate (3 trials for each). Surface EMG was recorded from Sol and mGas. Joint torques at ankle (Ta) and knee (Tk) were calculated from the shank movement and the ground reaction force (extending torque was defined as positive). The muscle (EMG) activity was predicted based on our previous work as follows (Fig.1): 1) the bi-articular mGas muscle activity is in proportion to the inner product between the torque vector (Ta, Tk) and "preferred direction" (PD) at which the mGas is maximally active on the torque plane and 2) the remaining part of Ta that mGas cannot cover is compensated by mono-articular Sol muscle. The best EMG prediction was obtained by adjusting the PD and other regression coefficients so that the squared error was minimized.

Results: Typical characteristics of torque trajectory on the torque plane were that 1) it moved along a line which has negative slope (Fig.1) and 2) the Tk was positive in almost all instants. The predicted EMG calculated from this trajectory succeeded to reproduce the actual EMG pattern quite well (Fig.2). The value of PD of mGas was –34.3±13.5 deg (Vol) and –36.8±9.1 deg (QS), and inter-trial and inter-condition variability were small.

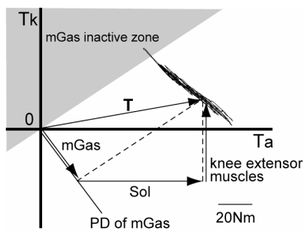

Fig.1 The torque trajectory during Vol and mechanism of determining muscle activities.

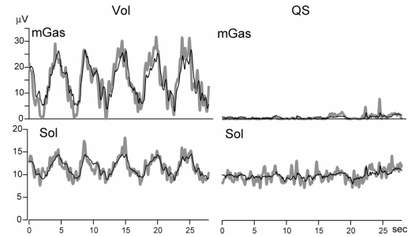

Fig.2 Actual (black line) and predicted (grey line) EMG during Vol (left) and QS (right).

Discussion: If the activity of triceps surae muscles depended on only Ta, both Sol and mGas should have showed the same activity pattern. However, this view obviously contradicts the observed EMG pattern (Fig.2). Most straightforward explanation for the EMG difference might be that the mGas motoneurons have higher recruitment threshold and gain. We demonstrate that the EMG difference can be rationally predicted without assuming such neuronal property differences. The key point is that, during standing, not only Ta but Tk is modulated in a specific manner (Fig.1) and this Tk modulation can affect the activity of mGas. One more remaining question is why the

knee flexor mGas is active under the situation requiring knee extension torque. This can be solved by considering that mGas activity is tuned with the orthogonal projection of the actual vector to its PD. Even when the torque trajectory is located in the first quadrant of the torque plane, its orthogonal projection to PD can be positive (Fig.1).

262 - Learning Different Postural Tasks In Patients With Poststroke Hemiparesis, Cerebellar Ataxia And Parkinson's Disease

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Introduction: Motor cortex, cerebellum and basal ganglia are known to play different role in learning new motor tasks [1]. However, it is not so clear for learning new postural tasks though posture impairments have been found in patients with lesions of the above structures [2, 3]. Therefore, the aim of this study was to compare ability to perform and to learn different postural tasks using visual feedback in patients with poststroke hemiparesis, cerebellar ataxia and Parkinson's disease.

Methods: 20 hemiparetic patients after cerebrovascular accidents, 33 patients with Parkinson's disease (stage 1-3 by Hoen & Yahr scale) and 37 patients with spinocerebellar degenerations were investigated. A control group consisted of 13 healthy subjects. The subjects stood on a force platform and were trained to change the position of the center of pressure (CP) presented as a cursor on the monitor screen in front of the patient. Subject was instructed to align CP with the target and then move CP thus shifting the target in the indicated direction. Two different tasks were used. In task A the target position varied randomly, so the subject learned a general strategy of voluntary CP control. In task B the subject had to move the target downward from the top of the screen to a definite position at the bottom, so a precise postural coordination had to be formed. A daily session lasted two minutes for each task. The training consisted of 10 sessions. Two parameters were analysed: the initial level of the task performance on the first day and a learning course during 10 days.

Results: The voluntary control of the CP position was impaired in all groups of patients. In both tasks, the performance in the first session was significantly impaired as compared to the healthy subjects. In task A, there were no differences between the groups of patients in the first day. The learning course was similar as well though the final level was somewhat lower in the cerebellar patients than in the other groups. In task B, the initial deficit was greater in the groups of parkinsonian and cerebellar patients than in hemiparetic patients. However, the learning course was better in the group of parkinsonian patients than in hemiparetic and cerebellar patients. The learning curve in parkinsonians did not significantly differ from that in healthy subjects. As a result, the final level of task B performance was approximately the same in the groups of parkinsonian and hemiparetic patients but it was much worse in cerebellar patients.

Discussion and Conclusions: The results suggest that motor cortex, cerebellum and basal ganglia participate in voluntary control of posture and in learning different postural tasks. However, these structures play different role in postural control. The differences mainly concern the performance and learning new postural coordination but not general strategy of voluntary CP control. Learning new postural coordination is impaired in a less degree after lesions of nigro-striatal system than after cerebellar or motor cortex lesions.

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277 - Patients with Chronic, Recurrent Low Back Pain Demonstrate More Generalized Joint Torque Patterns In Response To Postural Perturbations

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FUNDING SOURCE: Office of Patient-Oriented Research, Fletcher Allen Health Care, Burlington, VT and NIH/NCMRR/KO1 HD01194 – 05

Introduction: Persons with chronic low back pain (LBP) demonstrate altered movement patterns in response to postural challenges that may be attributed to changes in neuromuscular control. The purpose of this study was to compare the neuromuscular strategies of persons with and without LBP, in response to systematic postural perturbations. Net joint torques were used to reflect the net neuromusculoskeletal output at a given joint.

Methods: Twelve subjects (38.5 ± 8.0 yrs) with chronic, recurrent mechanical LBP of longer than 6 months (LBP) and ten subjects (38.2 ± 8.8 yrs) with no history of LBP (NLBP) stood on separate force plates, which were mounted on a moveable platform. The platform was translated unexpectedly in one of 12 horizontal directions for a total of 36 trials. Force data and 3-D body kinematics were combined with anthropometric data to calculate net sagittal and frontal plane joint torques for each subject at the ankle, knee (sagittal only), hip and trunk, using inverse dynamics. Torque integrals (normalized to body mass and height) were calculated over 75ms epochs spanning from 25-550ms after platform perturbation onset and used to create polar plots. Integrals derived from the 400-475ms epoch were analyzed using repeated measures ANOVA (directionXgroup).

Results: Visual analysis of polar plots indicates that, in general, the LBP group demonstrated predominantly non-direction specific responses across similar perturbations (i.e. forward and forward diagonal directions result in similar torque patterns) while the responses of the NLBP group were more tightly tuned temporally and spatially relative to perturbation direction. This finding is most evident in trunk extension/flexion torque responses illustrated in Figure 1. In addition, the LBP group demonstrated decreased magnitude of hip abductor/adductor torque on the unweighted leg and increased torque on the weighted leg for predominantly frontal plane perturbations compared to subjects with NLBP (dirXgrp, p=0.015).

Discussion: Patients with LBP exhibited altered automatic postural responses compared to NLBP subjects. The torque responses of persons with LBP appear more generalized compared to the direction-specific responses demonstrated by persons without LBP. Persons without LBP responded in a more dynamic manner to predominantly frontal plane perturbations, generating the required torque response with both lower extremities. The response of persons with LBP relied more heavily on the weighted leg in frontal plane perturbations suggesting an altered motor coordination response to postural perturbations.

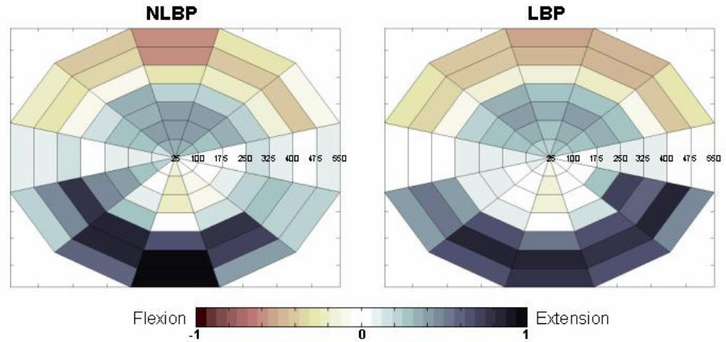

Figure 1: Ensemble polar plots of trunk extensor/flexor torque integrals. Cells represent torque integrals for each of 12 perturbation directions at 75ms epochs spanning 25-550ms following perturbation onset.

343 - Comparative Analysis of the Erecting Spine Muscle Activity During The Gait in Individuals with and Without Scoliosis.

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UniFMU - Brazil

Introduction: Scoliosis is a anterior subsequent deformation in lordosis, engendered by a sprain movement, that involves a three-dimensional structural modification of the vertebrae and ribs with vertebral rotation in the transverse plan. It is aI lateral deviation in the frontal plane and lordosis in the sagital plane. The scoliosis can be functional or structural. The functional curve is flexible and it tends to disappear when there is an inclination forward in the foot position; already in the structural curve, the vertebrae stray sidelong of the medium line of the body and at the same time, they are turned around of the longitudinal axis. The erecting muscles of the spine have origin in the lombossacra area and they interfere, in the lumbar and thoracic transverse processes and in the ribs. Its action is extension, and lateral bending. The cycle of the gait is divided, in a support phase and the swinging phase. There is countless measurement procedures to analisys gait which, in adult or smaller degree, they are related to themovement control. Eletromyography is the study of the muscle function through the analysis of the electric sign generated during the muscular contraction. This signs allow us to do interpretations in regular or pathological conditions. The purpose of this study was to compare through the surface eletromyography the recruitment of the erecting musculature of the spine during the gait in child with and without scoliosis.

Methods: Two 11 year-old children were accomplished during this study, and one presents scoliosis and the other no. It was used to allow a controlled speed gait an electric mat of the mark Nordictrac Apex 6000i, circle surface electrodes of chloride of silver of the mark 3M, alcohol to the 70% for asepsis and surface electromyography device of the mark Pathway model NMR 400 of 4 channels.

RESULTS: In the child with scoliosis, an asymmetry of the muscle activity could be observed, in which the side of the convexity presented a larger recruitment during the gait when it is compared with the side of the concavity. Besides, it was also observed that the average of the child's muscle recruitment with scoliosis was larger (22,5 mV) than the without scoliosis (19,3 mV). It is worth to stand out although that it was not found asymmetry of the muscular recruitment during the gait in the child without scoliosis.

CONCLUSION: Starting from the obtained results, it was possible to observe that during the gait there was a difference of the muscular activity of the lumbar spinal erectors among the children with and without scoliosis, and in the with scoliosis an asymmetry of the activity was observed with larger values on the convex side. Besides, the values of the average and of the maximum pick of the muscular activity observed in the child with scoliosis were larger than the without scoliosis. It is obvious that this study is just in the beginning of an important line research, however these quantitative data already supply conditions of studying the three-dimensional and specific characteristics of the scoliosis much better.

356 - Vibrotactile Feedback Improves Balance Control in Vestibulopathic Individuals During Pseudorandom Horizontal Surface Perturbations

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Recent studies have shown that a balance prosthetic device that provides vibrotactile feedback reflecting upper body tilt can help vestibular patients to maintain upright balance following a discrete tilt perturbation of the support surface. In the current study, well-compensated vestibulopathic subjects were tested in upright stationary stance and during continuous horizontal surface perturbations, using a moveable balance perturbation platform, while they either received or did not receive vibrotactile feedback reflecting sagittal plane body tilt. Ten 30 s trials under each of the four conditions were performed. Twelve vestibulopathic subjects (7 female 5 male, age 55±9, range 43-71 yrs, 8 acoustic neuroma, 3 idiopathic vestibular degeneration and 1 viral syndrome) were tested with their eyes closed with the instructions to stand as still as possible. Stabilogram-diffusion parameters and summary statistics for the Center of Pressure Signal (COP) and upper body sagittal plane tilt angle were analyzed. There was a significant decrease in average RMS body tilt angle both during stationary (33%) and dynamic (29%) conditions when vibrotactile feedback was available. A similar decrease was seen in average standard deviation of body tilt (55% & 43%, respectively) indicating less inter-trial variability due to the fixed upright reference provided by the vibrotactile feedback. Interestingly, the presence of feedback caused a significant increase in short-term diffusion coefficients the COP (increased stochastic activity over short time intervals) and a concomitant decrease in long-term diffusion coefficient and scaling exponent (increased antipersistence) of the tilt angle, both during stationary and dynamic conditions. Under stationary conditions with feedback present there was a 25% decrease in the planar component of the transition time of the COP suggesting that postural corrections were implemented earlier. Velocity and median power parameters of the COP increased when feedback was present under both stationary and dynamic conditions. The results indicate that vibrotactile feedback allows a tighter and more distinct control of body tilt under both stationary and dynamic conditions.

380 - Postural Coordination Dynamics During Voluntary Suprapostural Activity.

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Introduction: In two experiments we manipulated both the surface of support (hard surface vs. foam roller) and suprapostural task (head tracking frequency). Our previous research has demonstrated that different coordination strategies as measured by hip-ankle angular variability ratios emerge as a function of support surface during quiet stance. Presently, we sought to determine: 1) whether adding a suprapostural task in addition to changing the support surface would alter multi-segmental coordinative strategies and; 2) the impact of these simultaneous constraints on the emergence of postural transitions.

Methods: Twelve different participants (ages 18-35) in each experiment stood on one of two surfaces (hard surface vs. foam roller) with hands behind their backs looking at a computer monitor, 1m in front of them at eye height. They were instructed to maintain balance while tracking an oscillating (fore-aft) computer generated target with their head. Target frequencies ranged from .16 Hz to .75 Hz having a peak amplitude of 10 cm. Experiment 1 was conducted to determine the effect of single discrete frequencies on the postural response of the participant while controlling for support surface. Experiment 2 exposed participants to all frequencies in a single trial, by ramping the frequencies in an increasing or decreasing manner, this was done to determine the dynamical nature of both postural and suprapostural constraints. Angular displacement and translation data were collected from the head, neck, trunk, hip, knee and ankle with an electromagnetic tracking system (Flock of Birds).

Results: Experiment 1 determined the nature of coordination dynamics at discrete frequencies in the presence of two different surface constraints. Results demonstrate that on a flat surface, people use a continuum of hip/ankle ratios to accomplish the head-tracking task across the frequency conditions. On the foam roller, people used a rather rigid (less variable) mode of coordination throughout. On both surfaces, a predominant anti-phase, hip-ankle relationship was seen. The involvement of each joint to the attainment of a given task and subcomponents (e.g. head tracking and equilibrium maintenance) of the task can be further delineated. No large transition in postural coordination was seen by any method of analysis in any condition. This may perhaps be surprising to some, given the results of several previous studies (Bardy et al., 1999; Bardy et al., 2002; Marin, Bardy, Baumberger et al., 1999; Marin, Bardy, & Bootsma, 1999). In addition, voluntary production of movement to accomplish explicit goals appears to recruit different motor strategies than a perturbation paradigm elicits. Experiment 2 found much of the same results as the first experiment. No large postural transition was found and people adopted universally anti-phase hip-ankle relations across all conditions. However, the continuous changing of frequencies within a trial did elicit a hysteresis effect for AP head translation and several independent variable interactions not found in Experiment 1 – properties consistent with dynamic systems.

Discussion: These experiments provide evidence that is contrary to previous studies that have found in-phase hip-ankle movements during low frequency, suprapostural activity. No large transitions between postural strategies were seen, but rather, postural coordination modulation was gradual in the face of multiple and changing constraints. Lastly, postural coordination strategies seem to differ between voluntarily generated actions and movements generated by external perturbation, despite similar environmental constraints.

391 - Velocity Information Plays a Role in Controlling Ballistic Sway During Quiet Standing

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Introduction: Studies on human bipedal stance have usually focused on the average sway pattern over a certain time period. To investigate a small unit of spontaneous motion can provide profound understanding of the control mechanism. Loram and his colleagues (2001, 2002) demonstrated that small ballistic sways occur during a path of quiet standing using an anthropometric artificial inverted pendulum, and that the neural system regulates its amplitude. They also defined ankle impedance as change of ankle torque per unit change of ankle angle, which can be used as an evaluation parameter for ballistic sway. The purpose of this study is 1) to provide a method to investigate ballistic sway in normal quiet standing, 2) to demonstrate the wide variation of impedance in a path that induces the variation of ballistic sway's amplitudes, and 3) to investigate the mechanism of the variation through a simulation study in order to obtain insight into the control mechanism.

Methods: Eighteen healthy subjects, of whom six were female, were instructed to stand still for 70 s. A force platform was used to measure the position of the center of pressure and vertical force during quiet standing. The horizontal position of a lumbar point was measured using a laser displacement sensor to provide kinematics of body sway. We estimated the ankle joint torque and COM (center of mass) behavior using both signals according to the following assumptions; 1) The human quiet stance is an inverted pendulum, 2) The body pivots at the ankle joint, 3) The foot does not move and is a rigid body. Using the ankle torque and the COM kinematics, each path of body sway was divided into ballistic sways that were defined using velocity time-course as from zero-crossing time until the next zero-crossing time. For each ballistic sway, we calculated ankle impedance and sway amplitude. A simulation study using an inverted pendulum model and a PD controller was applied to investigate the control mechanism by simulating ballistic sways.

Results and **Discussion:** We successfully determined the ballistic sways in a path of spontaneous sway under the above-mentioned assumptions. It was found that both the sway amplitude and ankle impedance were continuously varying in a path rather than remaining constant. Additionally, the impedance was inversely proportional to the sway amplitude even if we removed the effect the sway speed on the impedance (Fig.). The proportion index was close to the theoretically predicted one (-0.5). The simulation study showed that the derivative gain plays an important role in generating variation of the impedance. Our results suggest that the derivative gain in the nervous control system notably contributes to the mechanism since the mechanical viscosity in the ankle joint is too small to be sufficient to the required derivative gain.

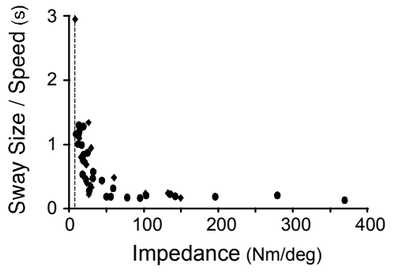

Fig. The inverse proportional relationship between ankle impedance and ballistic sway size divided by its peak speed in a representative trial of a subject.

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407 - Reduced Tonic Activity Of The Deep Trunk Muscle During Locomotion In People With Low Back Pain

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Introduction: Locomotion involves coordinated trunk muscles activity to move and control the spine and pelvis [4]. In general there are phasic bursts of activity in association with heel strike and in conjunction with movement of the lumbar spine and pelvis. Activity of the deepest abdominal muscle, transversus abdominis (TrA), is tonic with amplitude modulation in conjunction with locomotor and respiratory events [3]. When people have low back pain (LBP) variable changes in control of the trunk muscles have been identified. Although variable changes in superficial muscle activity have been identified [5], a relatively consistent finding is that activity of deep intrinsic spinal muscles, such as TrA, is delayed or reduced [2]. This study investigated the recruitment of deep and superficial trunk muscles in people with recurrent episodic LBP.

Methods: Electromyographic (EMG) recordings of the abdominal (TrA, obliquus internus (OI) and externus (OE) abdominis, rectus abdominis (RA)) and paraspinal muscles (deep (DM) and superficial (SM) fibres of multifidus at L4) were made in 10 subjects with recurrent LBP while walking on a treadmill at 1 ms^{-1}. All subjects were tested when they were in remission from symptoms. EMG activity was averaged over 10 step cycles. Onset and offset of bursts of activity and proportion of the gait cycle with activity were identified.

Results: Activity of the trunk muscles was phasically modulated across the gait cycle. Unlike healthy controls, activity of TrA was not tonic, but was phasically active for 46 (18) % of the gait cycle. Other abdominal muscles were active for between ~14 % (RA) and ~82 % (OI) of the gait cycle, and were not different to control subjects. Notably the power of TrA EMG at the frequency of respiration was ~2.8 (range: 0.2-9.7) times that at the frequency of locomotor events, in contrast to healthy individuals in whom the ratio is ~0.7.

Conclusion: The results of the this study indicate that people with LBP have changes in control of the deep trunk muscles and appear to have a shift in activity of TrA from locomotor to primarily respiratory activity. Considering the contribution of TrA to intervertebral control [1] these data would indicate that spinal control may be compromised during locomotion in LBP.

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412 - Comparative Analysis Of The Trapezius Muscle Before And After The Use Of The Subcaptal Bar Through Surface Electromyography (EMG)

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Introduction: Posture can be defined as a position or attitude of the body, the relative disposition of the parts of the body for a specific activity, or characteristic ways of sustaining one's body. The cranium is maintained in position by the muscles of the cervical spine. For the head to be maintained in an erect position and so that one can look forward, since the weight of the head tends to make it lean forward, the muscles that insert in the posterior part of the cranium should contract against gravity, these muscles showing larger potentiality in relation to the flexors of the neck. There is a narrow relationship between the stomatognatic system and the cervical musculature, and it could be said that any alteration in this system can also cause disequilibria of the head. One mode to evaluate and to diagnose the electrical activity that the muscle realizes in one contraction is through surface electromyography, through electrodes on the surface that interpret the bioelectric potential produced by the muscle revealing its activity in certain movements. The objective of this work is to compare the electrical activity of the descending fibers of the trapezius muscle, during a march, through surface electromyography, before and after the use of the subcaptal bar in individuals that present a prevalence of anterior muscular chain. The subcaptal bar has as objective to minimize the projection of the center of gravity, and consequently to reduce the electrical activity of the subsequent musculature during the march.

Methods: For the selection of the research subjects, the following exclusion criteria was considered: male individuals and individuals that presented predominance of posterior muscular chain. The participants were photographed in an appropriated device for view their posture. The pictures were analyzed by a computer program, called Fisiologic, to register the degree of anteriorization of the participants' head and to disqualify the individuals posteriorizated in the sagital plane. The descending fibers of the trapezius were evaluated for they had easier access and were superficial. The electrodes used were circular of silver chloride of the mark Skintact (T-601) between the motor point and the muscular insert. For the capture of the electric activity of the muscle an electromiografic apparatus of the mark Pathway was used, model NMR400 of 4 channels linked to a computer, in which the muscle's electromiografic activities was represented by graphs. They were registered the maximum voluntary isometric contraction (MVIC) and the muscular activity of the trapezius during the march before the use of the subcaptal bar and with the subcaptal bar.

RESULTS: As much in MVIC during the march the right and left trapeze, in a general way, presented a decrease in the electrical activity registered by EMGs after the application of the proprioceptive stimulus. The average of MVIC before the placement of the stimulus subcaptal was 311mV on the right side and 304mV on the left side. After the use of the subcaptal bar, the values decreased to 293mV and 277mV respectively. In relation to muscular activity during the march, the average values also decreased after the use of the bar. On the right side the average activity was 32mV before the bar and decreased to 23mV, Already the right side decreased from 40mV to 35mV.

CONCLUSION: The obtained results show that in the studied sample the use of the subcaptal bar reduced the muscular activity of the trapezius during the march, thereby demonstrating an intrinsic relationship exists among the muscular chains, proprioceptive stimulation and podoposturology. Such a relation should be studied better and more profoundly, seeking to base in secure evidence in clinical practice.

416 - Excitabilities of Stretch Reflexes in Antagonistic Ankle Muscles While Maintaining a Bipedal Standing Posture in Human

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Introduction: Recent studies on reflex and voluntary control of human gait and posture have suggested that reflex excitabilities of even antagonistic muscles should be adequately regulated during those fundamental movements. In the present study, we aimed to reveal how stretch reflex excitabilities are tuned in the antagonistic ankle extensor soleus (Sol) and flexor tibialis anterior (TA) muscles in quiet standing.

Methods: Ten neurologically normal subjects were participated in this study. Stretch reflex electromyograhpic (EMG) responses were elicited by imposing mechanical perturbations to the ankle joint (dorsi-flexion direction for Sol and plantar flexion for TA) in standing (ST) and supine (SP) postural conditions. The stretch reflex excitabilities were evaluated for each short-latency (SLR) and long-latency component (LLR). In addition, motor evoked potentials (MEP) were recorded in the Sol and TA by transcranical magnetic stimulation (TMS) in order to evaluate cortico-spinal excitability.

Results: In the Sol, the SLR was significantly larger in the ST compared to that in the SP condition (ST vs SP: 3.40±0.52 vs. 3.08±0.51 mV*msec, $p<0.01$), whereas the LLR did not show such a difference (1.9±0.32 vs. 1.8±0.39 mV*msec, n.s.). In contrast to the Sol, the LLR of TA significantly increased in the ST (3.61±1.02 vs. 0.82±0.40 mV*msec, $p<0.01$), although background EMG activity was silent in both conditions. It was noteworthy that, as clearly shown in Fig. 1, the modulation manner of the MEP according to the postural conditions was very similar to those of the LLR in both muscles.

