6th CONGRESS of ISEK
第6回 国際電気生理動作学会

PROGRAM & ABSTRACTS

Chairman
Tadaatsu Ito, M.D.
(Professor Emeritus, Nippon Medical School)

Supported by
Science Council of Japan
Ministry of Education, Science & Culture
Ministry of Health & Welfare

会 長
伊　藤　忠　厚
（日本医科大学名誉教授）

後 援
日本学術会議
文　部　省
厚　生　省

Greetings —ご挨拶

Tadaatsu Ito

Chairman, 6th Congress of ISEK
Professor Emeritus, Nippon Medical School

We are greatly honored to be hosting the 6th Congress of the International Society of Electrophysiological Kinesiology here in Tokyo.

This Congress has never been held in Asia before. Thus when we consider the importance of and possibilities for the development of research in this field, we can say that Tokyo's selection as the site of the 6th Congress is extremely significant.

Fortunately, we've received a number of excellent papers, and we have prepared hard to insure that this 4-day meeting may produces fruitful results. Since the Congress is held only once every 3 years, I hope that study reports will be fully discussed on this occasion. I believe that active participation and mutual understanding among members will lead to further development of these studies.

Finally but not the least importantly, I would like to extend my hearty welcome to the overseas participants who came all this way despite busy schedules. I hope that you will enjoy your stay in Japan.

Message —メッセージ

G.B.J. Andersson

President, ISEK
Professor, Orthopaedic Surgery
Rush Presbyterian St. Lukes Medical Center

Welcome to the 6th Congress of the International Society of Electrophysiological Kinesiology in Tokyo, Japan. We are here to enjoy, in the tradition of ISEK, scientific exchange of research and ideas, and the company of fellow members and guests.

The organizing committee, Congress Chairman Tadaatsu Ito, Secretary General Yasumasa Shirai, and their collegues Naoichi Tsuyama, Shiro Kondo, Takahide Kurokawa, Mitsuo Hasue, and Yukinori Tomoda, have done an outstanding job. We will enjoy more than 50 scientific presentations of high standard, and a social program promising to be the most exciting in ISEK history.

Our field of research has grown, attracting increasing and widespread attention. Through international congresses we can exchange and cultivate our efforts across borders and between disciplines. This first International Congress of ISEK in the far east is an important step in that direction. The organizing committee have done everything possible to set the stage. The success now depends on your interest, enthusiasm and participation.

Members of the Organizing Committee

Yoshihiko Akahoshi
Tetsuhiko Asakura
Hirohiko Azuma
Naoichi Chino
Mitsuru Ebe
Tatsuo Hashimoto
Mitsuo Hasue
Yasuhiro Hatsuyama
Susumu Hattori
Koichiro Hayashi
Hiroshi Hori
Takashi Hoshino
Tadasi Igari
Takaaki Ikata
Shunichi Inoue
Tetsuo Inoue
Masahiko Ioku
Tadaatsu Ito
Hiromoto Ito
Hiromitsu Iwakura
Ichiro Kato
Shiro Kondo
Tomihisa Koshino
Yoshigoro Kuroiwa
Takahide Kurokawa
Shigeo Matsuno
Hideo Miura
Yukio Miura
Masuta Mori
Chikami Morisada
Mitsuo Motegi
Kagehisa Murota
Shun Nakagawa
Ryuichi Nakamura
Kengo Nakano
Shigeo Niwa
Toshiharu Norimatsu
Morihiko Okada
Yoshio Ooi
Takashi Sako
Seiji Sano
Kinya Sato
Kanji Shichikawa
Akira Shimazu
Yasumasa Shirai
Hisao Shirasu
Masanobu Sugawara
Katsumi Suzuki
Ryohei Suzuki
Naoya Tajima
Tatsuya Tajima
Haruo Takazawa
Yoshiharu Takemitsu
Kouji Takeuchi
Gozo Tanabe
Kazuo Terayama
Yukinori Tomoda
Haruo Tsuji
Naoichi Tsuyama
Eiichi Udagawa
Kaneo Yamaji
Hiroshi Yamamoto
Takao Yamamuro
Yasuaki Yamazaki
Hideo Yano
Kyozo Yonemoto
Makoto Watanabe
Ryo Watanabe