Discussion: The present results revealed that the stretch reflex excitability of the TA muscle is dramatically enhanced in standing posture, whereas that of the Sol shows no remarkable changes. The similarity in the modulation manner between the LLR and MEP suggests that excitability tuning of stretch reflex pathway during upright standing is closely related to the cortico-spinal excitability.

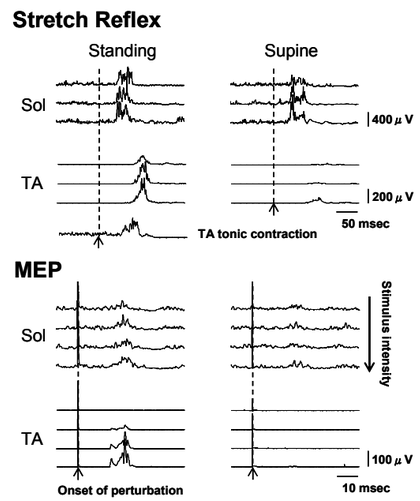

Fig.1 Typical example of the stretch reflex responses (top panel), and MEPs in the TA and SOL muscle in standing and supine conditions.

427 - Can Simple Biomechanical Tests Are Able To Identify Elderly Fallers?

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Introduction: The identification of specific risk factors for falls in community-dwelling elderly persons is required to detect early changes in postural stability and permit a preventative approach to management. The study determines the ability of various measures to identify fallers in the elderly population.

Methods: 19 subject's aged 65 and over (78.4±1.3 years old) who reported having fallen at least twice at the last half a year and the 124 non-fallers (77.8±0.53 years old), participated in laboratory experimental study. Stability was measured in up right standing using AMTI force platform, testing in six different visual and base of support conditions, Stability Limits Test was also measured. Static two-point discrimination (TPD) test to the skin of the sole of the feet was made to evaluate the innervation density of the slowly adapting receptors and maximal isometric strength (MVIC) at the lower limb musculature was measured using Isokinetic dynamometer.

Results The results suggest that control of balance in up right standing in narrow stance condition may be an important tool to identify elderly individuals in risk of falling and for future fall-preventative interventions. The findings showed an increase in postural sway in narrow base stance especially in the medio-lateral direction of elderly individuals who experienced recurrent falls. Another pervasive effect of aging is increase in two-point discrimination, which appears to be impaired in old fallers. The MVIC findings show no significant differences between fallers and non-fallers.

Conclusions: Simple and safe tests were able to identify elderly individuals under a risk of falling, suggesting a possible clinical application as a preliminary screening tool for predicting future falling risk in the elderly population.

439 - On a Common Fractal Property of Body Fluctuations in Human Gait and Posture

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Introduction: Both bipedal standing and walking in human need balance control to prevent the body from falling, which as a result induces a body fluctuation. Previous studies have reported that the body fluctuation in standing subjects is not random in time, but has a long-range correlation (i.e. fractal correlation) presumably emerged by fractal characteristics of the underlying neural mechanisms of bipedal standing [1]. However, it is unknown whether the neural mechanisms controlling body balance during walking also posses the same fractal characteristic or not. The purpose of this study, therefore, was to test if the fractal correlations of body fluctuation were observed while subjects were standing and walking as well. We used ground reaction force (GRF) as a common parameter to evaluate the fluctuations in balance control of these two movements.

Methods: Seventeen healthy subjects (26.1±4.8 years, height 1.72±0.07m, weight 64.5±8.4kg) participated in this study. Subjects were asked to stand (inter-malleolus distance 6cm) and walk (velocity 4.0km/h) on a treadmill that was equipped with two force platforms (ADAL3D, TECHMACHINE) in 10 minutes. During these tasks, GRFs in antero-posterior, medio-lateral, and vertical directions were recorded at 100Hz. A deviation force from the average (DS: Fig. 1) was calculated for each trial using these GRFs. For walking, an average value of a stride cycle was used for the subsequent analysis. We calculated the fractal scaling exponent of DS, using detrended fluctuation analysis (scaling exponent alpha) and power spectrum analysis (scaling exponent beta).

Results: Fractal scaling exponents of both DSs while standing (DSstand) and walking (DSwalk) showed larger values than the level of white noise (alpha= 0.5) by surrogating tests. In addition, there was a positive and significant correlation between the scaling exponents of DSstand and DSwalk ($p<0.05$, Fig.2).

Conclusion: The present results demonstrated that the fractal correlations in the body fluctuations while standing and walking were larger than the white noise level, and were significantly correlated. These results imply that a common balance control mechanism works while a human is standing and walking in an upright posture.

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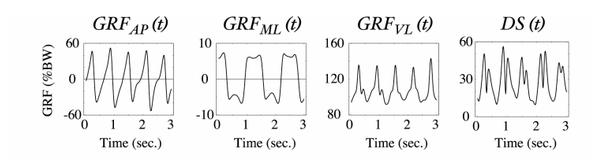
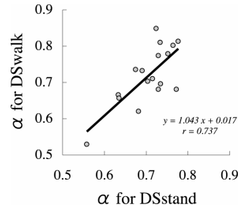


Fig.1 The definition of DS. The upper figures are example while walking.



448 - Influence of Audio Feedback on Structural Properties of Postural Sway

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Introduction: Previous studies have shown that visual (Dault et al., Hum. Mov. Sci., 2003) and tactile (Wall et al., IEEE Trans. Biomed. Eng., 2001) biofeedback of self-motion can improve stance stability. Recently audio-biofeedback (ABF) has proved equally valuable (Horak et al., Proc. SFN, 2003). Within the ABF paradigm we developed a portable system where trunk acceleration information recorded by biaxial accelerometers is used to reinforce self-perception in postural tasks of different complexity. Postural sway is encoded in real-time into a stereo sound by a sonification procedure. The aim of the present study is to investigate the structural changes in body sway following the administration of ABF.

Methods: Nine healthy subjects were included in the study. Subjects were instructed to stand with eyes closed on a force plate with and without a foam cushion under their feet in two conditions: with and without ABF. Each condition was repeated three times for trials of 60 s. Trial order was randomized. Subjects wore a light-weight, small (3 x 3 x 1.5 cm) acceleration sensing box fixed at their back at L5. A laptop computer acquired the signals from the sensor and generated a stereo sound encoding body sway information. Summary statistic scores were computed to quantify postural stability and stabilogram diffusion analysis (Collins & De Luca, Exp. Brain Res., 1993) was carried out to investigate structural properties of center of pressure (CoP) dynamics with a nonlinear model (Chiari et al., Hum. Mov. Sci., 2000)..

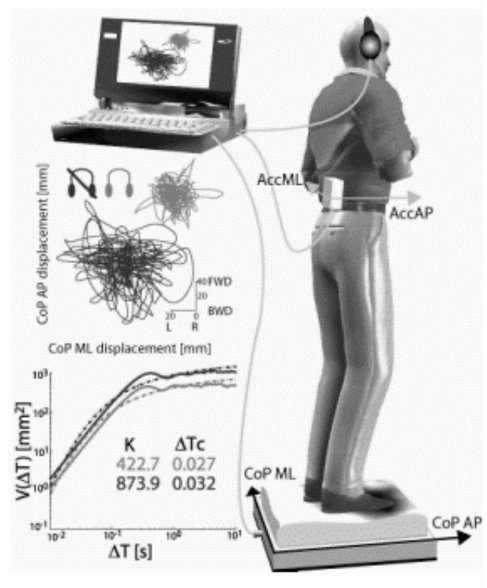

Fig. 2 The relationship between the scaling exponent (in case of alpha).

Results: The presence of ABF largely increased postural stability ($p<0.001$) on both firm and compliant support surfaces. The stabilogram diffusion analysis showed a systematic reduction in both parameters, K and □Tc with ABF ($p<0.01$). The condition with the least sensory cues, i.e. eyes closed on foam, benefited the most from ABF: Examples of changes in CoP displacement and diffusion plots due to ABF are shown in the figure.

Conclusion: Our results suggest that an audio-biofeedback system may help people control postural stability in stance in environments with inadequate surface somatosensory and visual information. Structural changes in postural sway due to ABF include a significant shortening of the short-term scaling region, unlike experiments with visual feedback (Rougier, Neurosci. Lett., 1999). This may reflect a larger role for conscious feedback control over feed-forward control of posture when using ABF. Future studies are needed to determine whether, with more practicing, subjects can use ABF without conscious control and hence how much this result is consistent over time.

462 - Generalizability of Stabilogram Diffusion Analysis

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Introduction: Force plate measures during quiet standing are commonly used in research. Stabilogram Diffusion Analysis (SDA) is one method that attempts to draw useful information from the center of pressure (COP) plot. Researchers in the past have varied methods of data collection, including different lengths of trials and number of trials conducted. The purpose of this study was to establish reliability estimates for SDA force plate measures.

Methods: Seven subjects (3 male, 4 female; age=19.9±1.3yr, ht=1.69±.04m, wt=72.2±12.5kg) completed this study. All individuals were asked to stand as still as possible on a platform for 90 sec. Subjects completed 10 trials with eyes open followed by 10 trials with eyes closed. Subjects stood as still as possible with their arms to their sides while staring a spot on the wall approximately 5 meters in front of them. An AMTI Force Plate was used to collect all data. Short-term diffusion coefficients (Dxs) with eyes open and eyes closed in the anterior-posterior (AP) directions were calculated for the first 30 seconds, the first 60 seconds, and the entire 90 seconds of each trial. Generalizability theory through a G study and follow-up D studies were performed to estimate reliability coefficients (G-coefficients). Generalizability theory allows us to investigate the reliability of a measure and the sources, or facets, that contribute to the variability. A reliability coefficient of 0.80 or greater is desired. The facets included were person (P), days of data collection (D), length of trials (L), and number of trials (T). The measurement model used was person by days by length of trials by trial (P x D x L x T).

Results: The G-coefficients for Dxs eyes open for 30 second trials ranged from 0.33 for one trial to 0.78 for ten trials; ranged from .38 to .80 for 60 second trials; and .55 to .81 for 90 second trials. The G-coefficients for Dxs eyes closed for 30 second trials ranged from 0.39 for one trial to 0.86 for ten trials; ranged from .49 to .93 for 60 second trials; and .67 to .93 for 90 second trials.

Conclusions: Generalizabilty is an attractive reliability assessment tool because it allows us to investigate various sources of error that contribute to the overall error in a measure. Through this study we investigated how participants, the length of a trial, number of trials, and number of days data collected contributed to the overall error in the short-term diffusion coefficient of SDA. Our results indicated that multi-trial assessment is required for a reliable measure. Another finding was increasing trial length did not enhance the reliability coefficients. Researchers and clinicians should be cognizant of the need for ten trials for reliable SDA results.

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465 - Influences to Human Posture Control in Cooling and Stimulation Conditions of Foot Soles

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Introduction: Foot soles are the only direct contact plane to the outside world during upright stance. Especially, foot sole sensory is an important informational source to maintain the upright stance and to prevent an accident from happening under the gravity. We investigated the changes of human posture control of upright stance which occur when somatosensory information are decreased or increased by the especially condition that was cooling or stimulation of foots soles.

Methods: Fourteen male college students were participated in this experiment. This study was approved by the Ethics Committee of the Sapporo Medical University, and all subjects granted their informed consent before participating. Subjects were evaluated on a computerized dynamic posturography platform (Equitest, Neurocom Int Inc, Clackamas, OR, USA) with a sensory organization test and motor control test. Each subject was performed the balance test under a natural condition (NC), a cooling condition (CC) and a stimulus condition (SC) of the food soles to reduce or increase the sensory information. The Wilcoxon signed rank sum test was used to analyze changes within conditions.

Results and Discussion: The equilibrium scores (ES) of the CC was lower than the ES of the NC, the ES of the SC was higher than ES of NC. The SC improved the degree of posture stability in upright posture, and the CC changed the static balance in upright posture unstably. The strategy score (SS) of the SC were higher than that of the CC and NC. It was suggested that the contribution of ankle strategy to the equilibrium was increased relatively by the stimulation to the foot soles compared to the hip strategy. It is suggested that the increase of the partial pressure to the foot soles stimulates the proprioception sense in the foot soles, and is increased the neural activation, and then is stabilized standing posture with frequent neural control. The CC inhibits the proprioceptive information from the foot soles, as a result the static equilibrium changes unstably with the confusion of neural control, however doesn't prevent the activity of ankle joint.

The reaction time (RT) in SC was shorter than that in the NC and the CC to the sudden forward sway during the standing position. There were no changes of the RT among the NC, the CC and the SC in the sudden backward sway. The reaction strengths (RS) of SC were no changed compared to that of the NC, however the RS of CC was increased in the sudden forward and backward sway compared to that of the NC. It was suggested that the proprioceptive information in the foot soles helps the prediction of sway strength in the sudden forward and backward sways. It was suggested that the proprioception in the foot soles doesn't have a roll of the trigger in the reaction to the sudden forward sway, but the stimulation of posterior proprioception in the foot sole has the roll of the trigger of the reaction to the sudden backward sway. We concluded the decrease of the proprioceptive information from the foot sole and the muscles has a possibility to promote the accident falls, and an increase of the information from the heel sensory has a possibility to prevent from falling backward.

476 - Vibrotactile Display of Body Tilt: Progression from Standing to Walking Experiments

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An analysis of balance and dizziness data from the 1994/1995 Disability Supplement of the National Health Interview Survey (Hoffman, et al. 2000) reveals that 6.2 million Americans report chronic (3+ months) problems with dizziness and/or balance, with significantly increased prevalence in the geriatric sector (9.1% compared to 1.9% for young adults). If prostheses could only help 5% of this population, more than 300,000 devices would be needed. Non-invasive balance prostheses, as opposed to implantable devices, can provide both long term supplemental aid for chronic or permanently impaired vestibular systems or temporary assistance for acute traumas, rehabilitative programs, or balance training regimes. Several devices that use externally applied stimulation for sensory substitution are currently being investigated. These include vibrotactile, auditory, and electrotactile devices. Experiments using vibrotactile display of body tilt, mostly with vestibulopathic subjects have demonstrated significant reduction in body sway when tilt feedback was available compared to the control conditions with no tilt feedback. Specifically, decreased sway during Computerized Dynamic Posturography Sensory Organization Tests 5 & 6, decreased responses to abrupt anterior-posterior translations, and reduction of body tilt during toes up pitch .

The present study considers the transition from standing to locomotion-based experiments. We have studied the body tilt during non-perturbed locomotion in healthy subjects, and body tilt during perturbations of locomotion. Our preliminary results, which just use tilt estimates designed for control of postural sway while standing, show significant reductions in body tilt when vibrotactile display of body tilt is provided. We also consider alternative body tilt display schemes that are designed specifically for locomotion.

484 - Vibrating Insoles Improve Balance in Patients with Stroke

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Human balance relies, in part, on somatosensory feedback. With stroke-related deficits, the inability to interpret afferent traffic from the periphery can impact the ability to perform seemingly simple tasks such as standing and walking. Recently, it has been demonstrated that subsensory mechanical noise can improve somatosensation in healthy young individuals, older adults, patients with diabetic neuropathy, and patients with stroke. Moreover, it has been shown that subsensory mechanical noise applied to the soles of the feet via vibrating insoles can enhance balance control in healthy young and elderly individuals.

Purpose: The goal of this study was to demonstrate that subsensory mechanical noise applied to the soles of the feet via vibrating insoles can be used to improve balance control in stroke patients.

Methods: Fourteen stroke patients who were at least six months post-stroke (aged 33-90 years) were asked to stand quietly, eyes closed, and barefoot on a pair of vibrating gel insoles. The vibrotactile threshold of each subject to a band-limited white noise signal was determined for each foot independently. The noise stimuli for the rest of the study were set to 90% of that threshold. Ten 30-second quiet-standing trials (5 with noise and 5 without noise) were performed, and the time-varying displacement of a shoulder marker for each trial was recorded by a Vicon motion analysis. To characterize balance during quiet standing, five traditional sway parameters (i.e., mean radius, swept area, maximum radius, anteroposterior (AP) range, mediolateral (ML) range), five sway parameters that are predictors of falls (i.e., ML RMS, ML sway, AP length, sway speed, area ellipse) and three sway parameters from random-walk analysis (i.e., critical mean square displacement, long-term diffusion coefficient, long-term scaling exponent) were computed for each trial. Sway parameters were normalized to the height of the reflective marker for each stroke patient. The mean value for each sway parameter was calculated for the noise and no-noise trials, respectively, for each stroke patient. A Student's paired t-test was used to compare the mean values of the noise and no-noise conditions of each sway parameter.

Results: *All* sway parameters decreased with the application of noise. In addition, maximum radius (17.9 ± 1.8 vs 15.6 ± 1.2), long-term diffusion coefficient (2.9 ± 0.5 vs 1.5 ± 0.3), and long-term scaling exponent (0.16 ± 0.01 vs 0.09 ± 0.1) significantly reduced ($p < 0.05$).

Conclusion: Subsensory mechanical noise applied to the feet of quietly standing stroke patients leads to enhanced somatosensory feedback and reduced postural sway. The use of randomly vibrating shoe insoles could provide a non-invasive technique for ameliorating somatosensory deficits and improving balance control in stroke patients.

499 - Reliability and Validity of a One-Leg Stance Protocol Using the Biodex Balance System

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Introduction: Lateral ankle sprain (LAS) is a common sport injury that often leads to joint instability and alteration of proprioception.[1] The impairment of joint receptors and neurofeedback mechanisms is likely to contribute to the high rate of recurrence of LAS. [2] Although standing balance training is commonly used to restore proprioception, no standard reliable and valid outcomes are readily accessible to assess the effectiveness of such training. The Biodex Balance System (BBS), made of a movable platform, allows to quantifying (8 levels of difficulty) the ability of a subject to maintain dynamic postural stability using a standardized outcome measure called the dynamic limit of stability (DLOS). The DLOS score varies from 0 to 100 (higher score = better outcome) and indicates the ability of a subject, while standing, to orient the platform by moving a cursor towards specific targets successively displayed in random order on a screen placed at the eyes level. The reliability and validity of the one-leg stance protocol using the BBS is unknown. The aim of this study was to investigate the test-retest reliability and construct validity of a one-leg stance protocol using the BBS with LAS. It was hypothesized that, based on DLOS scores, it would be possible to discriminate between the affected and contralateral non-affected limb as well as reference values, and that DLOS scores would decrease with the increase level of difficulty.

Methods: To verify the reliability of a one-leg stance protocol, 12 healthy subjects were tested bilaterally at level 8 (easiest) on two consecutive days. To verify the construct validity, 34 subjects with a grade II LAS (EXP) and 36 healthy subjects (CTL) matched for anthropometric data were tested bilaterally using the same protocol at level 8, 6 and 4 (L8, L6, L4). Intraclass correlation coefficients (ICC) were computed for the overall DLOS scores of the healthy subjects to assess test-retest reliability. The standard error of measurement (SEM) was also calculated to estimate the amount of random measurement error. T-tests were used to verify statistical differences in overall DLOS scores between affected and non-affected limbs and reference values. A repeated ANOVA was used to assess the difference in the overall DLOS scores between the three levels of difficulty.

Results: ICCs were 0.77 and 0.78 with a SEM of 4.6 and 5.4 for the dominant and non-dominant limb, respectively. The mean overall DLOS score of the affected limb was lower than the non-affected one for the L8 ($p=0.003$) and L6 ($p=0.04$) levels and than the non-dominant limb of the CTL group for the 3 levels ($p<0.008$). However, the magnitude of the overall DLOS score seen in the EXP and CTL group at L8 were clustered in the lower range of the theoretical score (below 28%). The mean overall DLOS score decreased ($p<0.01$) with the increase level of difficulty (Figure 1).

Conclusion: The one-leg stance testing protocol using the BBS is reliable. Although the overall DLOS can discriminate between levels of difficulty, the present results question the relevance of having 8 levels of difficulty, the easiest level being already very challenging for healthy subjects. Although statistically significant, the small absolute difference of the mean DLOS values between groups, which is similar to the SEM, suggests a low responsiveness of this measure to clinically significant changes. Other studies using the same protocol should be conducted with other populations.

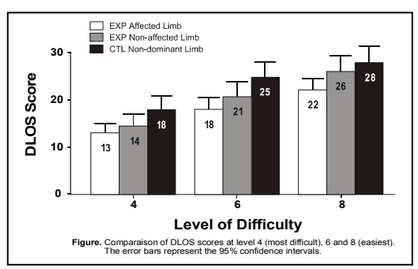

Figure. Comparaison of DLOS scores at level 4 (most difficult), 6 and 8 (easiest). The error bars represent the 95% confidence intervals.

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Rehabilitation Engineering

034 - Development of A New Motion Analysis System Using Gyroscopic Sensors

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Introduction: Non-invasive measures of joint movements are frequently employed in biomechanical studies of low back pain. Evaluation of the range and patterns of movement is also a key concern for a clinician in diagnosis and assessment for musculosketetal disease of patients. This study presents the novel development of triaxial gyroscopes and its appropriated signal-processing algorithm to analyze the three-dimensional joint motion. The motion analysis system consists of three orthogonally mounted single axis piezoelectric gyroscope (Murata ENC03-J) with its processing unit. It can be used to measure the angular velocities for determination of the three dimensional orientations by integrating of those processed data. The instrumentation were designed and fabricated. The aim of the study was to compare range of motion (ROM) determined by the new motion analysis device using gyroscopes and FASTRAK.

Methods: A new method of determining orientation with gyroscopes, including the coning effect on rotation, was developed. The ranges of motions in joint motion were measured using the gyroscopic system and an electromagnetic motion tracking system (Fastrak). Since Euler angles are sequence dependent, the axes of the gyroscopes were aligned with those of the simulator so that the Eulerian sequences of the two systems were equivalent. In both planar and 3 dimensional motion measured by the two systems were compared. Regression analysis was performed to reveal the relationship between the angles determined by the two systems.

Results and Discussion: The results showed that the gyroscope could provide reliable orientation information. The absolute values of planar and 3 dimensional motions determined by the gyroscopic and Fastrak systems were significantly correlated. The bias drift of the gyroscope was a limitation of the gyroscopic system. It was found to be dependent on its current orientation and velocity. The present study utilized a low pass filter which effectively minise the drift. The experimental results showed that it was valid to use the gyroscopic method for orientation determination. Further study was performed to investigate the feasibility of using this technique to measure lumbar spine motion for routine clinical use.

035 - Validity of an Inverse Kinematic Model in Determining the Intervertebral Movements of the Lumbar Spine

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Introduction: The human body is provided with redundant degree of freedom, giving us great flexibility in the performance of a movement. Forward bending movement of the spine can be accomplished with an infinite number of combination of configurations of the various intervertebral joints. The purpose of the present study was to determine an optimal combination of intervertebral joint configurations of the lumbar spine when performing forward bending motion. The study had two parts: a mathematical model was demonstrated to predict the intervertebral movements of the lumbar spine; and an experimental study in vivo which used to valid the implementation of segmental angle prediction using inverse kinematic model.

Methods: A human lumbar spine segment motion was modeled as an open-end, kinematic chain of a five-link system from the L1 to the L5 vertebra. An inverse kinematic model was proposed to determine an optimal combination of intervertebral joint configurations. Twenty-two subjects (mean age = 40 ± 14, range = 22 to 64) included in this study. Lateral radiographs of the lumosacral spines of subjects were taken in full flexion and extension while standing. Subjects with LBP diagnosis only were under analysis. The intervertebral movements predicted by the model were compared with those obtained from the radiographic measurements.

Results: High Intra-tester reliability ICC (3,1) ensured good validity of the algorithm. The results of regression analysis between the measured and predicted three kinematics parameters were summarized on Table.1. Large R-value of angle of rotation prediction implied that the inverse kinematic model was valid in angle prediction. The relatively small values of R for translations indicated that the prediction of translations (almost <5mm) were not as good as angle determination. The inverse kinematic method would be very useful when intervertebral rotation cannot be determined clinically. However, the technique may have limitation in accessing pathologies such as spondylolisthesis. A satisfactory method should be developed to determine movements of the intervertebral joints based on the combination of simple surface measurement and an inverse kinematic model algorithm. The method is useful in biomechanical modeling research where knowledge of the intervertebral movements is required. This is a pioneering work, which uses a robotic approach to solve a significant clinical problem.

Table.1. Regression between measured and predicted kinematics parameters among twenty-two subjects

	L5/S	L4/5	L3/4	L2/3	L1/2
Angle of Rotation	0.948	0.965	0.87	0.912	0.832
x-posteroanterior translation	0.152	0.673	0.154	0.345	0.644
y-posteroanterior translation	0.591	0.083	0.311	0.218	0.638

096 - Wearable Conductive Fiber Sensors for Measuring Joint Movements

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Introduction: Although various methods currently exist for physical therapists and sports care professionals to observe and measure joint movement in rehabilitation patients, a truly wearable sensor that would allow a continuous, direct read out of measured joint range during daily activities would be ideal. In this paper, a novel wearable sensor design is presented in order to measure multi-axis joint motion continually for a long period of time. Conductive fibers incorporated into flexible fabrics that fit tightly around a joint can detect joint movement in a non-cumbersome, non-intrusive manner.

Methods: Conductive fibers are incorporated into a form fitting fabric (see Fig. 1) in such a way that when a particular joint moves, fibers around the joint will either expand or contract. As the fibers stretch and change length, the electrical resistance across the fiber will also change. Acquiring signals from these fibers continuously, and processing the data appropriately, the changes in fiber resistance can be directly correlated to the changes in the orientation of the joint. Furthermore, a mesh-type arrangement of conductive fabrics is used to measure multi d.o.f. joints. Two arrays of conductive fibers crossing each other are arranged such that the two dimensional stretching of the skin may be measured and related to multi-axis joint motion.

Results: To test the feasibility of this type of technology, preliminary tests were performed

Figure 1 Conductive fibers are stitched into fabric covering knee joint to allow measurement of angle, ϕ.

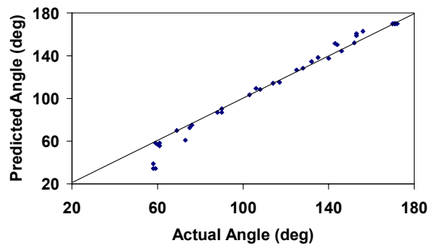

Figure 2 Joint angle measured with conductive fiber sensor, using two point calibration, compared with actual angle

for single axis measurements of a knee joint. Using a two-point calibration - reading the resistance across the conductive fiber at maximum and minimum joint angles - the joint was moved to various angles, and sensor measurements were recorded. Figure 2 shows the results from this test. Except for a few outlier measurements with the knee fully bent, this prototype sensor was quite accurate in predicting most single axis joint angles.

Discussion: Based on the desire for a wearable joint movement sensor, a design has been presented that uses conductive fibers to make such measurements. Preliminary tests have shown the feasibility of this technology. Through careful selection of design parameters, specifically fiber type and incorporation of the fibers into a fabric, single-axis or multi-axis movement can be measured.

138 - Issues Surrounding the Design and Testing Of A Surface FES Stimulator with an Output That Is Proportional To Surface Measurements Of EMG Signals Collected Whilst Stimulating

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Introduction: The design of an EMG triggered stimulator presents a number of technical difficulties that need to be overcome. Collecting and conditioning the EMG signal amidst the noise generated by stimulation; Establishing suitable control algorithms to provide stable smooth operation; Deciding upon user controls and displays that are simple to use and impart information not confusion. This technical paper details the solutions adopted along with the background to any decisions made.

Methods: Analysis of EMG measurements taken at the surface of the skin shows that typically the amplitude of the signal can range from 0 to 10 mV (peak-to-peak) and the usable energy of the signal is limited to the 0 to 500Hz frequency range. The stimulator was designed around the Microchip PIC 16F876 processor, which incorporates an analogue to digital converter (ADC) and supports the Serial Peripheral Interface (SPI) bus protocol. Digital potentiometers connected to the SPI bus controlled threshold and output levels. The detected EMG signal was amplified and conditioned before being feed into the ADC. Initial amplification done using an Instrumentation Op Amp (MAX4196). The amp being shutdown during the stimulation pulse. A 10 – 500Hz band pass filter followed by rectification carried out the initial conditioning, remaining conditioning used recursive filtering in software. Setting the lower reference voltage for the ADC of the microprocessor ensures that the threshold at which EMG is measured can be set above any noise on the signal; with the muscle at rest the threshold is lowered until a continuous background level is recorded. Then turned back until it just goes off, effort exerted by the muscle will then be registered as soon as the limb is moved. The user interface consisted of an LCD display and input buttons, for navigating through a series of menu screens where options can be chosen and parameters set.

Results: Early tests of the equipment have shown that it is possible to measure the EMG from a stimulated muscle between stimulation pulses, and use changes in the signal to alter the output of the stimulator in a way that is proportional to the voluntary effort exerted by the wearer. This has been demonstrated at stimulation rates of up to 30Hz.

Conclusion: This device could have marked benefits for stroke rehabilitation patients, where the positive feedback of movement following voluntary effort on a fully mobile wearable device could speed up recovery

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237 - Evaluation of BOTOX® Effect on Upper Limb of Stroke Patients by Portable Stretching Device Combined with EMG

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Introduction: Spasticity, a complicate symptom, is usually seen in patients with central nervous system lesions, and defined as a velocity-dependent increase in the resistance to imposed movement. Botulinum toxin type A (BT-A) offers the possibility of local treatment to spasticity. Several studies have suggested that BT-A injection can alleviate the muscle tone and thus improve the control of spastic limb. However, the treatment effects on muscle tone have been less documented and quantified. In our previous studies, we have developed a portable device for quantifying the velocity-dependent property of spasticity on upper limbs. The aim of this study is to utilize the portable muscle tone measurement device combined with surface EMG for investigating the changes in muscle tone after intervention of BOTOX® on the elbow flexors.

Methods: 13 chronic stroke patients (onset > 6 months) with hemiparetic limbs were included in this study. The reactive torque and reactive EMG (biceps brachii and triceps brachii muscles) of elbow joint induced at different stretching velocities (1/3, 1/2, 1 and 1.5 Hz) in limited range (60 to 120 degrees of flexion) were recorded simultaneously in 2 weeks before BOTOX®, and then 14 days, 2 months, and 3 months after intervention. The velocity-dependent viscous component (Bω) of the elbow flexors was derived from angular displacement and the corresponding joint torque, according a commonly used second-order biomechanics model, as one of assessed parameters. The EMG signals were fed through linear envelope (LE) for determining the threshold. The threshold of EMG activity was defined as the angle at which the sustained EMG activity surpassed two folds of standard deviation of rest EMG prior to stretch. The threshold of EMG at varied stretch velocities was normalized to be the percentage of total range. The Bω and normalized EMG threshold for each subject at four different frequencies were compared.

Results: We found that the patients with severe spasticity had a lower threshold of EMG activity and a relatively greater viscous component (Bω) (Fig1). For each individual, the value of Bω increased but the threshold of EMG decreased with the increase of stretch frequencies (Fig2).

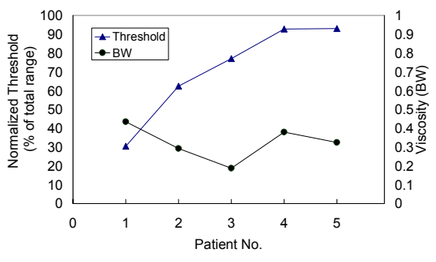

Fig1. EMG threshold and viscosity component

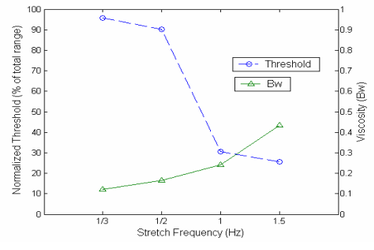

Fig2. Threshold and Bω at four frequencies

Discussion: This study employed a research design that used the experimental group subjects as their own control to record the time course changes after BOTOX® intervention and to minimize the errors induced by large variability among subjects. In current study, we demonstrated that the viscoelastic parameter as well as EMG threshold could be used for quantifying the degree of spasticity and thus for assessing the treatment effects of BOTOX® in stroke patients. Knowing the information of EMG pattern before and after intervention could be as an indicator for advanced guidance for BOTOX® injection in the future.

238 - Design Of Implantable Cuff Electrode With Surface Modification For Chronic Stimulation And Recording Of Peripheral Nerve Activity

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Introduction: Neural prostheses are devices that utilize electrical stimulation or recording technique to activate the damaged or disabled nervous system for function restoration. Among varied electrodes, nerve cuff electrodes have been used for sensing and stimulation in neuroprosthetic applications. Our research was in an attempt to minimize the protein absorption and elongate life of the implantable nerve cuff electrode by using the self-assembled monolayer (SAMs) surface modification technique. Gold electrode treated by SAMs permits the control of interactions of the biomolecule-electrode surface at the molecular scale. A thin film multi-polar spiral cuff electrode, composed of SAMs treated gold electrodes and flexible polyimide substrate, was designed and evaluated.

Methods: The Multi-polar electrode is manufactured in clean room on 4-in silicon wafer by using MEMS (micro-electrode-mechanical system) technology, composed of gold electrodes sandwiched in a flexible bi-layer polyimide insulating substrate. In order to improve the biocompatibility, we used biocompatible polyimide and gold as the materials of thin film electrode. Polyimide films of 25um thickness were used as substrate for E-beam evaporation of 2500Å thin gold layers. It consists of 12 nerve contact electrode on each multi-polar electrode which sizes were 800um x 800um at 6mm distance. We utilizes two kind of SAMs with different carbon chain lengths, including 1-Dodecanethiol (C12H26S) and 1-Octadecanethiol (C18H38S), in which the molecule with sulfur anchor group in solution can adsorb onto Au surface. The surface properties of electrode were evaluated by using water contact angle, high-resolution X-ray photoelectron spectroscopy (HRXPS), AC-impedance measurements and atomic force microscopy (AFM).

Results: In-vitro measurement of the electrode-liquid interface impedance was achieved by immersing the multi-electrode into a saline solution at room temperature. Impedance measurements were made by using LCR meter which allows for the assessment of impedance from 40Hz~15KHz testing frequency range. The electrodes remained low impedance after SAMs treatment, and exhibited stable impedance and low protein absorption rate during protein absorption test. An increase of water contact angle of SAMS treated surfaces was observed. The results of XPS demonstrated the C1s and S2p signal on the electrode surface, indicated the formation of SAMs on electrode.

Discussion: We demonstrated an electrode-tissue interface based on the surface modification technique. The multi-polar spiral cuff electrode exhibited stable impedance and low protein absorption rate after surface modification which was essential for implantable cuff electrode.

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349 - Network Technologies for Intelligent Modular Prostheses

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Introduction: A controllable multiple degree of freedom prosthesis must allow for distributed intelligence across multiple joints. CAN (Controller Area Network) and LonWorks are two widely available technologies that can facilitate this, by allowing multiple modules to be plugged into one central network. The development of modular control electronics has been encouraged by recent interest in designing a prosthesis as a set of interchangeable components. This simplifies servicing and reduces stock keeping, while retaining the flexibility to produce prosthetic devices that will fit all or most users. A modular approach to the electronics can also result in reliability gains, and makes it easier to add and test new intelligent features.

Methods: We have investigated LonWorks and CAN for use in modular prostheses in separate projects. They are mature technologies with wide application bases, and offer cost effective solutions to distributed applications. CAN was developed by Robert Bosch for critical automotive applications such as anti-lock braking systems (ABS) and engine management, which like prostheses require high reliability. LonWorks is a standard that was developed by Echelon originally for intelligent building applications such as lighting, heating, air conditioning and security, and is also used in other areas such as industrial automation and transportation. Here we compare LonWorks and CAN as technologies for prosthetics, and we also consider other emerging technologies that could be candidates for similar applications in the future.

Results: LonWorks and CAN both have features which are needed in a modular prosthesis. Each offers good immunity to electrical noise, adequate real-time performance, mechanisms for recovering from data errors, and widely available components which are energy efficient and have low weight and cost. They have different methods for dealing with network addressing, network configuration, data priority, error recovery, network robustness and a number of other issues.

Discussion: A modular prosthesis requires the following from a network: predictable real-time performance, low power consumption, graceful degradation and simple installation, among other things. Both LonWorks and CAN have the real-time capabilities needed. Serial busses that are becoming common for PC use such as USB and Firewire may also have a place here. However, while these promise higher raw data rates, they were not designed at the outset for real-time control in electrically and physically demanding environments, unlike LonWorks and CAN, which are ideally suited to the practical implementation for reliable control of a multiple degree of freedom prosthesis. This has been demonstrated through limited trials of a LonWorks system, and forthcoming fittings of a CAN based system in Edinburgh.

364 - Stimulation Current Waveform Shape Has No Influence on Motor Unit Activation During Transcutaneous Electrical Stimulation

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Introduction: in this study we investigated motor unit activation as resulting from transcutaneous electrical stimulation by different stimulation waveform shapes. The aim was to establish if different waveforms produced different types of progressive motor unit activation. The study is based on the analysis of the M-wave.

Methods: surface EMG signals were recorded during electrically elicited contractions of the dominant biceps brachii muscle of 11 healthy male subjects (mean ± SD, age: 25.2 ± 3.7 years; height: 176.4 ± 4.6 cm; weight: 70.5 ± 7.3 kg), using a linear adhesive array of 8 electrodes (5 mm inter-electrode distance). The arm of the subject was fixed at 120° (being 180° the full extension of the arm) in an isometric brace for torque measurement. Electrical stimulation was applied with monopolar technique. Six stimulation waveforms (mono and biphasic triangular, sinusoidal and rectangular), generated by a neuromuscular stimulator with hybrid output stage, were applied. During the stimulation, the peak current varied linearly between 0 mA and the maximum current tolerated by the subject (I_{max}). Both increasing and decreasing stimulation current pulse trains were delivered to the subjects. Stimulation frequency was 20 Hz and each contraction lasted 5 s, with a total of 100 stimuli. Measures were repeated on three non-consecutive days for each subject. The average rectified value (ARV) was computed as a measure of M-wave amplitude. The torque exerted during the contractions was measured to assess the mechanical outcome of the electrically elicited muscle. The ARV trend as a function of the stimulation current was normalized with respect to the respective values at 50% I_{max} in order to compare the trends without the effect of the energy of the waveforms.

Results: the mean value of the maximum stimulation peak current level was (N = 11, mean ± SE) 47.5 ± 2.2 mA (day 1), 46.7 ± 1.3 mA (day 2), 47.1 ± 1.1 mA (day 3). Average values for torque were (± SE) 1.57 ± 1.01 Nm (triangular monophasic), 1.56 ± 1.03 Nm (triangular biphasic), 2.08 ± 1.11 Nm (sinusoidal monophasic), 2.00 ± 1.14 Nm (sinusoidal biphasic), 2.76 ± 1.18 Nm (rectangular monophasic), 2.73 ± 1.26 Nm (rectangular biphasic). A four way ANOVA (factors: day, increasing/decreasing stimulation current envelope, waveform shape, stimulation current level) did not reveal any significant difference of ARV for M-waves elicited by isomorphic mono and biphasic waveforms. M-wave amplitude increased with the energy of the stimulus. Average values for ARV were (± SE) 381.60 ± 186.96 μV (triangular monophasic), 419.24 ± 283.55 μV (triangular biphasic), 453.81 ± 208.27 μV (sinusoidal monophasic), 473.74 ± 260.65 μV (sinusoidal biphasic), 527.44 ± 169.15 μV (rectangular monophasic), 536.23 ± 207.71 μV (rectangular biphasic). ARV significantly depended on the stimulation waveform but this was an effect due to the different energies of the investigated waveforms. Indeed, when ARV data were normalized with respect to the amplitude at 50% I_{max}, there was no significant difference between the results obtained by the different waveforms (ARV : $F = 17.38$, $p << 0.05$; normalized ARV: $F = 1.83$, $p > 0.05$). This indicated that the trend of ARV was the same for all waveforms. The torque exerted also increased with the energy of the stimulation pulse.

Discussion: motor unit activation is not altered by the specific waveform shape of the stimulation current pulse but by the energy of the pulse. The trends of both M-wave amplitude and force with increasing energy of the stimulation current pulse were comparable for the different waveform shapes by applying a scale factor in order to compensate for the different energies. These results can be useful for the design of neuromuscular stimulation devices.

365 - The Biphasic Waveform Compensation Technique Is Not Effective For Reducing the Stimulation Artifact in EMG Recordings

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Introduction: M-wave recordings during transcutaneous electrical stimulation are always accompanied by the presence of the stimulation artifact (SA), that significantly affects the variables extracted from the EMG signal. It has been suggested that using waveforms with non-zero total injected current may be a strategy for minimising the SA amplitude [1]. In case of biphasic stimulation, however, the amplitude and duration of the second phase may influence not only the SA characteristics but also the number of motor units activated. The main aim of this study was to investigate if varying the amplitude and duration of the second phase is effective for reducing SA.

Methods: surface EMG signals were detected during electrically elicited contractions of the dominant biceps brachii muscle of eight healthy male volunteers (mean ± SD, age: 25.2 ± 3.7 years; height: 176.4 ± 4.6 cm; weight: 70.5 ± 7.3 kg) with a linear adhesive array (8 electrodes, 5 mm inter-electrode distance). The subject's forearm was flexed at 120^o (being 180^o the full extension of the forearm) in an isometric brace. Stimulation was provided by a programmable neuromuscular stimulator with hybrid output stage. Twenty-one biphasic rectangular current waveforms were used. The amplitude of the second phase varied between 60% and 180% of the amplitude of the first phase (20% increments). The duration was 50%, 100%, or 200% of the duration T of the first phase (T=152 μs). Stimulation was delivered for 5 s for each waveform at a frequency of 20 Hz. Three minute rest were given to the subject between each stimulation. The average rectified value (ARV) was used as an amplitude measure of the artifact. Artifact ARV was also normalized with respect to the M-wave ARV (ARV_{norm}). Results are reported as means and standard error (SE) of the mean.

Results: the mean value of the maximum stimulation peak current level was (N = 8, mean ± SE) 43 ± 3.4 mA. A one-way ANOVA (factor: amplitude of the second phase of the stimulation pulse) of artifact ARV was significant for the biphasic waveforms with second phase of duration 100% and 200% of the first ($F > 2.90$, $P < 0.05$). In this case, the SNK test indicated pair-wise difference in artifact ARV between the amplitudes 120% and 180% of the first phase ($P < 0.05$). For 200% duration, there was a difference between 80% and 180% amplitude ($P < 0.05$). On the contrary, ARV_{norm} did not depend on the amplitude of the second phase for any duration of the phase. On average (±SE) ARV_{norm} was, for the three durations respectively, 117.7 ± 11.5 (50% T), 108.6 ± 9.9 (100% T), and 89.3 ± 7.4 (200% T). Moreover, a two way ANOVA (factors: amplitude and duration of the second phase of the stimulation pulse) of ARV_{norm} indicated that there was no interaction between the two factors. Comparison of the trends of ARV and ARV_{norm} indicated that the M-wave amplitude changed for different biphasic waveform shapes.

Discussion: the results presented indicate that the biphasic stimulation can not be used to effectively reduce the relative weight of SA on the M-wave during transcutaneous stimulation. Indeed, although there was a minimum point for SA ARV for specific amplitudes of the second phase of the biphasic stimuli, this was masked when normalisation with respect to the elicited M-wave was applied. If the amplitude of the second phase becomes greater than that of the first, some MUs may be activated by the second phase and not by the first. Thus, the increase of amplitude of the second phase determines both an increase of SA and of M-wave amplitude. The effect of SA relative to the M-wave is comparable for the different waveforms.

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367 - A Novel Multichannel Programmable Neuromuscular Stimulator

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Introduction: Electrical stimulation of the neuromuscular system is used in a number of clinical fields (e.g., the prevention of muscle atrophy) and in research. The detection of surface EMG signals during electrical stimulation of the muscle allows the detection of failures of the neuromuscular transmission due to fatigue or pathologies. Many issues of electrical stimulation need further investigation; it is not clear, for example, how the various stimulation parameters affect MU activation. In this work we describe a novel, versatile neuromuscular stimulator that has been recently designed for research purposes and can be used for the investigation of the effects of electrical stimulation, and for the assessment of the neuromuscular system during electrically elicited contractions.

Methods: A prototype of programmable, neuromuscular electrical stimulator for trans-cutaneous stimulation was designed in our laboratory. The device features eight independent stimulation channels. The peak amplitude and time course of the stimulation intensity (*envelope*) and the shape of the stimulation pulse (*waveform*) can be defined independently for each channel. Waveforms and envelopes can be selected among two internal libraries of 16 elements, eight of which can be defined by the user.

All the stimulation parameters, including waveform and envelope durations and repetitions, stimulation frequency, maximum energy per pulse are displayed on a LCD screen and can be adjusted in a wide range by means of a user-friendly interface.

A hybrid, optically isolated output stage delivers current stimulation with a maximum amplitude of ±100 mA_{pk}, and turns into an active short-circuit at the end of each stimulation pulse to minimize artefacts on the electrically elicited EMG signals. An adjustable blanking circuitry is also available for interface toward external electromyographs.

The stimulator can be used as a stand-alone device, or can be fully controlled by a PC through a proprietary software, which also allows to edit and download the user-defined waveforms and envelopes, and to store and recall from file the stimulation parameters.

The stimulator features a series of advanced functions and working modes (including stimulation frequency sweep) that makes it suitable for use in a wide range of advanced research protocols. The device is equipped with built-in self-test and calibration, with an adjustable energy/charge safety limiter and complies with international safety standards for biomedical equipment.

Results: The prototype has been successfully tested and has been used in a series of research protocols for the investigation of the effect of the stimulation waveform on motor unit recruitment [1], and on the stimulation artifact [2], within the framework of the project "Microgravity Assessment of Skeletal muscles investigated by surface EMG an mechanomyogram" (contract C15097/01/NL/SH), sponsored by the European and Italian Space Agencies.

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385 - Measurement of Joint Stiffness to Assess FES-Induced Muscle Strength

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Introduction: To restore degenerated muscle tissue (m.quadriceps) in denervated paraplegics, high stimulation current is required resulting in co-contraction of the antagonist (hamstrings) with high level of joint stiffness, but small torque output. Therefore a conventional static torque measurement with a knee dynamometer is less suitable.

Methods: To assess these FES-induced forces at the knee joint, a moving coil sensor-actuator with lever for leg manipulation was built. To sense stiffness with this actuator two approaches are discussed: direct sensing by recording the torque-angle curve in lateral position, and excitation of pendulum oscillations with frequency as stiffness indicator. As in the seated position hanging legs tend to oscillate in the field of gravity, the second approach seemed to be advantageous.

To initial the oscillation the lever was deflected by a single sawtooth-shaped pulse from the actuator. The oscillations were recorded for different levels of stimulation amplitudes.

As the muscle characteristic depends on the muscle length the pendulum test was performed at different knee angles (90°, 75°, 60°, 45°). This angle was set by adjusting the offset of the torque of the actuator. The actuator-sensor system is designed to superpose artificial (negative) stiffness by using a LINUX controlled realtime hardware. This can be used to prolong the oscillations if the joint stiffness is very high.

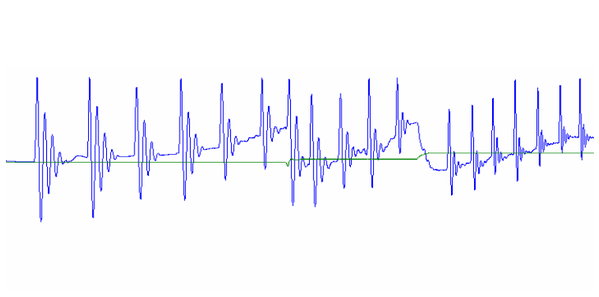

Fig.1

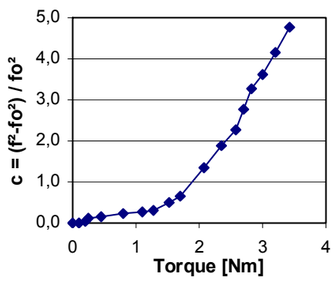

Fig.2

Results: The experiments showed that stable oscillatory responses are obtained during FES-stimulated thigh muscles. In Fig.1 oscillations during increasing tetanic el. stimulation are shown. Compensation of the torque is realized here stepwise. The relative joint stiffness (c) as a function of the joint torque is ploted in Fig.2. The increased slope indicates co-contraction of the hamstrings.

Discussion: This methode is suitable to measure muscle activity at the beginning of the FES training of long term denerated paraplegics where a torque is not yet detectable. In order to determine absolute stiffness and viscosity and to distinguish agonistic and antagonistic forces system identification by modelling is in progress.

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402 - Presentation of a Low Cost Orthosis That Makes Feasible The Orthostatism Of Bearers Of Cerebral Palsy

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Introduction: Cerebral palsy is characterized by alterations of posture and of movement, permanent, but not unalterable, resultants of a disorder of the encephalon, due to pre-, peri-, or postnatal factors, occurring during the first years of life. Due to the musculor-skeletial alterations in Cerebral Palsy, physiotherapeutic attendance and accompaniment within a multidiscipline team is important. Still, the physiotherapist can use different techniques and treatment approaches in agreement with his/her training or in agreement with the patient's needs. Independent of the therapist's technical opinions, the orthostatic positioning should be used, whenever possible, in the treatment program to make muscular invigoration, maintenance of the movement amplitudes, adjustments of abnormal posture patterns and stimulation of the neuropsychimotor development possible. To make orthostatism feasible, some patients need the aid of ortheses adapted specifically for the acquisition and maintenance of such posture, that have a high fabrication and maintenance cost, which makes unfeasible its prescription for patients with low income, mainly in developing countries. The objective of this work is the presenting of an orthesis of orthostatic positioning with different devices adapted that makes possible the orthostatic positioning of bearers of Cerebral Palsy with a low fabrication cost.