by Alphabetical order

Members of Exective Committee

Congress Chairman:	Tadaatsu Ito (Professor Emeritus, Nippon Medical School)
Vice-Congress Chairman:	Naoichi Tsuyama (Professor Emeritus, Univ. of Tokyo)
	Shiro Kondo (Professor Emeritus, Kyoto Univ.)
Secretary General:	Yasumasa Shirai (Professor, Nippon Medical School)
Chairman of Scientific Program:	Takahide Kurokawa (Professor, Univ. of Tokyo)
Member:	Naoichi Chino (Instructor, Keio Univ.)
	Hideo Yano (Instructor, Univ. of Tokyo)
	Hiromoto Ito (Instructor, Nippon Medical School)
Chairman of Finance:	Mitsuo Hasue (Director, Japanese Red Cross Medical Center)
Member:	Hiromitsu Iwakura (Professor, Teikyo Univ.)
	Yoshio Ōi (Professor, Jichi Medical School)
	Seiji Sano (Professor, Nihon Univ.)
	Haruo Takazawa (Director, Yokohama Municipal Port and Harbor Hospital)
	Shun Nakagawa (Assistant Professor, Nippon Medical School)
	Yasuhiro Hatsuyama (Director, National Rehabilitation Center for the Disabled)
	Koichiro Hayashi (Assistant Professor, the Univ. of Tsukuba)
	Kyozo Yonemoto (Assistant Professor, the Jikei Univ. School of Medicine)
Chairman of Hall Arrangement:	Yukinori Tomoda (Professor, the Univ. of Tsukuba)
Member:	Tatsuo Hashimoto (Assistant Professor, Nippon Medical School)
	Makoto Watanabe (Assistant Professor, Nippon Medical School)

実行委員会名簿

会長：	伊藤忠厚	(日本医科大学名誉教授)
副会長：	津山直一	(東京大学名誉教授)
	近藤四郎	(京都大学名誉教授)
事務局長：	白井康正	(日本医科大学教授)
学術委員長：	黒川高秀	(東京大学教授)
委員：	千野直一	(慶応義塾大学講師)
	矢野英雄	(東京大学講師)
	伊藤博元	(日本医科大学講師)
財務・募金委員長：	蓮江光男	(日本赤十字社医療センター部長)
委員：	岩倉博光	(帝京大学教授)
	大井淑雄	(自治医科大学教授)
	佐野精司	(日本大学教授)
	高沢晴夫	(横浜市立港湾病院部長)
	中川俊	(日本医科大学助教授)
	初山泰弘	(国立身体障害リハビリセンター研究所所長)
	林浩一郎	(筑波大学助教授)
	米本恭三	(東京慈恵会医科大学助教授)
会場運営委員長：	鞆田幸徳	(筑波大学教授)
委員：	橋本龍夫	(日本医科大学助教授)
	渡辺誠	(日本医科大学助教授)

INFORMATION FOR PARTICIPANTS

1. To all participants:

①	Advance registrants:	Please pick up your name plate and book of abstracts at the Registration desk.
②	New registrants:	Please pay the 45,000 yen registration fee.
	Registration Desk:	Aug. 26 (Mon) from 1:00 p.m./Aug. 27, 28, and 29 during the Congress (Desk will be set up in front of the Press Center Hall.)

2. To all speakers:

① 15minutes for Presentations, 5minutes for discussion

② Slides (only one screen to be used):

● number	—no more than 20 —speaker to cue the projectionist
● size	—standard 35 mm mount (50×50mm)
● markings	—please mark each slide with a direction arrow and presentation order number.
● submit slides	—at least one hour before your presentation (for those giving their presentation at 9:00 a.m., please submit your slides to the Slide Reception Desk by 8:40 a.m.)
● pick up slides	—at the end of the sessions, slides will be returned to the Slide Reception Desk.

参加者へのお知らせ

1. 参加の方へ

① 既登録者：受付にて参加章および予稿集をお受取り下さい。

② 未登録者：参加費45,000円をお支払い下さい。

（受付）　8月26日(月)は午後1時より、27日・28日29日は学会中プレスセンターホール前に設置いたします。

2. 一般演題発表の方へ

① 発表時間は15分です。ディスカッション時間は5分です。

② スライド（1面のみ使用）

●枚数……20枚以内（スライド原稿不要、演者合図）
日本語で発表の方は、内容の英文をサイドスライドで流しますのでご用意下さい。(スライド原稿必要)