Methods: For the accomplishment of this work, studies of different orthopedic workshops and questionnaires applied to professionals of the area were used, in order to verify the need presented by the different bearers of cerebral palsy, to therefore propose an orthesis for positioning appropriate orthostatic.

Results: After the research, it was observed that different materials of low cost and easy acquisition can be applied in the making apparatus of habilitation and rehabilitation, and for the finalization of this orthesis was used: wood for the main structure and as support for the adaptations, foam for contact points with the patient, and wheels to make possible the movement of the orthesis. Differences this orthesis presents: support table with height regulation; triangle foot support to promote thigh abdution with the possibility of being elevated according to the patient's growth; and movable lateral support for the trunk and hip.

Conclusion: Knowing of the importance of propitiating different positions for the bearer of cerebral palsy, as well as the emphasis in orthostatic positioning, the development of an orthesis with low cost that makes the standing position possible for needy children is fundamental. This work presented and developed a possibility for the physiotherapist to provide adequate orthostatic positioning, with low production and maintenance cost. It is important to emphasize the need of works that make feasible the adequate attendance and physiotherapeutic prescription for children who live in developing countries, or are without the means to acquiring materials with elevated costs.

431 - A New Method for Periodical In-Situ Re-Calibration of Force Platforms

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Introduction: Force plates are complex precision instruments and require an accurate calibration process that is usually accomplished by the manufacturer prior to delivery. Exposure and age, however, cause degradation of instrument's sensitivity over time, undesired cross-talks between measured variables, and general lack of accuracy. This causes systematic errors which can drastically affect quantities such as joint forces and moments estimated through an inverse dynamics approach (WINTER, 1991), or the location of body center of mass when obtained by double integration of shear forces at the ground (LENZI et al., J. Biomech., 2003). To this aim this study provides a new technique for the accurate estimation of a 6-component force platform calibration matrix, C, with the aid of an ad-hoc designed active device.

Methods: An active device was designed as a 'testing platform' which allows the combined application of vertical and horizontal time-varying loads to the force platform under test over which it is placed with its instrumented pylon. The device is equipped with two high accuracy load cells and acted by a linear motor which translates back and forth its top surface. The vertical load component is due to a subject standing on it while the horizontal load is generated by the motor and transmitted to the pylon by means of a spring. Simultaneous recordings obtained by the testing and the tested platform in 5 different load conditions repeated twice provide enough data to estimate the 36 elements of the calibration matrix. The estimation procedure consists of a robust calibration method (CAPPELLO et al., Med. Biol. Eng. Comput., 2004) including the angular errors (due to imperfect alignment of the applied loads with the axes of the platform) in the least-squares parameter vector thus reducing the bias in the estimated calibration matrix parameters.

Results: To evaluate the performance of the new estimation method, the calibration procedure was first simulated on a hypothetical platform with a known calibration matrix. Simulations show as in the presence of random alignment errors of the loads (SD=3°) the new robust method takes to errors in the estimate of the elements of C (expressed as a percentage of the respective diagonal term) always less than 0.4%, compared to errors up to 13% obtained with a traditional least-squares approach neglecting misalignment. Experiments performed with the active device on a commercial platform (4060-08, Bertec) disclosed a residual cross-talk of the vertical force less than 0.0002 N/N on the shear forces and less than 0.00005 Nm/N on the torque. Error on the estimate of the center of pressure after re-calibration is less than 0.5 mm.

Conclusion: This study provided a new method for the accurate estimation of a force platform calibration matrix that can be accomplished by simple, manual procedures and is robust to moderate load misalignments, e.g. when the direction of the applied loads cannot be perfectly aligned with the axes of the platform. Since the applied forces can also vary in time, this avoids measurement errors introduced by static friction and supports dynamic patterns for the load that explore the ranges of gait and balance control dynamics. The proposed algorithm and the resulting design of the testing platform reduce the complexity of the rigs needed for quality assessment and recalibration of the force platform. They also permit the use of manual procedures that can be applied by non-technical personnel.

501 - Lower Leg Activity Monitor for Deep Vein Thrombosis Applications

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Introduction: In the lower leg, through a process known as "venous return", the blood circulatory system is assisted by what is called the "calf muscle pump". The process of contraction and relaxation of the calf muscle circulates blood through the venous network embedded in the muscle and back to the heart. Failure to exercise the calf muscle results in limited blood circulation in the lower leg. This may occur during long periods of inactivity, examples include long distance travel, an office environment, or elderly people with limited mobility. Such inactivity very often results in little or no movement of certain muscle groups, most notably in the lower leg. One consequences of poor blood circulation is deep vein thrombosis (DVT).

Methods: An embedded system has been developed which, through the use of accelerometers (EMG calibrated for levels of calf muscle activity to movement) detects the level of movement in a patients leg. Using this feedback information and depending on predefined thresholds the system may activate a stimulator on the calf muscle. The movement of the calf muscle enables blood flow out of the leg thus greatly reducing the risk of DVT.

Results: The control unit is programmed such that if there has been no significant leg movement in fifty minutes then a defined level of stimulation is applied to the calf muscle. An LED indicator notifies the user when there is ten minutes to stimulation should they wish to exercise their leg rather than receive the stimulation. The LED turns off when the leg has been exercised sufficiently.

Discussion: Traditional DVT prevention focuses on counter acting sluggish blood flow by encouraging or enhancing the movement of the calf muscles. Compression stockings have been shown to reduce the risk of DVT and the use of exercise aids such as inflatable pillows is also an accepted practice[1]. These two means of DVT prevention require the patient to make a conscious effort to exercise at regular intervals. Patients at risk from DVT are recommended to exercise on a regular basis whilst on long distance flights. A portable movement monitoring electrical stimulation system has been developed which by monitoring lower limb movement the system will stimulate the calf muscle should the leg remain sufficiently inactive for an excessive period. The stimulation of the calf muscle increases blood circulation in the lower leg and greatly reduces the risk of DVT .The advantage of the lower leg activity monitor that no conscious effort is required by the user in order to ensure adequate leg movement.

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Sports Medicine & Human Performance

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027 - Surface EMG Modifications in response to anterior Cruciate Ligament Creep Elicited During Cyclic Exercise

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Introduction. Static and cyclic loads applied to various joints during occupational and sport activities can elicit a neuromuscular impairment consisting of changes observed within the electromyographic (EMG) signal, i.e. the presence of random spasms and a decrease in the EMG activity. The hypothesis of this work was that creep developed in the anterior cruciate ligament (ACL) due to cyclic load may have a relevant impact on the reflex activity of the musculature involved as well as on the viscoelastic structures, therefore increasing the risk of injury. This work was therefore aimed to test the effect of creep developed in the ACL on the function of knee flexor and extensors muscles in healthy males and females.

Methods. Twelve subjects (six males and six females) participated in the experiment. Force and surface electromyographic (sEMG) signals were recorded from the right quadriceps (RQ) and hamstrings (RH) during maximal voluntary knee flexion (MVCflex) and extension (MVCext) before and after a 10-min cyclic load (frequency: 0.1 Hz) was applied to the proximal tibia with the knee angle fixed at 90 degrees. The peak load imposed during the 10-min cycle was 200 N for males, and 150 N for females. The mean amplitude value (MAV) was computed over each EMG signal. The ACL displacement was also assessed during the 10-min cyclic load. The experimental protocol was repeated after two weeks with the knee angle at 35 degrees.

Results. During the 90 degrees experiment, the MVCext decreased significantly ($p<0.05$) after the 10-min cycle in both males and females; this was associated to a decrease in EMG MAV in both RQ and RH. The mean ACL displacement was significantly ($p<0.05$) higher in females (8.7 ± 0.8) than in males (7.2 ± 1.2) ($p<0.05$). Similar results were obtained for the 35 degrees experiment. Frequent EMG spasms were observed within the EMG signal, especially in the RH. No difference for all considered parameters was detected between the two experimental conditions (35 and 90 degrees).

Discussion. These results, though preliminary, suggest that sustained cyclic load results in neuromuscular changes that associated with the increased laxity of ACL ligament may increase the risk of ACL injury.

071 - A New Method of Quantifying The Bilateral Limb Deficit Phenomenon Using The Myoelectric Signal

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Introduction: The bilateral limb deficit (BLD) represents the difference in the maximal force generating capacity of corresponding muscles when contracted alone or together (1, 2, 3). The bilateral limb ratio (BLR) is the measure of the total bilateral force over the total unilateral force produced (3). The goal was to examine the use of myoelectric signals (MES) in the calculation of the BLR and to determine its relationship with the BLR calculated using torque (BLRTorque). The role of antagonist muscle coactivation, age, training status, voluntary activation and fatigue were examined during dynamic knee extensions and flexions and during isometric knee extensions.

Methods: Experiment 1 consisted of a six-week strength training session using an isokinetic dynamometer (33 subjects). Torque and MES data were collected during knee extension and flexion prior to and after the training program. Experiment 2 consisted of a series of isokinetic knee extensions and flexions including maximal voluntary contractions (MVCs) and submaximal contractions (15 subjects). Experiment 3 (12 subjects) consisted of a series of voluntary and stimulated isometric knee extensions as well as bilateral and unilateral fatigue.

Results: It was found that antagonist muscle coactivation and the physiological differences between the agonist and antagonist muscles affected the BLRMES. The results of Experiment 1 lead to the development of a new formula, which was further tested in Experiment 2. The new measure of BLRMES was well correlated with BLRTorque. Results from Experiment 1 also showed an improvement in BLR and muscle coactivation after strength training. Experiment 3 involved a series of isometric unilateral and bilateral knee extensions with and without stimulation of the quadriceps muscle. Voluntary (non-stimulated) data showed little or no BLD and a lack of antagonist muscle activity. These results support the findings of Experiments 1 and 2, which indicated that the BLD in dynamic contractions is largely due to antagonist muscle coactivation. Data collected from stimulation trials of Experiment 3 showed that, while activation is not complete for either unilateral or bilateral isometric knee extensions, there is little difference between conditions (bilateral versus unilateral). Measures of muscle fatigue detected no difference between unilateral and bilateral contractions.

Conclusion: The results from the three experiments showed that the new formula developed for calculating BLD using MES (BLRMES) is a robust measure. In addition, the BLD can be improved with training.

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076 - Control of Torque-Assisted Bicycle Based On Physical Activity During Repetitive Prolonged Cycling Exercise

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Introduction: Our final goal is to design custom-fitted control for the torque-assisted bicycles based on the individual relationships between physical activity and the performance of a vehicle. Initially, we took ECG and surface EMG (SEMG) as biological data for thirteen normal subjects (20 ± 0.8 yrs) in addition to torque, speed, and cadence as the vehicle data. The result showed effective assist control by monitoring muscular activity while climbing and the power ratio of the respiratory sinus arrhythmia, pr_{RSA}, trial by trial for repetitive prolonged cycling exercise.

Methods: An experimental set consisted of six consecutive trials with or without the motor torque assist and each trial comprised about 2.5 minutes of cycling followed by a 2-minute rest. The circuit path was approximately 840-m long and included a steep uphill section near the middle of the route. We represented the physical activity mainly by the time-frequency components of biosignals at each section with different path gradients, and then comparing them with the vehicle data. In practice, the time-varying behavior of pr_{RSA} was used to classify the physical activity into two types of states at each trial. Moreover, we focused on the difference in the short-term MPF of SEMG at the first and latter half of the first two strokes around the both ends of the corners while climbing.

Results: In 67% of the total assist-on trials, pr_{RSA} demonstrated a temporal decrease while climbing and then recovered afterwards. Such a clear pr_{RSA} change did not appear in 68% of assist-off and 33% of assist-on trials, and remarkable muscular fatigue was observed just before the hilltop by the short-term mean power frequency of SEMG. Note that the two states were not distinguishable in the vehicle data.

Discussion: It should be investigated further whether the lower torque and slower speed could create the prefarable state by torque-assisted bicycles, or whether the appropriate torque level would exist for individuals based on the physical work capacity. Besides, for customizing the control of torque-assisted bicycles, it would be preferable to combine objective and subjective indices.

085 - The Possibility of Anterior Cruciate Ligament Healing By Conservative Treatment Reinforced With Extra-Articular Artificial Ligament in Rabbits

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Introduction: It is generally recognized that there is little ability for anterior cruciate ligament (ACL) to heal after disruption without surgical intervention. Although ACL ruptures under a certain condition can be healed by the conservative treatment with the special knee brace. This experiment was designed to devise an animal model for the conservative treatment of ACL injury. Surgically lacerated femoral side tears of the rabbit ACL was examined histologically for 12 weeks in the stabilized knees with extra-articular circumferantial atrificial ligaments.

Methods: Twenty eight 30-weeks-old Japanese white rabbits were used. After the femoral attachment of the ACL laceration, two bone tunnels were made at the tuberosity of the tibia and posterior epicondyles of the femur. An artificial ligament was passed through these holes extra-articurally aligning the anatomical path of the normal ACL. The amount of anterior drawer was examined at four times by a side-to-side difference on the stress radiograph. Animals were sacrificed at 12 weeks after the surgery, then the historogical evaluation was examined. The oblique-sagittal sections of ACLs were stained by standard hematoxylin and eosin procedure for subsequent examination. The Wilcoxon signed rank test was used among each the anterior drawer values.

Results: There was no decrease in range of knee motion immaeidtely after surgery and at 12 postoperative weeks. The average value of anterior drawer (AV) was increased significantly by ACL cutting. Whereas, the increased AV was returned to normal immediately after the artificial ligament reinforcement. The AV had been maintained in normal range after 12 weeks cutting. The ACLs in sixteen rabbits out of 28 (57%) healed by bridging the gaps with hypertrophic “scar tissue”. The scar developed over the lacerated ligament in the inter-condylar space with the extension proximally to connect intercondylar notch of the femur. The some collagen fibers in the scar tissue showed oblique-sagittal orientation along with the original ACL fibers, however, its remodeling was not observed sufficiently.

Discussion: We observed that the artificial ligament implanted outside a capsule in the ACL lacerated knee worked as a substitute of the knee brace in animal models for 12 weeks, because the anterior drawer of the tibia in X-ray examinations was controlled. In this model, hypertrophic scar tissue connected the ruptured ACLs in 57% animals. These results suggested that the conservative treatment of the ACL ruptured knee has potential to induce ACL healing.

088 - Weakness And Voluntary Activation Failure Of Knee Muscles In Patients With ACL Deficiency And Reconstruction

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Introduction: The anterior cruciate ligament (ACL) functions not only biomechanically to restrain the knee joint but also as a neural resource to adjust the knee muscle stiffness and dynamic joint stability. Knee strength loss is frequently observed on patients with ACL insufficiency (ACL-D) and even on those who have gone through a repair, despite the efforts in surgery and rehabilitation. This study investigated the extent and time course of bilateral knee muscle weakness and activation failure before and after ACL reconstruction (ACL-R).

Methods: With ethical approval, patients diagnosed with ACL-D and admitted for a reconstruction with bone-patella tendon-bone autograft procedure were recruited for this study. They were tested bilaterally for their knee muscle performance before, three and six months after reconstruction surgery. The length-tension (10-90 degree of knee flexion, at 20 degree increment) and force-velocity (0-250 degree/sec, at 50 degree/sec increment) relationships of both quadriceps and hamstrings were investigated while sitting on an isokinetic dynamometer. Voluntary activation failure of both muscles was estimated with twitch superimposition technique using 1 Hz magnetic stimulation over quadriceps and hamstrings muscles at 70° of knee flexion. A group of healthy, age-matched young adults were recruited for comparison; they were only tested once on their preferred knees.

Results: Fifteen control (23 years ± 1) and 12 ACL-D (26 years ± 3, time since onset 19 months ± 7) subjects participated in this study. Compared with the controls (265.2 N ± 23.2 and 682.5 N ± 60.9 respectively), both knee flexors and extensors (208.8 N ± 29.2 and 549.0 N ± 69.3 respectively) were significantly weaker in the ACL-D knees; the length-tension and force-velocity relationships were essentially altered and activation failure evident (22.3% and 37.0% respectively). The contralateral knees were less affected after ACL injury and exhibited gradual improvement during the six months after reconstruction. At the ACL-R knees, hamstrings showed little changes in both isometric and isokinetic performance during the six months, however the quadriceps demonstrated even greater deficits (301.2 N ± 29.2) at the three-month retest with similar amount of voluntary activation failure (37.3% ± 5.3). By the sixth month, both quadriceps and hamstrings of the ACL-R knees still appeared weaker (435.8 N ± 34.4 and 210.4 N ± 17.6) and severer activation failure (27.1% ± 5.8 and 24.2% ± 7.5) than the contralateral knees and the controls.

Discussion: ACL insufficiency causes long lasting failures in voluntary recruitment and weakness of knee muscles even after the reconstruction. It seems there should be an exclusive mechanism responsible for quadriceps weakness and activation failure, and this will undoubtedly compromise the knee function further. Mechanisms responsible for these long-term deficits should be investigated, and adequately addressed in post-surgical rehabilitation.

122 - EMG Activity and Rearfoot Kinematics in Asymptomatic Persons with Low and High Arch Feet

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Introduction: Abnormal foot structure has been implicated as a causative factor of lower extremity in injuries yet a paucity of evidence linking abnormal structure to altered joint and muscle function exists.[1] Therefore the purpose of this study was to determine the effect of arch height on rearfoot kinematics and muscle activity during treadmill gait. We hypothesized that arch height would have no effect on rearfoot motion or lower leg muscle activity.

Methods: A convenience sample of 43 healthy, asymptomatic individuals (age range: 18 - 55 years) was recruited. Of these subjects, 12 (9 males, 3 females) met the inclusion criteria and were assigned to either a low or high arch group based upon the extent of their navicular drop. Subjects with a drop of less than 4 mm were classified as having a high arch foot while subjects with a drop greater than 13 mm were classified as having a low arch foot.

Procedure: While walking on a treadmill at a speed of 112 cm/sec, the EMG activity of the tibialis anterior and posterior muscles was recorded for 20 seconds. All subjects were afforded a 3 minute warm up period prior to data collection. Tibialis anterior muscle activity was recorded using a pair of Ag-Ag chloride surface electrodes. Tibialis posterior activity was recorded using a pair of indwelling fine wire electrodes. Coincident with the EMG data, 3D coordinate data of markers located on the lower leg and foot were acquired using a 3 camera motion analysis system as well as footfall data using footswitches attached to the plantar aspect of the foot. The overall gain of the EMG system was 1000 with an input impedance of 10 GOhms. The common mode rejection ratio at 60 Hz was 115dB. The video and EMG data were sampled at 60 and 2000 Hz, respectively.

Data Analysis: Using the footfall data, each subject's 20 second trial EMG and video data was divided into individual strides (producing 13 strides for each subject). The EMG stride data was then rectified and filtered (using a 4th order, zero lag, low pass Butterworth filter with a cutoff frequency of 10 Hz). The EMG data were then normalized to an isometric maximum voluntary contraction (MVC). The 3D coordinate, after filtering using the same Butterworth filter as used in the EMG processing, was employed to produce angular displacement histories for the rearfoot. The angular and MVC EMG data were then time normalized to 100% allowing for intersubject comparisons (0% and 100% representing heel strike and toe off, respectively). An independent samples t-test was used to determine what differences existed between the two groups in their mean integrated EMG and rearfoot angular motion from heel strike to foot flat and foot flat to midstance.

Results: A statistically significant difference ($p > .05$) was not noted between the two study groups in their rearfoot motion or mean integrated EMG of either muscle. Additionally, no differences were noted between the two groups in the onset of EMG activity or duration of that activity.

Discussion: Differences in navicular drop do not appear to affect rear foot motion and muscular activity of the lower leg muscles. Our findings, and those of other studies, suggest that traditional views of the impact of differing foot structures on normal and pathologic foot function need to be revised.[2]

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128 - Neuromuscular Perturbation Training Decreases Co-Contraction In Those with the Potential to Compensate Well for ACL Rupture

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Introduction: Rehabilitation that includes perturbation training, a form of training involving support surface perturbations, has helped improve dynamic knee stability in certain individuals with ACL rupture (potential copers) (Fitzgerald et al., 2000b). Analysis of muscle activity during gait has shown changes in muscle activity recruitment post-training (Chmielewski et al., 2002). The purpose of this study was to compare muscle activity patterns between potential copers and matched uninjured subjects before and after participation in perturbation training.

Methods: Sixteen individuals with acute, unilateral ACL rupture, categorized as potential copers, and 16 active, uninjured subjects were recruited for this study. All subjects participated in five trials of free speed walking (undisturbed), and trials during which a platform translated horizontally (anteriorly or laterally) at heel contact, before and after completing ten sessions of perturbation training augmented rehabilitation. Electromyographic (EMG) data from the gluteus maximus, vastus lateralis, medial and lateral hamstrings, medial gastrocnemius, soleus and tibialis anterior were collected. Electromyographic (EMG) data were collected at 960 Hz and band pass filtered from 20-350 Hz. Maximal voluntary isometric contraction (MVIC) and resting EMG signals were collected from each muscle group. All EMG data were post-processed and analyzed using custom written programs. A linear envelope was created from the raw EMG signals by full wave rectification and low-pass filtering with a 2nd order, phase-corrected, Butterworth filter (cut-off frequency = 20 Hz). Trials were analyzed for the muscle onset, termination of activity, peak amplitude and time to peak amplitude. Muscle co-contraction, the simultaneous activation of antagonistic muscles (lateral hamstrings-vastus lateralis and medial gastrocnemius-vastus lateralis), was calculated using the method of Rudolph et al (2001) for the following intervals: 100 ms prior to heel contact, weight acceptance (heel contact to peak knee flexion) and midstance (peak knee flexion to peak knee extension).

Results: Before training, potential copers had significantly higher VL-LH and VL-MG co-contraction indices in the disturbed-lateral and disturbed anterior conditions compared to uninjured subjects ($p<0.05$) in preparation for plate movement, during the weight acceptance interval and during midstance. After training, the cocontraction indices of the potential copers were significantly lower than before training ($p<0.05$) and no longer different from the uninjured subjects over all intervals.

Discussion: When performing the challenging task of disturbed walking, potential copers used a strategy of increased co-contraction to dynamically stabilize the injured knee. Although this strategy may prevent tibial subluxation, it is unlikely to be successful long-term, as higher than normal co-contraction has been found during gait in patients with ACL rupture who experience knee instability (non-copers, Rudolph et al 2001). Normalized co-contraction in potential copers post-training suggests that the program fine-tunes muscle recruitment, allowing individualized strategies for dynamic knee stability that are similar to the strategies seen in uninjured subjects.

CONCLUSION: Rehabilitation with perturbation training allows potential copers to recruit muscles for knee stabilization during challenging tasks in a manner that is indistinguishable from uninjured subjects.

129 - Gender Differences in Muscle Activity Patterns During Disturbed Walking Before and After Perturbation Enhanced Neuromuscular Training

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Introduction: Female athletes involved in jumping and cutting sports injure their anterior cruciate ligament's (ACL) 4-6 times more frequently than their male counterparts in comparable sports. Neuromuscular factors, including quadriceps dominance and decrease active knee stiffness have been incriminated as contributing to the higher rates of injury in women. Currently, the most effective form of intervention developed to reduce female ACL injury rates has been neuromuscular training. The purpose of this study was to 1) identify gender based muscle activity patterns during disturbed walking that may contribute to ACL injury, and 2) determine if a novel training program could positively influence patterns among healthy female athletes utilizing a disturbed gait paradigm.

Methods: Twenty healthy athletes (female=10, male=10) were tested. All subjects participated in five trials of free speed walking (undisturbed) and trials during which a platform translated horizontally in a laterally direction at heel contact before and after completing ten sessions of a perturbation training augmented neuromuscular training program. Electromyographic (EMG) data from the gluteus maximus, vastus lateralis, medial and lateral hamstrings, medial gastrocnemius, soleus and tibialis anterior were collected. EMG data were collected at 960 Hz and band pass filtered from 20-350 Hz. Maximal voluntary isometric contraction (MVIC) and resting EMG signals were collected from each muscle group. All EMG data were post-processed and analyzed using custom written programs. A linear envelope was created from the raw EMG signals by full wave rectification and low-pass filtering with a 2nd order, phase-corrected, Butterworth filter (cut-off frequency = 20 Hz). Trials were analyzed for the muscle onset, termination of activity, peak amplitude and time to peak amplitude. Muscle co-contraction, the simultaneous activation of antagonistic muscles (lateral hamstrings-vastus lateralis, and medial gastrocnemius-vastus lateralis), was calculated using the method of Rudolph et al (2001) as indicators of active knee stiffness in preparation for heelstrike, during weight acceptance and midstance.

Results: Prior to training, women had significantly higher peak quadriceps activity and higher quadriceps integral during midstance than men. Both medial and lateral hamstring integrals during midstance increased from pre to post training. Onsets time to peak activities for hamstrings and quadriceps were similar before training except for medial hamstring TTP which occurred after heelstrike in most women. Time to peak medial hamstring activity moved from after to just before heelstrike after training. Women had higher medial gastrocnemius-vastus lateralis cocontraction indices in the preparatory and weight acceptance phases of gait than men after training.

Discussion:_ Prior to training the athletic women in our sample demonstrated characteristic quadriceps dominance and decreased active knee stiffness when compared to male athletes. Modulation of activity and timing of ACL agonist musculature (hamstrings and gastrocnemius) from before to after training resulted in normal quadriceps hamstring balance and increased active stiffness. These alterations in ACL agonist muscle activation patterns resulting from perturbation training may reduce the risk of biomechanical strain injury among a high risk population.

141 - Leg Muscle Recruitment During Cycling is Less Constrained in Triathletes than Cyclists

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Introduction: Muscle recruitment during cycling is highly consistent and constrained in trained cyclists relative to novice cyclists[1]. This is consistent with previous evidence that adaptation of the neuromuscular system occurs with repeated performance of a motor task (e.g. Osu et al.[2]). Muscle recruitment in triathletes has not been investigated. Triathletes undertake similar cycling training loads to specialist cyclists, but must also undertake very high running and swimming training loads. The influence of these multidiscipline training demands on muscle recruitment remains unknown. This study compared patterns of distal lower limb muscle recruitment during cycling in triathletes, trained cyclists and novice cyclists.

Methods: Participants were seven highly trained triathletes, nine highly trained cyclists and ten novice cyclists who had cycled 332.9 ± 47.3, 393.9 ± 32.5 and 36.1 ± 10.3 km per week in the preceding three months, and had been cycling for 8.9 ± 1.5, 9.4 ± 1.7 and 1.3 ± 1.3 years, respectively. Electromyographic (EMG) activity in tibialis anterior (TA), tibialis posterior (TP), peroneus longus (PL), gastrocnemius lateralis (GL) and soleus (SOL) was measured using intramuscular fine-wire electrodes. Three experimental conditions involving variations in cadence were investigated.

Results: Differences were evident between triathletes and trained cyclists in recruitment patterns for all muscles, and patterns of muscle recruitment in triathletes were similar to those measured in novice cyclists. More specifically, triathletes and novice cyclists were characterized by greater variation in patterns of muscle recruitment between pedal strokes, more extensive and more variable muscle coactivation, and less modulation of muscle activity, i.e. in novice cyclists and triathletes, the relative amplitude of EMG was higher in periods between primary EMG bursts. In addition, EMG modulation decreased with increasing cadence in both triathletes and novice cyclists but was not influenced by cadence in trained cyclists. While group means for consistency of muscle recruitment and EMG modulation varied little between novice cyclists and triathletes, there was greater variability between novice cyclists for these measures, i.e. sample variance was greater.

Conclusion: These data demonstrate that muscle recruitment is less constrained in triathletes than trained cyclists despite near equal training loads. Although group mean scores for consistency of muscle recruitment and EMG modulation did not vary between triathletes and novice cyclists, greater sample variance for novice cyclists indicates that triathletes are a population distinct from novice cyclists. These findings suggest that multidiscipline training demands may impair adaptation of the neuromuscular system in triathletes, or may stimulate changes in muscle recruitment which optimize performance in multiple disciplines but result in patterns of muscle recruitment which differ from those utilized by trained cyclists.

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185 - Quadriceps Femoris Function and EMG Power Spectrum Profiles after ACL Reconstruction

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Introduction; Quadriceps femoris weakness is a common finding after anterior cruciate ligament reconstruction (ACLR) and can persist over many years. In addition to strength deficits, long term follow-up work has demonstrated reduced function in these patients (Pfeifer & Banzer 1999). It is thought that reduced voluntary activation, pain, and swelling may play a role in the failure to regain full function of the knee together with restoration of pre-injury levels of strength (Mangine et al. 1992). A reduction in activation is the inability to recruit all motor units to a maximum level during maximum voluntary isometric contraction (MVIC) and has been found in the knee extensors following chronic knee injury (Rutherford et al. 1990). Snyder Mackler et al. (1994) investigated activation levels in ACLR patients between eight and twelve weeks after surgery during which period the patients undertook a programme of intensive electrical stimulation and reported no loss of voluntary activation. The purpose of this ethically approved study was to monitor changes in strength and adaptation of the knee extensor neuromuscular mechanisms in the early stages following anterior cruciate ligament reconstruction (ACLR), and to explore the relationship of these changes with pain. The aim was to investigate whether levels of voluntary activation early after surgery would predict long term functional outcome after ACLR and to explore possible implications for therapeutic intervention.

Methods; Thirty one patients (28 M, 6 F) recovering from bone patellar tendon bone ACLR (mean ± SD, age 30 ± 8 yrs; body mass 76 ± 9 kg; height 1.75 ± 0.10 m) were tested one and three months after surgery. Muscle function tests included electrical twitch superimposition and a Fast Fourier Transform of the EMG recordings (5,000 cycles per second, filter 10-250 Hz) during 5-s MVIC to determine the median frequency of motor unit action potentials of rectus femoris at 100%, 75%, 50%, and 25% of MVIC. Knee pain was measured using a visual analogue scale and a self-report functional questionnaire was administered to patients at one, three and twelve months after surgery.

Results; 31% of patients achieved full activation of the knee extensors at one month, and 86% achieved full activation three months post surgery. EMG frequency and amplitude levels were significantly ($p < 0.05$) lower in the involved compared to the uninvolved quadriceps at both one and three months. A significant ($p = 0.01$) negative relationship was found between pain and % of activation of the quadriceps femoris. Regression analysis showed the questionnaire and % activation of the knee extensors can predict knee function one year after surgery.

Table 1. EMG median frequencies (Hz), MVIC (Nm), mean (±SEM) of rectus femoris after ACLR (n=22)

Frequency (Hz)	*MVIC(Nm)*	*100 % MVIC(Hz)*	*75 % MVIC(Hz)*	*50 % MVIC(Hz)*	*25 % MVIC(Hz)*
Uninjured leg (1 month)	210 ± 11*	82.99 (± 3.51)*	79.02 (± 3.49)*	68.62 (± 3.39)*	65.83 (± 3.43)*
Injured leg (1 month)	83 ± 9*	64.14 (± 3.50)*	62.46 (± 3.61)*	58.43 (± 3.25)*	56.18 (± 3.93)*
Uninjured leg (3 months)	202 ± 10*	82.48 (± 2.46)*	75.43 (± 2.21)*	73.26 (± 3.27)*	67.02 (± 3.11)
Injured leg (3 months)	127 ± 10*	70.64 (± 3.39)*	64.40 (± 3.35)*	60.15 (± 2.99)*	57.89 (± 3.49)

*P<0.05 or greater

Discussion; Improvement in volitional activation of the quadriceps, and lowered firing rates were shown three months after ACLR. The lowered firing rates suggest changes in patterns of use and change in the recruitment patterns of Type 11b fast contracting muscle fibres. These findings provide insight into neuromuscular adaptations after knee surgery and provide a basis for development of specific muscle strength training that includes fast twitch motor units.

186 - Muscular Representation of Bi-Lateral Transfer in Children Acquiring a Novel Skill

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Introduction. The ability to perform a motor skill bilaterally is rudimentary in many competitive sports. Bilateral transfer phenomenon is based on a motor control theory. According to the schema theory (Schmidt, 1975), action is controlled by a generalized motor program mechanism (GMP) and can be produced by different muscles on either laterality. Another mechanism responsible for the selection of muscles is the recall schema, which can be enhanced by practice variability. Lai et al. (2000) suggested that for a stable GMP to be developed it is a prerequisite to start training by constant practice for developing, at some later time, an effective recall schema by means of variable practice. The purpose of the current study was to examine this argument by testing the effect of three distinct practice models (constant, variable, and combined) on bilateral transfer during the acquisition of a specific judo skill in children.

Methods. 36 children (28 male, 8 females; ages 8-10) were selected by the coach as unskilled in the execution of the O GOSHI, a hip throw in judo. The subjects were divided randomly into 3 practice groups: 1) Constant practice (C); 2) Variable practice (V); and, 3) Mixed practice (M). Each group practiced the new skill in its own distinct practice modality, using the dominant arm and side. The coach taught the skill differently to each group:

To the C group, he gave instructions to use an evenly paced rhythm (1-2-3), a constant "grab" height, and a single, fixed direction in approaching the opponent and executing the follow-through motion.

To the V group, he gave instructions to use a varied, random pace (1--2-3, 1-2--3, etc.), a high and low "grab" height, and forward/backward/sideways directions in approaching the opponent and executing the follow-through motion.

To the M group, he gave instructions to use C group conditions for the first 2 weeks of trials and V group conditions for the second 2 weeks of trials.

Each group executed 120 practice trials over 4 weeks. Each group was tested three times, by means of a pre-test before the practice period, a post-test after the practice period and, on the day of the post-test, a transfer test on the non-dominant hand of the contra-lateral limb/side. Behavioral and physiological variables were measured: *behavioral:* time to completion of 6 throws in sequence (T), *physiological:* linear envelopes of the EMGs of the bi-lateral Rectus Abdominis (AB) and Rectus Femoris (RF).

Results. The transfer test revealed a significant positive effect on the V group with respect to the T variable. All groups showed significant improvement in the T variable from pre- to post- learning, as well. The transfer test also showed that, with regard to EMGs, the amount of muscle activation per muscle at any given time was more organized--more consistent, as well as more clustered for the V group.

Conclusion. While acquiring the described novel skill, the V practice group achieved better bilateral transfer than the C or M group. This would indicate that children should be coached to perform variety of judo skills bi-laterally and V practice modality will give the fastest results.

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199 - Muscle Activation During Knee Joint Torque Exertion Is Affected By Unintentionally Generated Hip Joint Torque: Intersubject Variability And Implication For Muscle Strength Training

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Introduction: One may consider that mono-articular torque exertion is suitable for muscle strength training, because it is the simplest task requiring no skills and specifying the joint torque can control the activity level of muscle spanning the joint with a high reproducibility and without intersubject variability. However, our previous work has shown that muscle activity level is indefinite unless the neighbor joint torque is also specified. This uncertainty can violate its preferable aspects as the muscle training method. We investigate this problem during knee extension task by examining 1) to what extent the hip joint torque is unintentionally generated, 2) if there is intersubject or intertrial variability in the hip joint torque, and 3) to what extent the hip joint torque profile affects the knee joint muscle activity.

Methods: Subjects (N=12) were seated on a chair with knee joint angle kept 70 deg and with right foot placed on custom made force measurement device. This device can measure the force acting at the ankle position in every direction. Subjects were asked to just exert isometric knee extension or flexion torque at various levels. No instruction on hip joint was provided (free condition). Not only knee joint torque (Tk) but hip joint torque (Th) generated unintentionally was calculated (extension torque was defined as positive). The activity of 10 lower limb muscles was quantified by the mean value of the rectified surface EMG. After the free condition, we requested subjects to exert Tk while controlling Th (controlled conditon).

Results: There was a considerable intersubject variability in the Th vs Tk plot (Fig.1A). For example, the knee extending torque accompanied the hip flexion torque for subject #1, while no apparent hip joint torque was observed for subject #3. On the other hand, the intertrial variability was relatively small. The relationship between EMG level and Tk was affected by the strategy that the subject used: when the subject changed the strategy (Fig.1B), the vastus lateralis activity increased, while the rectus femoris activity decreased. Generally, the profile of Th vs Tk plot determined the balance between mono- and bi-articular muscles.

Discussion: We show that, during Tk exertion, 1) the unintentional Th was often generated, 2) the Th vs Tk profile was different from subject to subject, and 3) the muscle activity was affected by the Th profile. Notably, even the level of mono-articular knee joint muscles was influenced by the torque of hip joint which they does not span. These results can be rationally explained by the fact that a part of joint torque is necessarily transmitted to the neighbor joint through the bi-articular muscles. Such inevitable torque interaction between adjacent joints during mono-articular torque exertion has been neglected so far. Our results suggest that the mono-articular torque exertion task conducted while monitoring only one joint cannot determine the muscle activity uniquely and requires a sort of "skill". This drawback can be overcome by developing a new method to control both joint torques together.

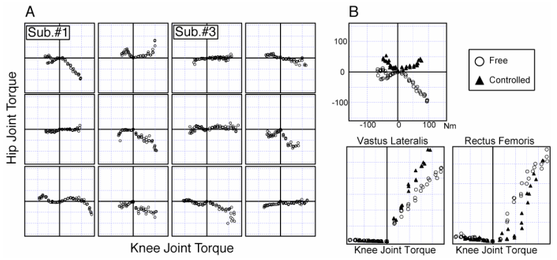

Figure 1. A: The Th vs Tk plots for all subjects during isometric Tk exertion (free conditon). B: The Th vs Tk plot for free (open circles) and controlled condition (closed triangles) in subject #1 (Top). This modification of Th changed the relationship between muscle activity and Tk (Bottoms).

202 - Effects of Strength Training Versus Balance Training On Paravertebral Automatic Muscle Responses

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Introduction: In a recent study on healthy subjects we found that strength training (ST) of trunk extensor muscles decreased postural stability measured during upright standing, whereas balance training (BT) improved stability. It is not known, however, how these types of training affect automatic postural responses in muscles that are major postural stabilizers of the lumbar spine. This study investigated the effect of ST and BT on automatic responses of lumbar paravertebral muscles following a controlled perturbation of the trunk in a prone position.

Methods: Twenty-six young healthy subjects (16 to 17 years old) were investigated at baseline, one and two months. Surface electromyographic (EMG) activity was monitored and recorded bilaterally from L1 and L5 levels to; 1) ensure muscle relaxation before the test; 2) detect onset of EMG activity following the perturbation; 3) measure EMG activity during a maximum voluntary contraction (MVC) during trunk extension. Subjects were randomly assigned to either daily ST or BT.

Results: A cross-over of training modalities between the groups was performed after one month. At baseline, onset of automatic EMG responses occurred at both the right (75ms) and left (63 ms) L5 sites compared to the right (63 ms) and left (66 ms) L1 sites (values are mean of both groups). One month of ST led to significantly longer EMG onsets at both the right (90 ms) and left (80 ms) L5 sites recording sites, whereas L1 onsets remained unchanged. One month of BT significantly shortened EMG onsets and they occurred near simultaneously at the L1 and L5 sites with no differences between the left and right electrode sites (53 ms -57 ms). The EMG onsets remained similarly short at the end of two months when the BT was followed by one month of ST. If ST was performed before BT no changes in EMG onsets were seen as compared to baseline. MVC torque improved significantly in both groups.

Conclusion: These findings suggest that onset of automatic EMG responses can be influenced by training and that these responses are highly dependent on the training modality. We recommend including motor skill and balance training already in the early phases of back pain prevention programs.

213 - Reliability of Electromyography and Peak Torque During Maximum Concentric Knee Extensions

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The aim of this study was to investigate the reliability of peak torque (PT) and surface electromyography (EMG) variable's root mean square (RMS) and mean frequency (MNF), of each of the subject's best performance during 10 maximum concentric knee extensions. Keeping in mind that EMG interpretation of dynamic contractions might become difficult, based on the fact that movement itself introduces additional factors which could affect it's signal characteristics, we also aimed to examine RMS and MNF reliability, without electrode removal, after a 1 hour resting period, and the same EMG variables reliability, with electrode removal, after a 1 week resting period.

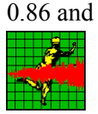
EMG signals of *Vastus Lateralis* (VL), *Rectus Femoris* (RF) and *Vastus Medialis* (VM) muscles were recorded in ten subjects (five males and five females) using surface electrodes. This data was analyzed considering RMS and MNF of each muscle and its corresponding intra-class correlation coefficient (ICC), presented in table 1.

Table 1 - Mean, Standard deviation (SD) and ICC of PT and EMG variables (RMS and MNF) in VL, RF and VM muscles, after 1 hour and 1 week resting periods.

	1 hour rest without electrode removal					1 week rest with electrode removal				
	Test 1		Test 2		ICC	Test 1		Test 3		ICC
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
PT (Nm)	172.40	38.38	172.70	42.78	0.98	172.40	38.38	177.60	38.76	0.99
RMS - VL (mV)	0.70	0.31	0.66	0.31	0.97	0.70	0.31	0.73	0.31	0.81
RMS - RF (mV)	0.57	0.19	0.59	0.36	0.85	0.57	0.19	0.59	0.26	0.83
RMS - VM (mV)	0.67	0.38	0.63	0.30	0.98	0.67	0.38	0.75	0.35	0.94
MNF - VL (Hz)	138.30	22.19	133.70	19.98	0.97	138.30	22.19	136.81	17.15	0.87
MNF - RF (Hz)	156.55	13.95	157.58	13.83	0.96	156.55	13.95	160.81	17.22	0.86
MNF - VM (Hz)	139.32	18.32	134.29	16.81	0.95	139.32	18.32	135.86	14.60	0.94

The results of this study show that PT, RMS and MNF obtained high reliability without electrode removal, after a 1 hour resting period (PT results indicated an ICC of 0.98; RMS results demonstrated an ICC between 0.85 and 0.98; MNF results revealed an ICC between 0.95 and 0.97). We also observed high reliability in all of the variables regarding the results obtained with electrode removal, after a 1 week resting period (in this case PT results indicated an ICC of 0.99; RMS results demonstrated an ICC between 0.81 and 0.94; MNF results revealed an ICC between 0.86 and 0.94).

In conclusion this study demonstrated that after a 1 hour resting period without electrode removal, PT and EMG variables reveal high reliability, and after a 1 week resting period with electrode removal, although results appear to be lower, they still indicate good reliability of PT and EMG variables.



234 - Evaluation of Quadriceps Femoris Median Frequency after Anterior Cruciate Ligament Injury

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Introduction: Electromyographic muscle fatigue is defined as a failure to mantain the required or expected force accompanied by changes in muscle electrical activity parameters (root mean square and median frequency). Frequency analysis of EMG signals using median frequency of the power spectrum (MDF) have been widely used to characterize peripheral muscle fatigue during isometric contractions. The ACL plays a sensory role in control of knee stability and recent studies have shown that ligament injury is associated with desensitization of the mechanoreceptors, reducing reflexive muscle activity and exposing the knee to instability. The aims of the present study were to evaluate the MDF of the vastus lateralis longus (VLL), rectus femoris (RF) and vastus medialis obliquus (VMO) muscles after ACL injury during maximal voluntary isometric contraction (MVIC) of knee extension at 30 and 60 degrees and verify whether was any difference in this parameter in: 1) ACL injury limbs (ACL-L), 2) ACL injury contralateral limbs (ACL-CL), 3) dominant control limbs (DC) and 4) non-dominant control limbs (NDC).

Methods: This study was approved by the Ethical Committee and all volunteers had sign the informed consent letter before participation. Twenty male volunteer subjects participated in this study, ten patients (10 ACL-L, 10 ACL-CL) and ten control healthy subjects (10 DC, 10 NDC). The subjects performed 3 MVIC of knee extension using a isokinetic dinamometer chair at 2 different knee degrees (30° and 60°) with duration of 5 seconds each. Surface EMG were recorded from quadriceps femoris muscle (VLL, RF, VMO) using surface differential electrodes (silvers bars 10mm apart, 10mm long, 2mm wide, 20x gain, input impedance 10GΩ and 130dB CMRR). The EMG signal were analogically amplified with gain of 200x, no filtered and sampled by 12 bits A/D covert board with a 2KHz frequency. The MDF (PSD, FFT, Hamming window processing) were normalized at MVIC of knee extension at 90 degrees.

Results: There were no significant differences of MDF values among the four groups ($p>0.05$ Kruskall Wallis ANOVA independent). However the VLL and RF MDF values ($p<0.05$ Wilcoxon Matched Pairs Test) at 60° were significantly shorter than 30° to ACL-L group ($p=0.021$), ACL-CL group ($p=0.005$), DC group ($p=0.005$) and NDC group ($p=0.021$).

Conclusion: The results suggest that ACL injury has not a significant effect on MDF values when compared with contralateral and control healthy limbs in these experimental study.

269 - Knee Musculature Response Strategies During Self-Initiated Vertical Jump Landings

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Introduction. Females suffer from disproportionately higher incidence of anterior cruciate ligament (ACL) injuries than males, particularly non-contact ACL injuries. Among other factors, research indicates this gender disparity may be due to intrinsic mechanisms, such as differences in neuromuscular stabilization of the knee. This study investigated differences between pre- and post-pubescent male and female quadriceps (vastus medialis; VM) and hamstrings (medial hamstrings and biceps femoris; HAMS) muscular activation patterns during self-initiated vertical jump landings.

Methods. Fifty-eight subjects (grouped by age and gender) who were recreational participants in jumping and landing activities and who demonstrated a mature vertical jump pattern, signed an approved consent to participate. Motion analysis, force plate, and surface electromyographic (SEMG) data were collected from all subjects as they jumped to reach a target (medium sized ball suspended on a retractable cord) then landed in a balanced position on the force plate. Root mean square of the SEMG (RMS) was determined for three landing stages: pre-landing (100 ms before initial contact [IC]), post-landing (100 ms after IC), and IC to maximum knee flexion. Data were normalized to within-trial peak values and averaged across 3-4 trials/subject before group means were calculated. Multilevel repeated measures ANOVA tests compared: 1) SEMG values during each landing stage; and 2) co-contraction ratios (CCR), that is the ratio of normalized hamstrings' activity to normalized quadriceps' activity during each landing stage. A 2 x 2 (gender x developmental) ANOVA examined differences in knee angle at IC. A p value < .05 indicated significant differences.

Results. Results showed significant developmental level differences, but no significant gender differences. Post-pubescent subjects displayed significantly greater HAMS activity and CCRs in the pre-landing stage relative to the post-landing stages. Conversely, pre-pubescent subjects displayed significantly greater post-landing and IC to maximum knee flexion CCRs. There were no significant differences in knee angle at IC.

Table 1. CCRs During Three Landing Phases (Mean ± SEM)

Group	**Pre-CCR**	**Post-CCR**	IC to Max-CCR
Pre-Pubescent Females (n=15)	313.4 ± 86.8	103.5 ± 5.0	101.5 ± 6.4
Pre-Pubescent Males (n=15)	288.2 ± 83.8	106.0 ± 4.8	108.7 ± 6.1
Post-Pubescent Females (n=14)	625.1 ± 86.8	80.3 ± 5.0	89.1 ± 6.4
Post-Pubescent Males (n=14)	652.6 ± 90.0	81.1 ± 5.2	95.2 ± 6.6

Discussion. The greater level of hamstrings' co-activation prior to landing by post-pubescent subjects indicated that they used a strategy of pre-tuning the hamstrings prior to landing (i.e., more central nervous system pre-activation) in anticipation of impact landing forces which create potential for anterior tibial translation during landing. On the other hand, pre-pubescent subjects controlled impact landing forces with greater hamstrings' co-activation just after and during landing. The pre-pubescent subjects' strategy represented more reflexive activation as opposed to the pre-activation (CNS) strategy evident in the post-pubescent subjects.

286 - Variation of Muscle Activity Pattern between Actual and Simulated Ski Jumping

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Muscle activity of ski jumping is composed of sustained contraction during gliding on the runway at high speed (80-90 km/h) and dynamic contraction with maximum power in order to take-off. For training of ski jumping during off-season, simulation of performance is generally used. The reasons why we introduce the simulation frequently are as follows:

1. The number of times for the actual field training is limited.
2. The training which is close to the movement of the ski jump Always and anywhere
3. To the minute movement Adjustment is easy

However, there are no reports about the comparison between simulation of ski jumping and actual ski jumping in terms of muscle activity. We measured muscle activity during ski jumping and during simulation by surface electromyogram (SEMG) and analyzed SEMG signals by time-frequency analysis. We used two-bar active electrodes passed on the vastus lateraris, biceps femoris, tebialis anterior, and gastrocnemius muscles. Measured SEMG signals of 1-minute were analyzed by the wavelet transform with the Gabor function.

The results showed that muscle activity during ski jumping differed from muscle activity during simulation, although the performance at the take-off was the same with each other. That is, the frequency component was higher during simulation than that during ski jumping. Moreover, coordination of muscle activities at four muscles was different.

Based on the feasibility study, we are considering that the performance simulation should introduce SEMG analysis to feed back the physiological data for players. Thus, it is important to develop the instruments and introduce information technology for field exercise.