●大きさ……35㎜標準マウント（50㎜×50㎜）

●記入事項……マウント方向を示す矢印、通し番号を記入して下さい。英文のサイドスライドは番号を付し、スライド原稿と合せて下さい。

●提出……発表時間の1時間前までに（午前9時発表の方は当日午前8時40分までに）スライド受付に提出して下さい。

●返却……発表終了後、スライド受付にてお返しいたします。

GENERAL INFORMATION

1. Opening Ceremony

Date: August 26 (Mon)
Time: 16:00～

Opening Declaration:	Naoichi Tsuyama Vice Chairmsn, 6th Congress of ISEK
Opening Remarks:	Tadaatsu Ito Chairman, 6th Congress of ISEK
Address:	G.B.J. Andersson (Rush Presbyterian St. Lukes Medical Center) President, ISEK
Cougratulatory Address:	Hikaru Matsunaga Minister of, Education, Science and Culture
	Hiroyuki Masuoka Minister of Health and Welfare
	Jiro Kondo President, Science Council of Japan
Closing:	Shiro Kondo Vice Chairman, 6th Congress of ISEK
Special Lecture:	Naoichi Tsuyama Prof. Emeritsu, Univ. of Tokyo Topic: "Some reflections of my study of EMG" Moderator: Tadaatsu Ito, Chairman

2. Welcoming Party

Time: After the Opening Ceremony
Place: Restaurant "ALASKA"

3. Banquet

Date: August 28 (Wed)
Time: 18:00～
Place: Chinzan-so "Kaizan-do"
Address 2-10-8 Sekiguchi, Bunkyo-ku, Tokyo
Phone: 03-943-1101

※Buses will depart from the Nippon Press Center Bldg, at 17:00.

大会ならびに関連行事

1. 開 会 式

日時：8月26日(月) 午後4時～

開会の辞	副会長	津 山 直 一	(東京大学名誉教授)
挨　拶	会 長	伊 藤 忠 厚	(日本医科大学名誉教授)
	理事長	G. B. J. Andersson	
	(Professor, Rush Presbyterian St. Lukes Medical Center)		
祝　辞	文部大臣	松 永 光	
	厚生大臣	増 岡 博 之	
	日本学術会議会長	近 藤 次 郎	
閉会の辞	副会長	近 藤 四 郎	(京都大学名誉教授)
〈特別講演〉		津 山 直 一	(東京大学名誉教授)
	演 題：「Some reflections on my study of EMG」		
	座 長：会 長	伊 藤 忠 厚	

2. ウェルカミング・パーティー

日時：8月26日(月) 開会式終了後

場所：レストラン・アラスカ (日本プレスセンタービル10階)

3. バンケット

日時：8月28日(水) 午後6時～

場所：椿山荘「開山堂」

東京都文京区関口2－10－8　電話 03－943－1101

※8月28日午後5時頃、プレスセンター前より専用バスが出ます。

SCIENTIFIC PROGRAM

学術プログラム

CONGRESS SCHEDULE

Time \ Date	August 26 (Monday)	August 27 (Tuesday)	August 28 (Wednesday)	August 29 (Thursday)
9:00		00 S-1 Motor Control (I)	00 S-5 Analytical Methods	00 S-9 Clinical (I)
10:00		00 Break 15 S-2 Motor Control (II)	40 Break 55 S-6 Neurophysiology (I)	40 Break 55 S-10 Clinical (II)
11:00		35 Lunch		
12:00			35 Lunch	35 Lunch
13:00	Registration	30 S-3 Locomotion (I)	30 S-7 Neurophysiology (II)	30 S-11 Clinical (III)
14:00			50 Break	
15:00		10 Break 25 S-4 Locomotion (II)	05 S-8 Methodology	10 Break 25 S-12 Posture
16:00	Opening Ceremony (Special Lecture)	45	45	
17:00				05
18:00	Welcoming Party		00 Banquet	
19:00				
20:00			00	
21:00				
22:00				

8/27
(TUESDAY)

A.M.

S—1 (9:00～10:00) MOTOR CONTROL(Ⅰ)

Moderators:
P. Pinelli(Italy)
R. Nakamura(Japan)

<S—1—1> **THE LEFT-TO-RIGHT DIFFERENCE IN REACTION TIMES WITH ANKLE JOINT MOVEMENTS**

Y. Kamada[1] and T. Kinugasa
1.Dept. of Physical Education, Iwate University (Japan)
2.Inst. of Health and Sport Science, University of Tsukuba (Japan)

<S—1—2> **SPINAL PLASTICITY IN MOTOR CONTROL DISORDERS. THE RESTORATIVE EFFECTS OF POSITIONAL FEEDBACK STIMULATION TRAINING (PFST).**

P. Pinelli[1], and A. Villani[2]
1.Ist. Neurological Clinic, University of Milan (Italy)
2.Dept. Neurology, Medical Centre of Rehabilitation, Veruno (NO) (Italy)

<S—1—3> **MOTOR TIME AND ITS COMPONENTS IN PATIENTS WITH CENTRAL NERVOUS SYSTEM (CNS) DISEASES**

I. Tsuji and R. Nakamura
Inst. of Rehabilitation Medicine, Tohoku University School of Medicine (Japan)

● ● ● Coffee Break ● ● ● (10:00～10:15)

S—2 (10:15～11:35) MOTOR CONTROL(Ⅱ)

Moderators:
L. Carriere(Canada)
Y. Ooi(Japan)

<S—2—1> **REACTION TIME OF ELBOW EXTENSION AT DIFFERENT VELOCITIES IN VERTICAL PLANE**

R. Nakamura and T. Kitahara
Inst. of Rehabilitation Medicine, Tohoku University School of Medicine (Japan)

<S—2—2> **THE RELATION OF INTEGRATED EMG OF THE TRICEPS BRACHII TO FORCE IN RAPID ELBOW EXTENSION**

F. Aoki, H. Nagasaki and R. Nakamura
Inst. of Rehabilitation Medicine, Tohoku University School of Medicine (Japan)

<S—2—3> **EFFECT OF PRACTICE IN UNCERTAINTY CONDITIONS ON CONTROL MECHANISMS OF BALLISTIC MOVEMENTS**

L. Carrière and J. P. Boucher
Dept. of Kinanthropologie, Université du Québec à Montréal (Canada)

<S—2—4> **BALLISTIC FOREARM FLEXION PRACTICE EFFECTS UPON SURFACE EMG SIGNAL CHARACTERISTICS**

J. P. Boucher, M. S. Flieger, E. A. Harman and L. Carrière
Dept. of Kinanthropology, Univ. du Québec à Montréal (Canada)

8/27
(TUESDAY)

P.M.

S—3 (13:30～15:10) LOCOMOTION(Ⅰ)

Moderators:
P. Boelens (The Netherlands)
S. Watanabe(Japan)

<S—3—1> **ELECTROMYOGRAPHIC STUDY OF RUNNING IN CHILDREN OF VARIOUS AGES**

N. Kazai[1], Y. Goto[2], A. Tsujino[2], T. Okamoto[3], H. Tsutsumi[3] and H. Maruyama[4]
1.Bukkyo University, Kyoto (Japan)
2.Hyogo University of Teacher Education (Japan)
3.Kansai Medical University (Japan)
4.Seibo Jogakuin Junior College (Japan)

<S—3—2> **NEUROMUSCULAR CONTROL OF FORCE OUTPUT OF ANKLE EXTENSORS DURING STANCE PHASE IN HUMAN RUNNING**

M. Suzuki[1], T. Kinugasa[1], M. Suzuki[1], T. Fujita[1], S. Suzuki[2], K. Kaiya[2] and S. Watanabe
1.Tsukuba University (Japan)
2.Kyorin University (Japan)

<S—3—3> **ELECTROMYOGRAPHIC STUDY ON RUNNING —HOW STEP LENGTH AND STEP FREQUENCY CHANGE—**

Y. Goto[1], A. Tsujino[1], K. Matsushita[1] and T. Okamoto[2]
1.Hyogo University of Teacher Education (Japan)
2.Kansai Medical University (Japan)

<S—3—4> **THE EFFECT OF ANKLE-TAPE ON LOWER LIMB MUSCLE ACTIVITY**

P. Boelens and T. Loos
NIJMEGEN (The Netherlands)

<S—3—5> **DEVELOPMENTAL CHANGES IN MUSCLE ACTIVITY FOR WALKING UP AN INCLINE**

H. Maruyama[1], Y. Goto[2], T. Okamoto[3], H. Tsutsumi[3] and N. Kazai[4]
1.Seibo Jogakuin Junior College (Japan)
2.Hyogo University of Teacher Education (Japan)
3.Kansai Medical University (Japan)
4.Bukkyo University (Japan)

● ● ● Coffee Break ● ● ● (15:10～15:25)