327 - Muscular Intensity Activation at Open and Closed Kinetic Chain Exercise

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Introduction: Open and closed kinetic chain exercises can be used in exercise training programs for strengthening and coordination but there is little information available to indicate which exercise is preferred when targeting a specific muscle group. Furthermore, for an individual open or closed kinetic chain exercise, there may be differences in muscle activation across a joint. Under these circumstances, it would be advantageous to know whether the intensity of muscular activation is comparable among the exercises when the same percentage of maximal load is used in such training programs. The purpose of this study was to compare the muscular intensity activation between open and closed kinetic chain, during maximal load.

Materials And Methods: The sample was composed of 5 males (mean age 37.2± 11.03) without history of musculoskeletal disorders. Initially (Day 1), a 1-repetition maximum (1RM) was measured during knee extension and hip extension (open kinetic chain) and squat (closed kinetic chain) exercises. Surface EMG was recorded (Day2) from vastus lateralis (VL), rectus femoris (RF) and biceps femoris (BF) in each of these exercise at 1RM. Activation intensity was calculated on the basis of the peak RMS of the signal.

Results: There were no significant differences in muscle activation level for comparisons between open and closed kinetic chain exercises for the VL and RF muscles. However, such differences were present for the BF muscle, which was significantly more active in hip extension (open chain) than in the squat (closed chain) exercise. Comparisons between muscles for a given exercise resulted in significant differences, as summarized in Table 1.

Table 1: Comparison between muscle activities during each exercise

Task	Exercise type	Significant Findings ($p<0.05$)
Knee extension 1RM	Open Chain	(RF and VL) > BF; RF > VL
Hip Extension 1RM	Open Chain	BF > (RF and VL)
Squat 1RM	Closed Chain	VL > BF

Discussion And Conclusions:

The results suggest that for training regimens targeting the BF, some open chain exercises such as hip extension are preferred over some closed chain exercises, such as squat, when the goal is to facilitate muscle activation. No such advantages for knee extensor muscles were found for comparisons between the squat and knee extension exercises. However, the results demonstrating that muscle groups are activated at different intensity levels for a given exercise may have implications for training. Kvist and Gillquist (2001) and Escamilla et al. (1998) had demonstrated it with some differences in the results. How variety of exercises of this kind are available in rehabilitation, further studies are needed to determine whether these findings are consistent among targeted patient populations.

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Escamilla, RF; Fleisig, GS; Zheng, N; Barrentine, SW; Wilk, KE and Andrew, JR. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. Medicine Science of Sports Exercise, 30:556-569, 1998.

338 - Differences of Tibial Impact Acceleration during Running at Different Overground States

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Introduction: The repetition of impact shock loadings of musculoskeletal system during running has caused overuse disorders of lower extremity. An overground surface state during running is one of the factors on lower extremity overuse disorders. The purpose of this study was to investigate the differences of the magnitude of impact shocks generated by heel strikes between grass condition [using on cross-country (XCY) race] and asphalt condition (using on marathon race) during running.

Methods: Eleven healthy, male long-distance runners [age: 19.9 (SD 1.0) years; mass: 59.1 (5.1) kg; height: 1.70 (0.07 m)] participated in this study. No subjects had any disorders and injuries in lower extremity. All subjects were provided informed consent prior to this study.

The subjects had two trials that one was grass state running (grass running) and the other was asphalt state running (asphalt running) and ran at 5.0ms-1 across two overground surface states. During testing, a piezoelectric accelerometer was used to measure acceleration of the distal anteromedial aspect the right tibia. Tibial peak impact acceleration (G) was recorded from the acceleration profiles. The peak impact acceleration was used to analyze that the difference between overground surface states.

Results: In eight subjects out of 11, the peak impact acceleration was higher during asphalt running than during grass running. There was significant difference between asphalt running and grass running, and the ratio of peak impact acceleration during asphalt running for during grass running was 123% (89-171%).

Conclusion: It was concluded that peak impact acceleration at tibia were affected by the overground surface states. It was considered that running in a soft overground surface like grass was at lower risk of developing tibial stress fracture than running in a hard overground surface like asphalt.

384 - Differential Patterns of Muscle Activation in Patients with Symptomatic and Asymptomatic Rotator Cuff Tears

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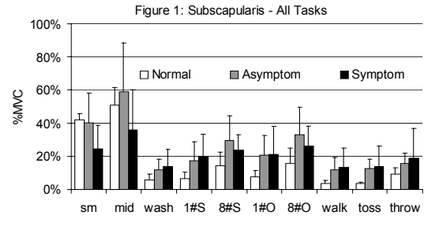
Introduction: Some patients with 2 tendon, full thickness (large) tears of the rotator cuff present with pain and limited motion, while others have near normal function [6,7]. We hypothesized there were differences in muscle firing patterns during functional tasks 1) between patients with large tears and normal controls; and 2) between symptomatic (SYMP) and asymptomatic (ASYMP) cuff tears of the same size. 23 subjects were tested:6 controls, 8 ASYMP and 9 SYMP rotator cuff tears. All subjects signed IRB approved informed consents. Subjects were examined and completed questionnaires (L'Insalata [4], ASES Shoulder Score Index [5]). MRIs documented supraspinatus and infraspinatus tendon tears and ultrasounds showed no cuff pathology in controls. Surface Ag/AgCl electrodes (1 cm spacing) were used for deltoid (ant, mid, post); trapezius (upper, mid, low); pectoralis major; latissimus dorsi; and serratus anterior. Wire electrodes (1 cm spacing) were used for supraspinatus, infraspinatus, and subscapularis [1]. Maximal voluntary isometric contractions (MVC) against manual resistance were performed [2,3]. A MA-100; (Motion Lab Systems) was used to collect EMG signals (1 kHz) which were filtered (20-350 Hz), rectified, linearly enveloped and normalized to MVC. Subjects completed10 tasks: 2 internal rotation tasks (touch small of back (sm) and mid back (mid)); 5 elevations (touch opposite shoulder (wash), lift a weight to shoulder level: 1 lb (1#S) and 8 lbs (8#S), lift a weight overhead: 1 lb (1#O) and 8 lbs (8#O)); a carrying task (20 lbs at the side (walk)); and 2 throws (softball underhand (toss) and overhand (throw)). EMGs were collected simultaneously with 3-D kinematics (60 Hz). Kinematic data delineated the phases of each task. The mean %MVC for each task and phase were calculated. ANOVA, two-sample t-tests and post-hoc tests were corrected for multiple measures (alpha = 0.05).

Results: All three groups differed for the L'Insalata and Shoulder Score Index ($p < 0.05$). During internal rotation tasks, ASYMPs had greater ($p < 0.05$) subscapularis %MVC than SYMPs (Fig. 1). During the carrying task, ASYMPs demonstrated less ($p < 0.03$) upper trapezius %MVC than SYMPs (15 vs 48% MVC). During elevation tasks, SYMPs had greater supraspinatus ($p < 0.03$), infraspinatus ($p < 0.05$), and upper trapezius ($p < 0.04$) activation compared to ASYMPs. During 8 lb elevation, ASYMPs showed a trend toward increased activation ($p < 0.06$) of the subscapularis compared to SYMPs (34 vs 21%).

Figure 1: Subscapularis - All Tasks



Discussion: Compared to ASYMPs, SYMPs have increased firing of their torn rotator cuff muscles; a lack of adaptive firing of an intact subscapularis; and exaggerated firing of upper trapezius when countering downward loads and during elevation that results in compromised function. Our data suggest that large cuff tears may benefit from increased emphasis on subscapularis strengthening during rehabilitation.

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Support: ISMR & OREF.

386 - Differences in Biceps Brachii Isometric Endurance and Isokinetic Torque Between Young And Older Men

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Introduction: The present study was aimed at further investigate the interplay between force and muscle shortening speed reduction as possible causes of the age related impairment of muscle performance in elderly (E) compared to young (Y) subjects. Muscle performance was investigated in terms of isometric endurance and torque/velocity relationship of the biceps brachii. This was achieved by assessing in the same subject, in separate experiments, the myoelectric and mechanical parameters of contraction. In order to avoid a possible confounding effect due to differences in absolute force between Y and E, subjects participating in the study were selected as such to have comparable values of maximal voluntary force (MVC).

Methods: The elbow flexors performance was studied on 10 male subjects (5Y age 28.3±4.8 y and 5E age 71.3±0.8 y). The following variables were measured: 1) the MVC and specific force; this latter was the force scaled by the muscle cross sectional area (PCSA). 2) the isometric endurance time (ET) at 80, 50, 30 %MVC . During the isometric contractions the average muscle fibres conduction velocity (3) of action potentials (CV) and (4) the median frequency (MDF) of the sEMG signals were assessed. Finally, 5) the torque-velocity curve was assessed by means of maximal isokinetic contractions at fixed angular velocities of 15, 30, 60, 90, 120 and 150 deg s^{-1}. The isokinetic dynamometer was used for isometric and dynamic experiments.

Results: Comparable values of MVC were obtained (315 N in E, 290N in Y). Also PCSA values were comparable between E (18.4 cm^2) and Y (17.5 cm^2). All the above differences were not significant. ET, CV and MDF results are reported in the table below.

%MVC	ET [sec]		CV decay [% sec^{-1}]		MDF decay [% sec^{-1}]	
	Y	E	Y	E	Y	E
50	**62±13**	**108±32**	0.21±01	0.15±0.07	**0.38±0.15**	**0.19±0.07**
80	**17±6**	**29±14**	**0.89±0.16**	**0.46±0.24**	**1.46±0.37**	**0.82±0.33**

CV and MDF are scaled for the initial values. In bold are indicated the significant differences Y vs E; at 30%MVC were not significant differences in all variables ($p<0.05$). Both in E and Y the angular velocity was correlated with Torque (T). In fig. 1 the data are fitted by a similar exponential curve. The two curves diverged significantly at AV values over 30 degree sec^{-1} ($p<0.05$).

Discussion: The greater ET in E vs Y is marked *at* higher MVC values only, i.e. when recruitment involves most powerful motor units (MU). MDF and CV decay have been considered as suggestive of a progressive impairment of fast twitch MUs. Thus the less marked decay of both variables in E vs Y at higher force demand is suggestive for a minor contribution of fast twitch MUs. The results of dynamic contractions are coherent with this statement: indeed, at low AV the torque is the same in the two groups but become progressively lesser in E vs Y when velocity is increased. In conclusion our results suggest that in subjects with the same MVC the real impairment of E vs Y is a lack of velocity that can depend on a minor percentage of type 2 MU. The relative preponderance of Type 1 MU seems in accordance with the lower fatigability in E.

396 - Analysis Of Quadriceps EMG Activity In Counter Movement Jumping - A Comparative Study Between Eccentric And Concentric Muscle Contraction Phases.

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This study's main goal was to verify the existence of differences in EMG signal activity between the eccentric and concentric phases of a counter movement jump. For this purpose we evaluated a sample of 27 youth volleyball players of both sexes (14 male and 13 female athletes). The best jump performance of each athlete was selected from 3 maximum counter movement jumps on the force plate, according to the higher time of flight.

EMG signals of *Vastus Lateralis* (VL), *Rectus Femoris* (RF) and *Vastus Medialis* (VM) muscles were recorded in all of the subjects, using surface electrodes. The Average full wave rectified signal of each muscle as well as its integral, both isolated and over time, were selected as phase defining parameters. This selection was made bearing in mind that to compare EMG signal activity in muscle contractions of different time length we may use the ratio between iEMG and the time in which the same integral was recorded, as long as integration time effects are removed. Its corresponding results are presented below

Table 1. Mean, Standard deviation (SD) and independent samples t test of eccentric and concentric phase's EMG parameters.

	Eccentric		Concentric			
	Mean	SD	Mean	SD	t	p
AvgEMG VL (mV)	0.22	0.14	0.65	0.33	-6.165	0.000*
AvgEMG RF (mV)	0.17	0.07	0.59	0.22	-9.604	0.000*
AvgEMG VM (mV)	0.26	0.12	0.72	0.31	-7.126	0.000*
iEMG VL (mV.s)	0.11	0.06	0.20	0.09	-3.978	0.000*
iEMG RF (mV.s)	0.08	0.04	0.17	0.07	-5.671	0.000*
iEMG VM (mV.s)	0.12	0.06	0.20	0.08	-4.491	0.000*
Duration of phase (sec.)	0.51	0.10	0.30	0.07	8.915	0.000*
VL AvgEMG / Δt	0.46	0.32	2.37	1.39	-6.961	0.000*
RF AvgEMG / Δt	0.34	0.18	2.15	1.16	-8.014	0.000*
VM AvgEMG / Δt	0.53	0.30	2.65	1.74	-6.254	0.000*
VL iEMG / Δt	0.22	0.14	0.66	0.31	-6.729	0.000*
RF iEMG / Δt	0.17	0.07	0.59	0.22	-9.731	0.000*
VM iEMG / Δt	0.26	0.12	0.71	0.32	-6.935	0.000*

*Existence of statistically significant differences with p<0,05.

Our results indicated the existence of statistically significant differences in all of the EMG parameters analysed, as well as in the duration of each phase, between the eccentric and concentric phases of a counter movement jump. EMG signal appears to be stronger in the concentric phase, suggesting superior electrical power in the signal of quadriceps muscles in this phase, thus providing support to the differences found in EMG parameters between

phases. On the other hand, although we verified that the eccentric phase is longer than its concentric counterpart, this does not indicate superior EMG activity.

In conclusion, it seems to be clear that there are significant differences in EMG average full wave rectified signal as well as in its integral, between eccentric and concentric muscle contraction phases in counter movement jumping.

398 - Analysis of Quadriceps EMG Activity in Counter Movement Jumping - A Comparative Study between Eccentric and Concentric Muscle Contraction Phases Of Subject Groups with Different Sexes

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This study's main goal was to verify the existence of differences in EMG signal activity on the eccentric and concentric muscle contraction phases of a counter movement jump between subjects of different sexes. For this purpose we selected from a determined initial population, a sample of 12 youth volleyball players of both sexes (6 male and 6 female athletes), according to flight time (in this case the average flight time of each group was the same). The best jump performance of each athlete was selected from 3 maximum counter movement jumps on the force plate. EMG signals of *Vastus Lateralis* (VL), *Rectus Femoris* (RF) and *Vastus Medialis* (VM) muscles were recorded in all of the subjects, using surface electrodes. The Average full wave rectified signal of each muscle as well as its integral, both isolated and over time, were selected as phase defining parameters. The results corresponding to eccentric and concentric phase analysis between sexes are presented below in table 1.

Table 1. Mean, Standard deviation (SD) and independent samples t test of eccentric and concentric phase's EMG parameters between sexes.

	Eccentric phase					
	Male		Female			
	Mean	SD	Mean	SD	t	p
AvgEMG VL (mV)	0.23	0.19	0.24	0.17	-0.081	0.937
AvgEMG RF (mV)	0.16	0.07	0.21	0.10	-1.061	0.313
AvgEMG VM (mV)	0.30	0.16	0.24	0.07	0.861	0.419
iEMG VL (mV.s)	0.10	0.08	0.12	0.08	-0.492	0.633
iEMG RF (mV.s)	0.07	0.02	0.11	0.04	-2.148	0.057
iEMG VM (mV.s)	0.14	0.07	0.13	0.03	0.390	0.709
Duration of phase (sec)	0.46	0.08	0.54	0.08	-1.615	0.137
VL AvgEMG / Δt	0.53	0.46	0.47	0.37	0.262	0.799
RF AvgEMG / Δt	0.37	0.20	0.42	0.24	-0.402	0.696
VM AvgEMG / Δt	0.70	0.44	0.47	0.17	1.174	0.268
VL iEMG / Δt	0.23	0.18	0.24	0.17	-0.099	0.923
RF iEMG / Δt	0.15	0.07	0.21	0.10	-1.201	0.257
VM iEMG / Δt	0.31	0.17	0.24	0.07	0.876	0.410
Flight time	0.50	0.02	0.50	0.02	0.136	0.894
	Concentric phase					
AvgEMG VL (mV)	0.70	0.34	0.68	0.35	0.066	0.948

AvgEMG RF (mV)	0.58	0.16	0.59	0.24	-0.100	0.923
AvgEMG VM (mV)	0.78	0.23	0.68	0.20	0.771	0.459
iEMG VL (mV.s)	0.21	0.11	0.21	0.09	-0.029	0.978
iEMG RF (mV.s)	0.17	0.04	0.18	0.09	-0.302	0.769
iEMG VM (mV.s)	0.23	0.05	0.21	0.08	0.338	0.742
Duration of phase (sec)	0.30	0.06	0.32	0.06	-0.460	0.656
VL AvgEMG / Δt	2.44	1.32	2.30	1.67	0.156	0.879
RF AvgEMG / Δt	2.06	0.97	1.95	0.91	0.212	0.836
VM AvgEMG / Δt	2.79	1.32	2.21	0.80	0.908	0.385
VL iEMG / Δt	0.70	0.34	0.68	0.34	0.111	0.914
RF iEMG / Δt	0.59	0.16	0.59	0.24	0.029	0.978
VM iEMG / Δt	0.79	0.24	0.67	0.20	0.901	0.389
Flight time	0.50	0.02	0.50	0.02	0.136	0.894

*Existence of statistically significant differences with p<0,05.

Our results indicate that there aren't statistically significant differences in eccentric and concentric muscle contraction phases between sexes, in all of the parameters selected for analysis. In conclusion we determined the inexistence of differences in EMG signal activity between sexes when analysing the eccentric and concentric phases of a counter movement jump.

400 - Relationship between Exercise-Related Interleukin-6 Production, Mechanical and Myoelectric Manifestations of Fatigue

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Introduction: Strenuous exercise is a well recognized physical stressor. Acute intense aerobic exercise that exceeds 60% of the maximum aerobic power and anaerobic exercise above the maximum oxygen uptake enhance the activity of the hypothalamic-pituitary-adrenal axis. During maximal exercise, muscular inflammation occurs with the consequent release of the inflammatory cytokine interleukin-6 (IL-6) from contracting skeletal muscles into the systemic circulation.

This work aims to couple the mechanical and the myoelectrical manifestations of fatigue to the cytokine response with the following objectives: 1) to characterise the IL-6 response to the exercise in elite athletes of different disciplines, and 2) to determine the relationship between the IL-6 production and the manifestations of fatigue in both voluntary and electrically elicited contractions.

Methods: An evaluation of the muscular response to an acute bout of maximal isokinetic exercise (maximal contractions of the knee flexor and extensor muscle groups at 180°/sec angular velocity throughout the constant range of motion of 100°) was made in a group of twenty elite athletes. Before, immediately after the isokinetic exercise and at different time points in the subsequent 120 minutes of recovery, serum lactate and serum IL-6 were determined and EMG signals were recorded from the dominant leg during isometric Maximal Voluntary Contractions (MVC) and electrically elicited contractions. Mean frequency (MNF) of the EMG signal spectrum, the average rectified value (ARV), and the muscle fiber conduction velocity (CV) were estimated.

Results: In the entire athletes' group the isokinetic exercise test elicited significant IL-6 and lactate responses ($p<0.05$ Friedman's ANOVA). We used the peak levels and the Area Under the Curves (AUCs) to describe the IL-6 responses among the subjects. The median values of these variables allow to distinguish two groups: "High IL-6 Responders" (HR, 539.9±334.5 pg/ml*150 minutes) and "Low IL-6 responders" (LR, 52.4±69.5 pg/ml*150 minutes, $p<0.001$ Mann-Whitney U test). The HR group showed higher lactate responses in comparison to the LR (831.6±187.2 mmol/l*150 minutes vs 478.2±160.9 mmol/l*150 minutes, $p<0.01$ Mann-Whitney U test).

The rate of decrease of the maximal voluntary knee extension torque during the isokinetic exercise allows to distinguish seven power athletes and thirteen endurance athletes. Six out of seven power athletes were found HR, while nine out of the thirteen endurance athletes resulted LR. Consistently, a positive correlation was found between the IL-6 and lactate AUCs ($r=0.81$, $p<0.001$). Finally, in electrically elicited contractions, the CV estimates of the HR group required more time (+15 minutes post exercise) to return to values comparable to the baseline with respect to LR (immediately after the exercise).

Discussion: The inflammatory cytokine IL-6 was significantly increased after the exercise, possibly as a function of the muscular release of this chemical, according to the literature. Our observations originally suggest that the exercise related IL-6 increase is higher in power than in endurance-trained athletes. Since the lactate responses and mechanical and myoelectrical manifestations of fatigue were found significantly greater in the HR than in the LR group, we suggest that the muscle fiber type composition is a possible determinant of the muscular inflammatory reaction to the exercise. Further studies are in progress aimed to confirm and extend, in a wider population of athletes, these preliminary observations.

411 - Analysis of M. Vastus Lateralis and M. Biceps Femoris Temporal Patterns During Gait of Transtibial Amputees Athletes

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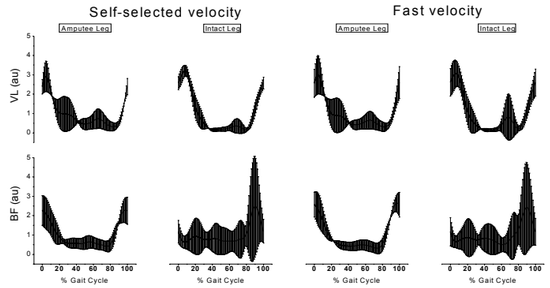

Fig. 1- Ensemble average

Introduction: The amputation condition and the prosthesis affect the patterns of myoeletric activity on gait during normal and sports movements (SANDERSON & TOKUNO, 2002; WINTER & SIENKO, 1988). Therefore, the aim of this work is to analyze the temporal pattern of m. vastus lateralis (VL) and m. biceps femoris during gait of amputees athletes.

Methods: Three transtibial amputees (40±12 years old, 73±2 kg mass and 1.76±0.01 m height) were the subjects of this study. They wore endoskeletal prosthesis with dynamic feet. EMG system (Bagnoli-8, Delsys, Inc) and an instrumented treadmill (Gaitway- Kistler, Inc) with two force plates were the instruments used for data collection. Surface electrodes were placed 1 cm below the point motor of each muscle. Two horizontal gait velocities were chosen: 1) self-selected (1.50±0.33 m/s) and 2) fast (1.83±0.45 m/s). Data was low-pass filtered with 2 order Butterworth filter at 5 Hz and it was calculated ensemble average of each signal during one signal step to show the gait cycle (GC) behavior. One factor was studied: differences within subjects (between the amputee leg (AL) and intact Leg (IL)).

Results: There was no effect of velocity on EMG pattern (Fig. 1). For IL, VL was activated from 0 to 30% GC. For AL, VL was activated from 0 to 40% GC. BF showed the same pattern for both legs during swing phase, from 80% to the end of GC, and it was different pattern during stance phase. For IL, BF was activated from 0 to 5% GC; and for AL from 0 to 20% GC. VL activation peak were earlier for AL (4% GC) than for IL (8%GC). BF activation peak were later for IL (97% GC) than for AL (90% GC).

Discussion: According to RAB (1998), main muscular action was not affected by amputation. Moreover, increased time activation and earlier VL peak during the initial phase of AL support probably occurs to fix the knee. For BF, different time peaks may be due to prosthesis inertial characteristics.

Conclusion: The movement control of the knee by VL and BF is different between AL and IL of transtibial amputee athletes. Such behavior may be due to joint stability and prosthesis inertial characteristics.

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438 - Coactivation in the Knee Joint after Anterior Cruciate Ligament Reconstruction and Rehabilitation

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Introduction: The literature shows evidences that the coactivation in the knee joint during isokinetic exercises is useful to protect and stabilize the joint specially during powerful contractions. This protection is achieved by pressure distribution through the joint resulting in fatigue reduction and smaller joint damages. In this context, the aim of the present study was to evaluate the coactivation mechanism in subjects that had undergone arthroscopic ACL reconstruction.

Methods: The EMG activity of the vastus lateralis and long head of biceps femoris was recorded, using bipolar surface electrodes (*Delsys-Bagnoli 8*), during active extension of the knee. We evaluated 15 male subjects, five of them had undergone arthroscopic patellar tendon ACL reconstruction (Test Group - GT) and 10 healthy subjects constituted our control group (Control Group - GC). The *Cybex 6000* system was used to load the knee while the subjects were sitting on the bench and extended their knee from 120 to 0 degrees at the rate of 100 and 300 degrees/s. The electromyographic activity was collected simultaneously and synchronically with the torque, joint position and were sampled at 1000 Hz for periods of 10 s. In order to identify the thigh muscles coactivation, we developed a proportion variable: antagonist hamstring EMG activity was normalized by the percentage of agonist hamstrings EMG activity during the maximal flexion phase.