S—4 (15:25～16:45) LOCOMOTION(Ⅱ)

Moderators:
D. Wever (The Netherlands)
H. Yano (Japan)

<S—4—1> **ELECTROMYOGRAPHIC OBSERVATIONS ON THE DEVELOPMENT OF INDEPENDENT WALKING IN INFANTS**

T. Okamoto[1], H. Tsutsumi[1], Y. Goto[2], N. Kazai[3], H. Maruyama[4] and M. Kumamoto[5]
1.Kansai Medical University (Japan)
2.Hyogo University of Teacher Education (Japan)
3.Bukkyo University (Japan)
4.Seibo Jogakuin Junior College (Japan)
5.Kyoto University (Japan)

<S—4—2> **ELECTROMYOGRAPHIC STUDY ON PRIMITIVE AUTOMATIC WALKING AND SUPPORTED VOLUNTARY WALKING IN INFANTS**

Y. Goto[1], H. Oka[1], T. Okamoto[2], H. Tsutsumi[2], N. Kazai[3], H. Maruyama[4], P. D. Andrew[5] and M. Kumamoto[6]
1.Hyogo University Teacher Education (Japan)
2.Kansai Medical University (Japan)
3.Bukkyo University (Japan)
4.Seibo Jogakuin Junior College (Japan)
5.Bobath Hospital
6.Kyoto University (Japan)

<S—4—3> **EVALUATION OF THE EFFECT OF PHENOLISATION BY MEANS OF A QUANTITATIVE FOLLOW UP STUDY**

D. Wever, J. Buurke, H. J. Hermens and G. Zilvold
Rehabilitation Centre het Roessingh (The Netherlands)

<S—4—4> **GAIT ANALYSIS OF POSTOPERATIVE CLUB FOOT**

J. T. Chang[1], M. Fujita[1], T. Norimatsu[1], N. Matsusaka[1], A. Hamamura[2] and R. Suzuki[1]
1.Dept. of Orthopaedic Surgery Nagasaki University School of Medicine, (Japan)
2.National Sanatorium, Nagasaki Hospital (Japan)

8/28 (WEDNESDAY)

A.M.

S—5 (9:00～10:40) ANALYTICAL METHODS

Moderators: M. Solomonow(U.S.A.), K. Maie(Japan)

<S—5—1> **MYOELECTRIC PROFILE OF ELECTRICALLY STIMULATED MUSCLE AND ITS RELATION TO FORCE**

M. Solomonow, R. Baratta, T. Miwa, H. Shoji and R. D'Ambrosia
Dept. of Orthopaedic Surgery, LSU Medical Center (U.S.A)

<S—5—2> **RELATION BETWEEN MUSCULAR FUNCTIONS OF THE QUADRICEPS FEMORIS AND MAXIMUM WALKING CAPACITY**

H. Ito[1], K. Hashizume[1], H. Maruyama[1], H. Saito[1] and R. Nakamura[2]
1.Dept. of Rehabilitation Medicine, Tokyo Metropolitan Inst. of Gerontology (Japan)
2.Inst. of Rehabilitation Medicine, Tohoku University School of Medicine (Japan)

<S—5—3> **FOOT MUSCLE ACTIVITIES AND FOOT MOVEMENT DURING WALKING WITH FOOTWEARS**

K. Maie[1], T. Yamada[2] and S. Kondo[1]
1.Inst. of Human Living Sciences, Otsuma Women's University (Japan)
2.Bridgestone Corporation (Japan)

<S—5—4> **PATHOLOGIC GAIT DIAGNOSIS WITH THE RATIO MEASUREMENT COMPUTER AVERAGE ELECTROMYOGRAPHIC PROFILES**

M. Sugawara
School of Allied medical Science, Hirosaki University (Japan)

<S—5—5> **COMPRESSION OF EMG DATA**

B. Diemont[1], M. F. Maranzana[2] and H. Hermens[1]
1.Het Roessingh Rehabilitation Center (The Netherlands)
2.Centro Teoria Sistemi CNR, Dip. Elettronica, Politecnico (Italy)

●●●Coffee Break●●● (10:40～10:55)

S—6 (10:55～12:35) NEUROPHYSIOLOGY(I)

Moderators: W. Wallinga-de Jonge (The Netherlands), T. Kurokawa(Japan)