Results and Discussion: Table 1 shows the EMG coactivation data results. The hamstrings was considerably more active during knee extension than the quadriceps during flexion. Two GT subjects showed lower value of coactivation in the injury limb and 3 of them showed the highest biceps femoris coactivation. The hamstrings would not normally be expected to be active during extension of the knee by the quadriceps, instead, reciprocal inhibition of the hamstrings might be expected. Our observations support the hypothesis that the activity of the hamstrings combined with the restraints of the ACL acts to prevent anterior displacement of the tibia. Although considered rehabilitated, 2 GT subjects did not show any coactivation. Besides hamstrings strengthening, quadríceps strengthening in the rehabilitation process appears to be important to induce coactivation.

440 - Peroneal EMG Onset Patterns During Laterally-Tilted Treadmill Running With and Without Ankle Orthoses

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Introduction: Ankle orthoses are commonly used to prevent inversion ankle sprains. However, little is known about the neuromuscular recruitment patterns, or the protection offered by external devices against induced inversion compared to the dynamic stability provided by muscle activity alone. It has been suggested that ankle joint muscles must be activated 85-90 msec in advance of heel strike to provide the requisite dynamic joint stability. We hypothesized that subjects would rely on orthoses for support resulting in longer EMG onset durations prior to heel strike compared to a control. Our purpose was to determine if differences exist in peroneal longus/brevis EMG onset while wearing selected ankle orthoses when running on a laterally tilted treadmill.

Methods: Ten healthy volunteers (6 females, 4 males; mean age, 24 ±7 yr) with no history of ankle injury participated in the study. Bipolar EMG surface electrodes were applied over the peroneus longus/brevis muscle. Telemetered EMG (2400 Hz) and 2-D kinematic data (60 Hz) were collected as subjects ran at 8 mph on an 8.5 deg laterally tilted treadmill designed to induce inversion. Using a repeated measures counterbalanced ANOVA design, each subject was tested under 5 conditions: 3 ankle braces, closed basketweave taping, and control (no support). Peroneal muscle onsets were identified by EMG activity prior to heel strike that exceeded threshold for a duration of 20 msec. Threshold was defined as the mean quiet period of the signal plus three times the standard deviation. EMG onsets, expressed as the amount of time prior to heel strike (msec), were averaged across 5 strides within each condition.

Results: Peroneal muscle EMG onsets with the Swede-O condition were significantly later than the Control condition ($p<0.05$). No statistically significant differences in onsets were found among any of the ankle orthoses ($p>0.05$). The Control condition tended to have earlier peroneal onset activity prior to heel strike than any of the ankle orthosis conditions. Conclusions: These findings suggest that an ankle orthosis may alter the neuromuscular recruitment patterns in healthy subjects during a dynamic activity. Subjects wearing an orthosis recruited their peroneal muscles much closer to heel strike potentially diminishing muscular dynamic stability at the ankle. Therefore, individuals wearing ankle orthoses may rely on the orthoses for support, potentially weakening the surrounding ankle musculature with long-term use.

Group	Control	AirCast	Swede-O	Speed	Tape
Mean (msec)	105.8	95.8	71.8*	99.1	101.9
± SD	35.3	48.3	44.9	51.8	48.9

* statistically significant difference compared with the control ($p<0.05$)

449 - Analysis of Force Perception and Electric Activity In Forearm Flexion Movements Through Dynamometry And Electromyography

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Introduction: In the everyday life when we transported or raised objects with different dimensions and masses, we have countless experiences with the environmental in which we are interacting. This frequent interaction is the result of a series of muscular contractions that guarantee to notice, in the daily situations, if a broom has more mass than a chair, if a body position is better than other to get up of the ground. For the athletes of high level that look for minimum improvements of performance, the application of a little more intense force than that necessary can mean mistake and, consequently, a performance fall. Electromyography (EMG), a method that involves capture and analysis of electric potentials of the muscles in activity, can supply important data about the effective participation of each muscle in the several voluntary movements of skeletal muscles, enlarging knowledge or modifying well-established concepts. The aim of this study was to evaluate and to compare the force perception and electric activity of the *Biceps Brachii* (BB) and *Brachiorradialis* (BR) muscles in forearm flexion movements through the maximum isometric voluntary contraction in trained and untrained individuals in resisted exercises.

Methods: Twenty male volunteers participated in this study and were equally divided in two groups: (1) trained volunteers (TV) and (2) untrained volunteers (UV). During the experiments, the volunteers stayed seating in a bank with support, with forearm flexion at 90^o ($90^o \pm 5^o$) in the supinated position. EMG signs were captured throughout the movement (3 s interval) in three series using a computerized 8-channel electromyography. Simple differential active surface electrodes and reference (ground) electrode were used, the latter being common to all the channels. Firstly, the electric activity was collected in rest; later, the one of maximum isometric voluntary contraction, together with the maximum load obtained as demonstrated by the dynamometer. After the identification of the maximum load, the percentages of 20, 30, 40, 50, 60, 70, 80 and 90% were calculated. Afterwards, it was requested to the volunteer to execute a force in the dynamometer according to the maximum load percentages in the increasing order. The volunteers did not possess any feedback on the load that had performed.

Results: The results demonstrated that the electric activity of the BB muscle in TV were significantly higher in the maximum contractions ($p = 0.0198$), 80% ($p = 0.0069$), and 90% ($p = 0.0194$) as compared to that of BR muscle. In contrast, no significant difference was found in UV, but the BB muscle showed the highest electric activity. When analysing the electric activity of the BB muscle between the groups, TV always presented the highest electric activity, being significant in the maximum isometric load ($p = 0.0265$), 70% ($p = 0.0471$), and 80% ($p = 0.0396$). On the other hand, regarding the BR muscle, TV also showed the highest electric activity, being significant in the maximum isometric load ($p = 0.0478$), 40% ($p = 0.0146$), 50% ($p = 0.0302$), 60% ($p = 0.0316$), and 70% ($p = 0.0220$). When analysing the results about force perception, we noticed that the error limit was significant only for TV and UV in the load of 90% ($p = 0.0217$ and $p = 0.0334$, respectively).

Conclusion: It can be concluded that the BB muscle presents higher electric activity than the BR muscle, mainly over 80% of the maximum isometric voluntary load. We also observed that the electric activity of TV, for both muscles, is larger than in UV and that both groups presented the higher error limit for the estimated loads, the closer of the maximum load.

450 - Electromyographic Study of the Simultaneous Action of the Flexor Carpi Radialis, Extensor Carpi Radialis Brevis and Pronator Teres Muscles In Forearm Flexion Movements

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Introduction: Prior to the advent of Electromyography (EMG), one of the features that allowed deducing the muscular action was the knowledge of their fixations. These anatomical aspects are important, but they do not supply any information on the action mode of the muscle, such as what muscle begins or stops its activity first and the degree of participation of each muscle and its sinergists and antagonists in a specific movement. EMG, as method of kinesiologic investigation encloses all these possibilities. The aim of this study was to analyse through EMG the simultaneous action of the muscles *Flexor Carpi Radialis* (FCR), *Extensor Carpi Radialis Brevis* (ECRB) and *Pronator Teres* (PT) in forearm flexion dynamic movements, considering 50% of maximum voluntary load (MVL) in supinated, semipronated and pronated positions.

Methods: Ten untrained male volunteers, 21 ± 4 years old, with no history of diseases or anatomical alterations were used. The volunteers performed forearm flexion movements in two modes: (1) the apparatus handle fastened in the hand (closed hand) and (2) the apparatus handle fastened in the wrist (opened hand) in the dominant limb using a double-pulley apparatus. EMG signs were captured using simple differential active surface electrodes and recorded in a computerized electromyograph with simultaneous acquisition up to eight differential channels and ground electrode common to all the channels. Electric activity of the muscle was captured in 4 s and analysed using the Alc-EMG software, which supplied numeric values of RMS (root mean square). RMS values were statistically analysed by Student *t* test, with significance level at 0.05.

Results: The results demonstrated that when analysing the opened hand, the electric activity of the studied muscles was lower than that seen with the closed hand, except for the PT and FCR muscles in the pronated position. The PT and FCR muscles exhibited higher activity in the pronated position and lower activity in the supinated position, with the opened hand. In contrast, the ECRB muscle showed higher and lower activity in the supinated and pronated positions, respectively. When analysing the closed hand, the highest electric activity occurred in the supinated position while the lowest was recorded in the pronated position for the PT and FCR muscles. For the ECRB muscle, the highest activity was shown in the pronated position and the lowest in the supinated position. It was also verified a small increment of electric activity of PT and FCR muscles in semipronated and supinated positions with the closed hand rather than the opened hand, whereas in the pronated position a decreasing of electric activity was found. The activity increment seen with the opened hand could be attributed to the simultaneous action of the muscles on the two articulations, being FCR a sinergist muscle and PT a articular fixer. The activity decrease of PT in the pronated position can be due to its shortening and thus having less importance in the elbow stabilization. In contrast, the ECRB muscle showed a great activity increment with the closed hand as compared to the opened hand, with the highest activity recorded in the pronated position and the lowest in the supinated position, where the muscle is more shortened.

Conclusion: It can be concluded that these muscles have influence on the forearm flexion movements, particularly when some apparatus is held in the hand. Therefore, when prescribing resisted exercises that are performed through forearm flexion movements it should be considered the participation of these muscles in both the training session and the recovery therapy.

Temperomandibular Dysfunction

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001 - Electromyographic Analysis of Masticatory and Facial Muscles in Individuals with Schwartz-Jampel Syndrome

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Introduction: Schwartz–Jampel syndrome (SJS), also known as osteochondromuscular dystrophy or chondrodystrophic myotonia, is a rare genetic disorder (71 cases related in world-wide literature). The affected individuals have short stature, muscular stiffness, skeletal alterations, and a typical mask-like facies characterized by ocular adnexal changes, and contracture of the perioral muscles. The aim of this study was to evaluate the electromyographic (EMG) activity of the orbicularis oris, orbicularis oculi, masseter and temporalis muscles in brothers with Schwartz-Jampel syndrome, in different clinical activities, compared to normal individuals.

Methods: An Electromyography K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA) with eight channels was used. Applied electrodes were duotrodes, silver-chloride surface, disposable, diameter of 10 mm, and inter-electrode distance of 21 mm.

Results and Discussion: The analyzed results (ANOVA), for the masseter muscle's activity showed significant differences ($p<0.01$) among the groups. The individuals with the syndrome presented higher muscular activity (1.37μV) than the healthy volunteers (1.21μV). In the temporalis muscle, the difference was not significant for both groups. In both muscles significant differences occurred among the clinical activities and groups/clinical activities' interactions ($p<0.01$). The orbicularis oris muscle did not show significant differences although muscular activity was greater in patients with the syndrome. The orbicularis oculi muscle presented significant differences in the groups, the clinical activities and the groups/clinical activities' interactions ($p<0.01$), and the largest averages were found in patients with the syndrome (31.64μV) in comparison with the normal ones (15.82 μV). We concluded that individuals with Schwartz-Jampel syndrome showed higher masticatory and facial muscle activity.

003 - Effect of Denture Quality on Perioral Muscle Activity During Speech

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The maxillary and mandibular fascicles of the orbicularis oris muscle, along with alveolar processes and dental arches, constitute a functional complex, which is in intimate contact with lips flanks, basis, and teeth of dental prosthesis. Any alteration of this system might produce disarrangement of muscular activity. This study aimed to evaluate the electromyographic activity of the orbicularis oris muscle in patients using clinically inadequate conventional dentures before and after the insertion of clinically acceptable new conventional denture. Six patients, using inadequate dentures, were asked to pronounce the syllables PAH, BAH, MAH, SAH, FAH, VAH, MEE and the word MISSISSIPI. During this activity, we analyzed the Electromyographic activity of the orbicularis oris muscle. This was done before and after changing the inadequate denture for a acceptable new denture. A K6-I EMG Light Channel Surface Electromyograph was used (Myo-tronics Co). Results were analyzed by repeated measures ANOVA, with 3 sources of variation (Syllables, Muscles, and Clinical Conditions). ANOVA revealed higher electromyographic readings in the mandibular fascicle of the orbicular oris muscle, as compared to those of the maxillary fascicle ($F = 79.02$; $P<.01$). The comparison regarding clinical conditions indicated higher electromyographic values after insertion of acceptable new denture ($F= 32.64$; $P<.01$).

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116 - Comparison among Subjects with Different Occlusion Classes of With and Without Bruxism Angle

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Introduction: Considering the need of further understand the relationship among occlusion, bruxism, posture, and muscle activity, the purpose of this study was to compare the cervical posture and the bilateral electromyographic activity of the anterior portion of temporal and masseter muscles in subjects with different occlusion classes of Angle with and without bruxism.

Methods: Thirty-four female students participated in this study. The subjects were divided into two groups (Group 1: with bruxism, Group 2: without bruxism). A dentist evaluated each subject and classified their occlusion according to the Angle method (class I, class II or class III). A clinical analysis of the cervical posture was conducted to determine head posture (forward, slightly forward, and normal position). Photos were taken and analyzed using a software quantifying the head posture angularly. The points used as reference to calculate the head-neck angle were mentus, accustic meatus and manubrium. An electromyographic analysis (Lynix Eletronics) was performed with active differential surface electrodes (Ag). The electrodes were placed in the masseter and temporal muscles perpendicular to the muscles fibers. The electromyographic data (EMG) was recorded during bilateral isotonic mastication using Parafilm material between the premolar and molar teeth. The EMG values (root mean square - RMS) were analyzed using the software Matlab (6.1 version).

Results: The EMG data was different for each occlusion class of Angle. Subjects with class I showed a functional EMG pattern when compared with class II and class III. Differences were not present when the data was normalized. Thus, the normalization has hidden the muscles disorders in these subjects.

Conclusion: The relationship among head posture, malocclusions and muscle alterations was stronger for subjects with Angle class II. Class II subjects presented higher muscle activity, head anteriorization, and head-neck angle.

130 - Pattern of Electric Activity of the Masticatory and Cervical Muscle In Violinists and Violists

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Introduction: The purpose of this study was to evaluate the electric activity of the masticatory and cervical muscles in violinists and violists.

Methods: Thirteen musicians (violin and viola players) with age of 17 to 45 years old, 06 female and 07 male, with average of 5 years of instrument's practice, volunteered in this study.The musicians were submitted to a surface electromyographic (EMG) exam of the sternocleidomastoideus, upper trapezzi, masseter and temporal muscles, bilaterally, in the rest, maximal voluntary contraction and chewing. The EMG was accomplished with Myosystem Br-1 equipment, of 12 acquisition channels, 12 resolution bites , amplified with gain of 5000, sampled at 2000 Hz, bandwidth of 10-500Hz.The sEMG amplitude processing used was the Root Mean Square (RMS) measured in µV.

Results: Mean RMS values were higher in the temporal muscle in rest, during chewing and maximal voluntary contraction, than in the masseter muscle . About cervical muscles, the results showed the highest value of RMS in the right SCM muscle in the rest and, in the maximal voluntary contraction this muscle and the right trapezius showed higher values than the same muscles in the left side.

Conclusion: It is concluded that the musicians presented prevalence of the temporal muscles activity, probably to compensate the lowest participation of the masseter muscle. The highest activity presented in the trapezius and SCM muscles in the right side can be attributed to the head's posture adopted during the instrument's practice.

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131 - Electromyography Evaluation of Chewing Muscles before and After Body Posture Treatment in Mouth Breathing Children

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Introduction: The purpose of the present study is to evaluate the effect of body posture treatment in the electrical activity of the chewing muscles in mouth breathing children.

Methods: Nineteen mouth breathing children, with 09 to 12 years old, 08 female and 11 male, volunteered in this study. The subjects were evaluated before and after body posture treatment with exercises in the Swiss Ball during 03 months, twice a week. The evaluation consisted of bilateral electromyographic recordings of the masseter and temporal muscles, bilaterally, during three situations: relaxed , chewing and maximal voluntary contraction. The EMG was accomplished with Myosystem Br-1 equipment, of 12 acquisition channels, 12 resolution bites , amplified with gain of 5000, sampled at 2000 Hz, bandwidth of 20-1000Hz.The sEMG amplitude processing used was the Root Mean Square (RMS) measured in μV.

Results: There were no statistically significant differences after treatment in relaxed situation. In maximal voluntary contraction, there was a significant increase in all studied muscle activity and an improvement in the symmetry of the muscular activity after treatment. During chewing, there was a significant increase of the muscle activity (except, right temporal muscle) and a more symmetric activity of the temporal muscles.

Conclusion: The body posture treatment interfered positively in the chewing muscles.

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149 - Electromyographic Study of Hyperactive Masticatory Muscles in Patients with Temporomandibular Disorders

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Introduction- Electromyography can be used to analyse the resting status of masticatory muscles, and the static evaluation provides an objective measurement of chronically hyperactive muscles, which are used to be higher in TMD patients. When the craniofacial pain is associated with this syndrome, the treatment become complex and unspecific. So the purpose of this study is to investigate the relationship between muscular hyperactivity at rest and craniofacial pain in TMD patients.

Methods- A total of 133 female patients with temporomandibular disorders and craniofacial pain, verified through anamnesis and clinical examination, had the electromyographic resting activities of anterior temporalis, superficial masseter and digastric muscles evaluated. Their ages varied between 20 and 60 years old. The EMG signal were acquired with Ag/AgCl surface electrodes and ECG conductive adhesive electrodes Meditrace® 200 by Kendall. The raw EMG signals were digitalized by a 12 bit A/D converter board, low-pass of 500 Hz and high-pass of 10 Hz filter. It was considered hyperactive muscles above 2.0 μV.

Results- We found 97% of resting activity and 29 kinds of hyperactivity combination in the patients with craniofacial pain, and 27,8% of the resting activity was present in the three groups of muscles and the exclusive temporalis activity (10,5%) were higher than exclusive masseter (1,5%) and exclusive digastric activities (1,5%) like the findings of Cooper in 1997.

Discussion- The results have shown that craniofacial pain, in the most of cases (97%), seems to be associated with muscular hyperactivity and electromyographic resting activity, wich needs of more studies. Attention must be paid to the complexity of the hyperactivity combinations, that take us the conclusion that the treatment of the craniofacial pain should be more personal, in accordance with the muscular activity got in the electromyogram of the patient.

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155 - Effectiveness of Manual Therapy on the Electric Activity of the Chewing Muscles in Temporo-Mandibular Disordered Patients

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Introduction: The purpose of this study was to evaluate the effectiveness of the manual therapy on the electric activity of the chewing muscles in temporomandibular disordered patients (TMD).

Methods: Eleven female, with 19 - 40 years old (24,91 ± 7,76) with TMD volunteered in this study. The subjects were evaluated before and after application of the mobilization of TMJ, with an electromyographic exam (EMG) of the masseter and temporal muscles, bilaterally, in rest and during maximal voluntary contraction. After the evaluation, the subjects were submitted to the following mobilization: 1) joint de-coaptation synchronized with the breathing cycle (lower traction intra-oral of the temporo-mandibular joint), for 90 seconds (3 repetitions of 30 seconds, with intervals of 10 seconds) for each side and, 2) stretching of the jaw elevating muscles through the buccal opening against resistance with 06 repetitions of 15 seconds of duration and 10 seconds of interval. The EMG was accomplished with Myosystem Br-1 equipment, of 12 acquisition channels, 12 resolution bites, amplified with gain of 5000, sampled at 2000 Hz, bandwidth of 10-500Hz.The sEMG amplitude processing used was the Root Mean Square (RMS) measured in µV.

Results: For analysis of the obtained results the t Student statistical test was used. The results showed significant decrease of RMS (mV) in rest situation, after the mobilization in all the studied muscles. In the maximal voluntary contraction there was not significant difference after the mobilization.

Conclusion: It can be concluded that the joint de-coaptation and muscles stretching promoted the muscular relaxation, demonstrated by the decrease of the studied muscles electric activity during rest.

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183 - Electromyographic Analysis Of Chewing Muscles In Mouth And Nasal Breathing Children

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Introduction: The purpose of this study was to analyze the electrical activity of the chewing muscles in mouth and nasal breathing children.

Methods: Sixteen mouth breathing children, with mean age of 10,4 years old, six female and ten male, and twelve nasal breathing children, with mean age of 10,9 years old, four male and eight female, volunteered in this study. The subjects were evaluated by means of a bilateral electromyographic exam (EMG) of the masseter and temporal muscles, in rest, during chewing and maximal voluntary contraction. The EMG was accomplished with Myosystem Br-1 equipment, of 12 acquisition channels, 12 resolution bites, amplified with gain of 5938, sampled at 4000 Hz, bandwidth of 20-1000Hz.The sEMG amplitude processing used was the Root Mean Square (RMS) measured in µV.

Results: The data, statistically analyzed, showed no significant difference, among the groups, in rest. However, there was a significance difference among them in the left masseter and temporal muscles activity during chewing and maximal voluntary contraction, being the nasal breathing children group showed symmetric pattern of muscle activity in these situations. It was also verified, in both groups, a significant higher temporal muscles activity than masseter muscles.

Conclusion: These results demonstrate that mouth breathing children present asymmetry in the activity of the studied muscles during chewing and maximal voluntary contraction when compared to the nasal breathing children, which can be related to the masticatory lateral preference.

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231 - The Effect of Cervical Mobilization on Electromyographic Activity of Masticatory Muscles in Patients with Temporomandibular Disordes

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Objective: The aim of this study was to determine the immediate effect of cervical mobilization on the electromyographic activity of the sternocleidomastoid and masseter muscles and the anterior part of the temporal muscles in patients with temporomandibular dysfunction (TMD).

Methods: Twenty-two female volunteers participated in this study. The experimental and placebo groups were composed of patients with TMD and had rotation of at least one of the three first cervical vertebrae, while the control group was composed of TMD-free subjects without rotation of the cervical vertebrae. After analysis of an X-ray examination, the volunteers selected were submitted to a bilateral electromyographic examination of the following muscles: masseter, anterior part of the temporal, and sternocleidomastoid. Subsequently, a passive articular mobilization procedure of the cervical column was applied to the volunteers of the experimental and control groups, while placebo group volunteers received a simulation of the procedure. The electromyographic examination was carried out immediately and 24 h after treatment. Electromyographic signals were recorded utilizing the *Myosystem I*® (*Prosecon Ltda),* with a sampling frequency of 2KHz and 12-bit resolution. After digitalization, the signals were again passed through a digital filter with 10 to 500Hz bandpass. Pure silver (Ag) simple differential active surface electrodes (*Lynx Tecnologia Eletrônica Ltda*.) were utilized, with an input impedance of 10GΩ, and CMRR of 130dB and gain of 100 times. The electromyographic signals were determined with respect to time, for both the resting and isometric contraction positions, and measured in root mean square (RMS) values. Wilcoxon's paired non-parametric test was utilized to compare separately the RMS values for the three times at which it was determined: before and immediately and 24h after the cervical mobilization procedure in each of the groups.

Results: The results showed that there was an immediate increase in the electromyographic signal amplitude of the masseter and sternocleidomastoid muscles after the cervical mobilization procedure in the treated groups, without any alteration in the temporal muscles in any of the groups.

Conclusion: This effect tends to diminish the imbalance of the abnormal pattern of activity between the muscles controlling masticatory force and the positional muscles of the jaw present in TMD patients.

232 - The Direct Effect of the Functional Orthopedics Maxillary Treatment In Mastigatory Muscles´s Electromyographic Activity. A Case Report.

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Objective: The main of this work was to relate a clinical case which shows the direct treatment effect by a Functional Orthopedic Maxillary Appliance (named SN 6 : Simoes´s Network 6) over the electromyographic activity on the mastigatory muscles of an adult patient, who has malocclusion (teeth fill up and non occlusal equilibration), with a relate of pain in mastigatory muscles.

Methods: Both sides of the masseter, right anterior temporalis and suprahyoid muscles were evaluated electromiographically before the installation of the Functional Maxillary Orthopedic Maxillary Appliance SN 6 and 8 minutes after. Electromyographic signals were recorded utilizing the Myosystem I equipment from Prosecon Ltda, with a sampling frequency of 2KHz and 12-bit resolution, using a digital filter with a bandpass of 20 to 500Hz. Simple differential active surface electrodes (pure silver by Lynx Tecnologia Eletrônica Ltda) with a gain of 100 times.

Results: The electromyograms analysis shows a great improvement of the electromyographic signal, inspiring a decrease of the masseter and anterior temporalis muscles hyperactivity, with the decrease of RMS (Root Mean Square) signal of these muscles, in rest mandibular position as in isometric contraction in maximal mandibular elevation (Table 1).

Conclusion: It's possible to conclude that the treatment by Functional Maxillary Orthopedics can gives a relaxation in the muscles with hyperactivity, which is possible to see by qualitative and as quantitative way. This relaxation runs to a normal muscle activity pattern, which is basic for the treatment goals, giving conditions to the Stomatognathic System repair its physiological capacity and reach equilibrium between form-function binomials, independently of the patient's age.

Table 01. RMS (μV) values before and after installation of the appliance SN6, in mandibular rest position and in maximal intercupidation position (maximal mandibular elevation).

	Rest Position		Maximal Interscupidation	
Muscles	Before	After	Before	After
Rigth Temporalis	19,4	4,4	65,6	52,8
Rigth Masseter	32,0	14,1	186,6	72,2
Left Temporalis	4,2	3,7	58,8	23,8
Left Masseter	3,1	2,8	96,2	98,8

233 - Electromyographic Evaluation of Balance Function in Wearers of Complete Dentures

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Introduction: Edentulous subjects even those with well-adapted dentures are considered as oral invalids with reduced capacity in various functions of the stomatognathic system. To compensating for the loss of natural teeth with denture, the mechanical aspects of occlusion can be only partially restored. Balanced occlusion is an important factor associated with stability of complete dentures and the relationship between occlusion and behaviour of masticatory muscle already was described. Bilateral contacts during eccentric movements are well known and accepted technique. The lack of easily mensurable objective physiological activity parameters of the masseter and temporalis muscle during jaw movements in humans has led to the consideration to revise data of surface electromyographies (EMGs) by applying a computerized quantification method.

Objective: The aim of this study was evaluate the activity electromyography in wearers of double complete dentures adjusted to obtain balance in the eccentric movements.

Methods: Ten volunteers were selected, 3 men and 7 women, free from signs and symptoms of DTM with average age 64,7 years, for which total dentures were made and through the establishment of contacts interferentes during the accomplishment of the eccentric movements functional balance was provided. Electromyographic signals were recorded utilizing the Myosystem I equipment from Prosecon Ltda, with a sampling frequency of 2KHz and 12-bit resolution, using a digital filter with a bandpass of 20 to 500Hz. Simple differential active surface electrodes (pure silver by Lynx Tecnologia Eletrônica Ltda) with a gain of 100 times. The evaluations electromyography were accomplished in the dentures installation and with one month of use, planning realize more two evaluations, one with two and other with three months after the installation. The evaluations were accomplished at the moment of dentures instalation (T0) and one month after instalation (T1) throught of the electrical activity meansurament in the muscles masseter (RM and LM) and temporalis anterior (RT and LT) in the rest position and forced maximum closing. For each position were accomplish three evaluations with a time of collection of five seconds in each one.

Results: The partial results (RMS) showed that the medium activity of the muscles was decresead at the rest position for LM (9.37 ± 10.7 to 7.1 ± 3.1), LT (9.04 ± 4.91 to 7.6 ± 2.5) e RT (9 ± 5.37 to 7.4 ± 2.6) after one month of installation with exception of the RM (7.49 ± 6.34 to 7.68 ± 4.17) and in the maximum closing in the same period the activity of the both muscles masseter incresed RM (48.48 ± 34.05 to 55.34 ± 31.17), LM (42.6 ± 31.3 to 55.76 ± 29.76) and both temporalis decresed, for RT (63.5 ± 58.9 to 43.6 ± 33.3) and LT (40 ± 27 to 35.28 ± 17). The results partial not permit any significant conclusion yet.

235 - Study of Electromyographic Signs of the Masseter Muscle in Sleep Bruxism after Use of an Occlusal Splint

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Introduction: The electromyographic (EMG) signal has been used broadly as an auxiliary method in the diagnosis and evaluation of the muscles of mastication in rest and also during the accomplishment of compression in several levels, mainly during the sleep. A review of the literature shows the existence of a correlation among the electromyographic activity of the masseter muscles in patients with dysfunction, such as bruxism. The purpose of this study was to examine the effect of an occlusal splint on masticatory muscle activity in sleep bruxism subjects. Sleep Bruxism is usually recognized as a parafunction and can be defined as unconscious activities of the masticatory system that is non-functional and physiological.

Methodology: Ten sleep bruxism subjects (mean age 25 ± 5 years) participated in this study. The Electromyographic (EMG) activity of the masseter muscle was recorded before and after use of an occlusal splint in the end of the work day. The signals were captured by an electromyographic system composed of bipolar surface electrodes with pré-amplification of 20 times, amplifier with gain of 1000, filters with band of frequency 20 to 1000 Hz, common mode rejection of 120 dB, a 12 bit A/D converter and sampling frequency of 2000 Hz. The electrodes were positioned bilaterally on the masseter muscles. The EMG signal procedures followed the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK). The signal was full-wave rectified, band-passed through a Butterworth of 4th order, lowpass filtered at a frequency of 5Hz, normalized in the base of time and of the width, and the width was normalized by the average. The variability of the intensity of the EMG signalwas calculated through the variability coefficient (CV). The comparison among the signs of EMG of the different studied muscles was made through the test-t for parallel samples, and the level of adopted significance was set at 0,05.

Results: In both muscles the maximal EMG activity decreased significantly by wearing the appliance using the splint during the night when compared with muscle activity levels in the end of day.

Conclusion: These findings suggest that nocturnal masticatory muscle activity is significantly reduce by wearing an occlusal splint and that the use of such an appliance at night could help to relax masticatory muscle.

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244 - Electromyography Study of Sternocleidomastoid Muscle Co-Activation Pattern in Different Jaw Movements.

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Although the co-activation of the cervical muscles during the movement of the jaw has been studied in literature, this verification is still less studied when healthy subjects and patients with muscular dysfunction are compared. The aim of this study was verify by surface electromyography the bilateral co-activation of the sternocleidomastoid (SCM) muscle, regarding to chewing muscles in healthy and bruxism volunteers. To record myoelectric signs, it was used a 16 channel signal conditioner with 12 bits dynamic band resolution, Butterworth-type band pass filter (10,6-509 Hz) with gain of 100 times, and A/D converter board, placed inside of an Electrostatic Cage of Faraday. The myoelectric signs were displayed through Aqdados software, and showed simultaneous presentation of the used channels with frequency of sampling of 1000 Hz. The electrodes impedance of input was of 10G, 130 dB of CMRR and 2pF, with 100 times of gain. The data had been evaluated statistically by ANOVA-repeated measures and impaired T tests, on accordance with the studied situation. The results had evidenced the presence of SCM co-activation in both groups and the analysis of RMS average values by chewing muscles showed significant statistical differences between groups referring muscles, sides and situations analysed. In healthy volunteers, the SCM co-activation was significantly fewer during chewing that in clenching, while that in bruxism subjects, these differences had not been verified. During clenching, a reduction of SCM co-activation referred as temporalis anterior muscle was verified; besides the reduction of masseter muscle with an increase of temporalis anterior muscle activation was observed in bruxism subjects. Comparing the values of SCM activation on jaw movements with its maximal isometric contractions, was verified a significant reduction of muscular activity in right side on bruxism subjects. The results of this research had allowed concluding that the SCM co-activation during the jaw movements was verified in humans and that this seems to suffer influences from the neuromuscular alterations by bruxism.

255 - Electromyographic evaluation of Masticatory Muscles Before and after Functional Orthopedics of Maxillary Associated with Orthodontics Therapy in a Patient with Absence of the Coronoid Process - Clinical Case Report

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Introduction: It's widely spreaded that the muscular mandible processes, such as the angular and coronoid processes depend on the function of their muscles of insertion for the maintenance of their format and structure. The anatomical-functional importance of the coronoid process is justified for the insertion of the temporalis muscle in its border and medial face, having clinical importance due to its obscure etiology and the impact on the orthodontics treatment. With the intention of evaluate the electrical activity of the chewing muscles before and after the beginning of the therapy with Functional Orthopedics of Maxillary (BIONATOR) during six months followed by Orthodontics in the Tweed Merrifield technique, we were able to relate a clinical case with absence of the coronoid process on the left side, female, 15 years-old. The patient showed Class I malocclusionI with significant deviation to the left side, significant facial asymmetry, brachyfacial and without any painful symptoms.

Methods: Electromyographic exams were taken of the Masseter muscle and anterior portion of the Temporalis, bilaterally, in the situation of mandible repose, bilateral chewing and maximum intercuspation, before (Pre) and after a month (Post) and also 1 year (Post 2) after the beginning of the treatment. Simple differential active surface electrodes were utilized (Lynx Tecnologia Eletrônica Ltda.), pure silver (Ag) and a gain of 100 times. Electromyography signals were recorded utilizing the Myosystem I® equipment from Prosecon Ltda, sampling frequency of 2KHz and 12-bit resolution, digital filter with a band pass of 20 to 500Hz.

Results: The analysis of the values of RMS of the electromyography signals suggests a decrease of the hiperactivity of the Masseter and Temporalis muscles, either in the situation of isometric contraction of maximum elevation of the mandible or during bilateral chewing, exception to the right Masseter muscle, which values of RMS increased because of the better occlusion relationship in this side, probably. Clinically, after 12 months, we could notice a better maxilo-mandibular relationship as well as the soft tissues around, implying in more favorable esthetics.

Conclusion: It can be concluded that the treatment done by the Functional Dentofacial Orthopedics followed by the orthodontics correction could produce a relaxation of the hyperactive musculature. Those alterations in the electrical activities of the chewing muscles are important for a good performance during the treatment, as well as give conditions for the craniofacial system perform properly.

261 - Electromyographical Analysis of the Masseter Muscle In Dentulous and Partially Toothless Patients with Temporomandibular Joint Disorders

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Stomatognathic system muscles perform an important function concerning mastication, deglutition, facial expression, posture, phonation, and breathing. These phenomena are essential to maintain the body as a whole. Some of the great concerns of dentistry nowadays are the functional disorders that affect the stomatognathic system, including the muscles spasms that accompany pain and the abnormal and pathologic conditions which are caused by physical stress and primary alterations of the muscles and temporomandibular joints (TMJ). This study had as objective to analyze with computerized electromyography the masseter muscles bilaterally in twenty individuals with temporomandibular joint dysfunction (DTM), being: the group I consisting of ten individuals with complete dentition and group II constituted by ten individuals with posterior dental absences; comparing nine clinical activities: rest before and after exercises, maximum habitual intercuspation (MIH), right and left laterality, forced centric occlusion, protrusion, bilateral molar bite and chewing. It was utilized the Electromyography K6I-Myotronics, with eight canals and surface silver electrodes. By means of the results analysis, we verified significant differences between the groups ($p<0.01$), being group I, presented greater electromyographic activity (32.98 microvolts), than the group II (22.31microvolts), suggesting that this individuals presented low muscular activity. The interaction between the groups and the clinical activities was significant ($p<0.01$), as well as between the groups, clinical activities and muscles ($p<0.05$). To clarify which amongst the relative averages the clinical activities were different, calculated the critical value of Tukey, being that rest before and after exercises, MIH, right and left laterality, presented averages with similar distributions, with values below of the values of Tukey, as well as forced centric occlusion, protrusion, bilateral molar bite and chewing presented higher values than Tukey. Based on this research's data, we concluded that the electromyographical analysis of the masseter muscles in Individuals with TMD, dentulous and with dental absence showed that individuals with TMD, dentulous or not, presented elevated muscular activity in rest position and individuals with TMD, dentulous, presented higher electromyographical activity than the individuals with TMD and lacking posterior teeth.

278 - EMG Analysis of the Orbicular Oris Muscle, In Edentulous Patients, Before and After Complete Denture Implantation

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Introduction: The orbicular oris muscle, including its upper and lower fascicles, the alveolar processes and dental arches, constitute a complex functional system, located in the lower third of the face, which is very important for the clinical determination of the occlusal vertical dimension. Any alteration of this system, as in the case of edentulous patients, might produce esthetic problems and alterations in the muscular tonicity.

Methods: This study was aimed to evaluate the electromyographic behavior of that musculature in patients while pronouncing the syllables PAH, BAH, MAH, SAH, FAH, VAH, MEE, and the word MISSISSIPPI. Edentulous patients were submitted to electromyographic tests under two clinical conditions: before and after the implantation of complete dentures. A K6-I EMG Light Channel Surface Electromyograph was utilized (Myo-tronics Co. Seattle, WA, USA).

Results and Discussion: The Analysis of Variance, with 3 sources of variation (Syllables, Muscles and Clinical Conditions) and 12 repetitions, indicated statistically significant differences in the pronunciation of the different syllables. For the Muscles factor, the analysis revealed higher electromyographic readings in the lower fascicle of the orbicular oris muscle, as compared with those of the upper fascicle. The comparison among the Clinical Conditions indicated higher electromyographic values for the edentulous condition (i.e., before complete denture implantation), as compared to those recorded after denture implantation.

291 - Kinesiologic Analysis of Tempromandibular Joint in Pregnant Women

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Introduction: The objective of this study was to realize the kinesiologic analysis of Temporomandibular Joint (TMJ) and the stomatognathic system in pregnant women and list the influence of changes in pregnancy on the TMJ.

SUBJECTS: 22 pregnant women were studied and divided into first, second, third quarter and those who had baby until three mouths.

RESULTS: We observed the dynamics of the mandible movements and the major amplitudes had been found in the third quarter. In the same group there was noted a systematic hypermobility and signs of Temporomandibular Disorders, including muscular pain and joint symptoms (deflections (45,45%), deviations (18,18%), opening or closed clicking (50%)). We also observed postural alterations in the cervical area, which could be responsible for the presence of symptoms in the other quarters. Parafunctions also had been checked in all groups.

CONCLUSION: The hypermobility joint, postural alteration and other modifications can influence the biomechanics of the joint and provoke Temporomandibular Dysfunction in pregnant women and other personss who have similar disturbances.

374 - Study of Postural Pattern and Muscular Activity in Temporo-Mandibular Disordered Patients: Biophotogrametric and Eletromyographic Analysis

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Introduction: The purpose of this study was to study the body posture and the muscle electrical activity of chewing and cervical muscles in temporo-mandibular disordered patients (TMD).

Methods: Thirty seven volunteers , from both sexes, with 20 - 54 years old were evaluated, with an electromyographic exam (EMG) of the masseter, anterior temporalis, sternocleidomastoid and upper trapezius muscles, bilaterally. All muscles were monitored at rest an during maximal voluntary contraction (MVC). The EMG activity was also evaluated during chewing function for masseter and anterior temporalis muscles. The postural evaluation was accomplished with computerized photos and analyzed in a software (Alcimage).The study group was consisted of twenty two subjects with TMD and the control group was consisted of fifteen subjects. The EMG was accomplished with Myosystem Br-1 equipment with 12 bites , amplified with gain of 5000, sampled at 2000 Hz, bandwidth of 10-1000Hz.The sEMG amplitude processing used was the Root Mean Square (RMS) measured in μV.

Results: For analysis of the obtained results the t Student statistical test was used. The results showed no significant differences among groups in all situations, but it was observed higher values in the anterior temporalis muscles then in the masseter for both groups. The digitalized photos showed angles (mentum/acromium/ear) of $57,77^0$ and $53,73^0$ for study and control group, respectively, which demonstrates head posture forward in DTM patients, with statistical significant difference.

Conclusion: With the similar results of both groups, it can be concluded that the control group also showed alterations in the EMG pattern and head posture, not caused by DTM.

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455 - Electromyographic Analysis of the Mouth's Orbicular Muscle in Individuals with Bucal Respiratory Patterns.

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Introduction: Bucal respiration is believed to bring serious effects in cranio-facial development and occlusion, when there is no correlation among the internal and external forces of bucal musculature. This way, for a precocious diagnosis and the formulation of a suitable treatment plan it is fundamental to know whether the individuals' peribucal musculature has suffered ambient influences, to the point of altering its physiology. This electromyographic study's purpose was to compare the medial superior region of mouth's orbicular muscle in two groups : G1 (predominantly nasal respiratory pattern) e G2 (predominantly bucal respiratory pattern).

Methods: 50 Brazilian children from 6 to 9 years old were evaluated, 25 boys and 25 girls with Angle's Class II division 1 malocclusion. Signals were acquired by an electromyograph composed of bipolar surface electrodes with 20 times pre-amplification, amplifier with 1000 times gain, 20 to 1000 Hz band pass filters, commom mode rejection of 120 dB, 12 bits A/D converter and 2000 Hz sampling frequency. The electrodes were placed bilaterally over the mouth's orbicular muscle. All applicable recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures. Signal handling consisted in full wave rectification, linear envelope through 4th order Butterworth filter, with 5 Hz cut off frequency, normalized in time base and amplitude, this one through average value. EMG signal's intensity variability was calculated through the variability coefficient (VC). The comparison between the EMG signals from the various muscles was made with the t-test , with significance level of 0.05.

Results: Variations of around 20% were found among samples during the pronunciation of letters A and F, not found at rest.

Conclusion: Other new observations to confirm these findings should be performed, specially with older children, to detect the time frame in which occurs a differentiation (the time frame in which, for instance, the bucal habits are installed, and the time frame in which ortodontists or phono must interfere), resulting in labial incompetence. The deep knowledge of muscular dynamics gives the basis to the correct terapy. In this context, electromyography becomes a vast exploration field, with valuable contributions not only to Ortodonty, but also to Physioteraphy and Phonoaudiology.

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456 - Evaluation of Electromyographic Activities of Masseter and Temporal Muscles, Before and After the Use of Palatal Device in Individuals with Temporomandibular Dysfunction

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Introduction: Electromyography (EMG) has been widely used as a method to help in the diagnosis of temporomandibular disfunctions (TMD) and to evaluate the functional behavior of mastication muscles at idle state and during jobs' execution, as mastication or tightening in some levels. The literature review shows the existence of a correlation between the electromyographic activity of anterior masseter and temporal muscles and the occlusion in patients with TMD. This study's objective was to evaluate the changes in electromyographic activity of anterior masseter and temporal muscles, before and after seven days of utilization of a modified Hawley device, linking these alterations with TMD's signs and symptoms and this way to verify the clinical effectiveness of this device.

Methods: Twenty female patients**,** 25 $\pm$ 5 years old, showing spontaneous pain in the region of mastication muscles or in temporomandibular articulation(TMA). Modified Hawley device: A palatal device made with acrylic resin, with circular holders adapted to the last teeth present in the superior arc and a vestibular front in the lip's portion of the anterior teeth with an anterior platform, for the contact in centric relationship with the antero-inferior teeth. Patient's electromyographic measurements were made at rest and at maximum voluntary contraction. Signals were acquired by an electromyographic system composed of bipolar surface electrodes with 20 times pre-amplification, amplifier with 1000 times gain, 20 to 1000 Hz band pass filters, commom mode rejection of 120 dB, 12 bits A/D converter and 2000 Hz sampling frequency. The electrodes were bilaterally placed over the anterior masseter and temporal muscles. All applicable recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures. Signal handling consisted of full wave rectification, linear envelope through 4th order Butterworth filter, with 5 Hz frequency of cut, normalized in time base and amplitude, this one through average value. EMG signal's intensity variability was calculated through the variability coefficient (VC). The comparison between the EMG signals from the various muscles was made with the t-test , with significance level of 0.05.

Results: The electromyographic signals before and after the seven day period showed a tendency for increase in the muscular activity, at rest as well as at maximum contraction, without statistically significant differences. Clinical evaluation showed an improvement in the patients' symptoms after the palatal device's use.

Conclusion: The above results suggest that the palatal device's use can bring improvements for patients with temporomandibular dysfunction, being necessary to increase the number of observations and follow up time in each case.

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474 - Orofacial Contraction Does Not Affect Neck Muscle Activity In A Clinical Test

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Introduction: Contraction of the orofacial muscles is often instructed to enhance clinical exercise for temporomandibular joint pain, yet evidence to support such a practice is very limited. The purpose of this study was to determine the effect of orofacial muscle contraction on neck muscle activity during an endurance and reaction test for the head and neck.

Methods: Five women and one man (age = 29.6yr., S.D. = 7.8; height = 1.74m, S.D. = 0.04; mass = 60.2kg, S.D. = 6.84) were recruited from the university population. All subjects were healthy with no history of temporomandibular joint pathology. Subjects laid supine and held their heads isometrically in anatomic neutral slightly off of the support surface while SEMG of the suprahyoid (digastric), masseter, sternocleidomastoid (sternal head), suboccipital, and upper trapezius muscles was measured. Three conditions were randomly assigned: no orofacial activity (NO), light orofacial activity which involved placing the tongue on the roof of the mouth, keeping teeth apart, and lips together (LO), and forceful orofacial activity which involved pressing the tongue into the roof of the mouth, keeping teeth apart, and pursing the lips (FO). Three trials, each of 15s, were collected for each condition. EMG was A/D converted at 12 bit resolution at 1024Hz. Signals were full wave rectified and low pass filtered (single pass Butterworth) at 2.5 Hz, and then normalized to maximum activity recorded from isometric MVC trials taken in the test position. Differences in average normalized activity (nEMG) between conditions for each muscle was assessed using a one-way ANOVA with Bonferroni correction ($\alpha = 0.01$).

Results: Level of orofacial activity did not have a significant effect on average muscle activity in the test position (F= 0.0076 to 0.4823, Fcrit= 6.359). On observation of the results graphically, many subjects exhibited significant left-right differences in EMG activity, especially for digastrics (mean = 24.4% nEMG; SD = 21.1) and sternocleidomastoid muscles (mean = 11.3% nEMG; SD = 10.9). The absolute differences in nEMG between left and right muscles for each trial were then analyzed to determine if any asymmetries changed with contraction of the orofacial musculature. A one-way ANOVA with Bonferroni correction ($\alpha = 0.01$) did not reveal any differences in asymmetrical muscle activity present in each condition (F=0.0005 to 0.3967, Fcrit = 6.359).

Discussion: We found that contraction of the orofacial muscles does not alter neck muscle activity, at least in this clinical test. The digastric muscles had the highest level of contraction for an endurance and reaction test for the neck. This may highlight the digastric muscle as a potentially important muscle for clinical consideration in neck problems. Additional research on specific training for the orofacial muscles should be investigated.

498 - Evaluation Of Masticatory Muscles In Deaf Subjects During Mastication

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Introduction: In deaf subjects inadequate use of the masticatory muscles during phonation could lead to alterations in electromyographic (EMG) activity of those muscles however they were not found studies that have been verified such possible alterations. The purpose of this work was to evaluate the EMG activity and the variability of EMG sign of the right and left temporalis muscle (RT and LT) and right and left masseter muscle (RM and LM) during mastication activity in deaf subjects compared to a non-deaf control group.

Methods: Participated in this study 32 subjects, 16 deaf (DG) and 16 controls (CG) pared according to age (DG: 18,87 ± 7,2 years and GC: 20,94 ± 8,7 years), sex (5 men and 11 women), height (DG: 1,57 ± 0,09m and CG: 1,62 ± 0,1 m) and weigh (DG: 51,47 ± 9,4Kg and CG: 57,41 ± 11,2 Kg). The deaf subjects considered were not mute and adept to LIBRAS (Brazilian Language of Signs). EMG activity of RT, LT, RM, LM was evaluated during two situations: non-habitual bilateral chewing (NHBC) and during maximum dental clenching (MIVC) using differential electrodes (silver bars 10mm apart, 10mm long, 2mm wide, 20x gain, input impedance 10GΩ and 130dB CMRR). The EMG signal was analogically amplified with gain of 200x, filtered and sampled by 12 bits A/D convert board with a 2KHz frequency. The volunteers performed two masticatory registrations during 5 seconds at 1Hz of masticatory frequency, considering a resting period of 2 minutes between each cycle and 2 seconds of MIVC. In total time of registration 3 cycles were considered (windows of 250ms) initial, medium and final for analysis of Root Mean Square (RMS) and Median Frequency (MF) variability of EMG sign inter and intragroups. In the same way, medium values of RMS and MF among three windows of masticatory cycles were normalized by the values of MIVC and considered for statistical analysis. This study was approved by the Committee of Ethics in research from Faculty of Odontology of Ribeirão Preto-USP.

Results: Comparing the medium values among the three windows of masticatory cycles from two collected registrations it was not observed differences for RMS and MF normalized values in DG and CG (Friedman ANOVA, $p \leq 0.05$). Significant differences in RMS and MF mean values among three cycles in two registrations were not observed (t-test, $p \leq 0.05$), however larger variability was observed for RMS mean values in DG (F- test, $p \leq 0.05$) for LM ($p=0.002$), RM ($p=0.002$), RT ($p=0.003$) and for MF mean values of RM ($p=0.005$). In intergroup comparisons of normalized mean values of RMS and MF from each window of masticatory cycle, it was observed that RMS values of LM during initial phase of masticatory cycle showed significant reduced in DG in relation to CG (test-t, p=2.15275-E), and also MF values of LT during initial cycle ($p=0.04$) and MF values of RT during initial and medium cycles ($p=0.008$) according to t-test.

Conclusions: Analysis of the data demonstrated there were not differences in EMG activity of the masticatory muscles when considering the cycles along a registration period, however, the variability between groups of RMS and MF values showed larger in the deaf than in control subjects, mainly for masseter muscle, suggesting that intergroup differences should take in account intragroup variability of EMG sign. Intergroup comparisons of the windows of each masticatory cycle it could be verified differences in RMS and MF values during initial and medium cycles of registrations suggesting differences in EMG activity that could be inconsiderate when an analysis of mean values of masticatory cycles were considered during a registration period. The results suggest possible alterations in deaf masticatory muscles when compared to non-deaf controls.

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