<S—6—1> **POSITION AND MOVEMENT DETECTORS IN COMPOSITION OF WRIST JOINT AFFERENTS IN THE CAT**

V.I.Zalkind
Pavlov Institute of Physiology of the Academy of Sciences of the USSR, USSR

<S—6—2> **ELECTRO-MECHANICAL RESPONSES DURING AND FOLLOWING ELECTRICALLY INDUCED MUSCLE CONTRACTION FROM LOW OR HIGH FREQUENCY STIMULUS**

A. Nagata[1] and M. Muro[2]
1.Bio-Dynamics Lab. Niigata University (Japan)
2.Bio-Dynamics Lab. Tokyo College of Pharmacy (Japan)

<S—6—3> **CHARACTERIZATION OF FAST EDL AND SLOW SOLEUS MOTOR UNIT ACTION POTENTIALS**

W. Wallinga-de Jonge[1], B. Albers[1], J. Eeltink[1], A. Lafortl, J. Put[1], W. Rutten[1] and P. Wirtz[2]
1.Biomedical Engineering Division, Twente University of Technology (The Netherlands)
2.Dept.of Cytology and Histology, University of Nijmegen (The Netherlands)

<S—6—4> **THE CHANGES OF EVOKED SPINAL POTENTIALS ON PARTIAL BLOCKING OF SPINAL BLOOD FLOW IN CATS**

M. Kawai, Y. Shirai, S. Kota, T. Takeuchi and T. Shibasaki
Nippon Medical School (Japan)

<S—6—5> **AUGMENTATION OF THE EVOKED SPINAL POTENTIAL CAUSED BY COMPRESSION ON THE SPINAL CORD**

K. Lee, T. Kurokawa and H. Yano
Dept. of Orthopaedic Surgery, University of Tokyo Hospital (Japan)

8/28 (WEDNESDAY)

P.M.

S—7 (13:30～14:50) NEUROPHYSIOLOGY(II)

Moderators: C. J. de Luca(U.S.A.), M. Ioku(Japan)

<S—7—1> **SYNCHRONOUS MOTOR UNIT FIRING AT REGULAR INTERVALS PRECEDING RAPID VOLUNTARY MOVEMENT AND ITS RELATION TO MOTOR PREPARATION**

K. Tanii[1] and T. Kinugasa[2]
1.Human Factors Research Dept, Industrial Products Research Inst. (Japan)
2.Inst. of Health and Sport Science, University of Tsukuba (Japan)

<S—7—2> **THE COMMON DRIVE CONCEPT OF MOTOR UNIT CONTROL**

C. J. de Luca
Neuro Muscular Research Center Boston University (U.S.A)

<S—7—3> **THE BLINK REFLEX, CLINICAL OBSERVATION UPON THE LATER RESPONSE R2, ESPECIALLY CONSENSUAL R_2 IN THE INTRACRANIAL LESIONS**

M. Ioku
Dept. of Neurosurgery, Kinki University School of Medicine (Japan)

<S—7—4> **INFLUENCE OF THE PONTINE ATROPHY TO AUDITORY BRAIN STEM RESPONSES IN SPINOCEREBELLAR DEGENERATIONS**

T. Konishi, Y. Mano, S. Morimoto and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

●●●Coffee Break●●● (14:50～15:05)

S—8 (15:05～16:45) METHODOLOGY

Moderators: M. F. Maranzana(Italy), N. Chino(Japan)

<S—8—1> **COMPARISON OF WIRE AND SURFACE ELECTRODE RECORDINGS BETWEEN AN ANTAGONIST PAIR OF MUSCLES**

B. Etnyre[1] and L. D. Abraham[2]
1.Rice University (U.S.A)
2.The University of Texas (U.S.A)

<S—8—2> **A SIMPLE PROCEDURE TO CUT DOWN ARTIFACTS IN SURFACE ELECTRODE RECORDINGS —HOW TO PAINLESSLY LOWER SKIN RESISTANCE—**

T. Okamoto[1], H. Tsutsumi[1], Y. Goto[2] and P. D. Andrew[3]
1.Kansai Medical University (Japan)
2.Hyogo University of Teacher Education (Japan)
3.Bobath Hospital (Japan)

<S—8—3> **COMPARED STATISTICAL EVALUATION OF CNEMG MEASUREMENT PROTOCOLS**

N. E. Feig[1], S. Barbieri[2] and M. F. Maranzana
1.Centro Teoria dei Sistemi CNR, Dipartimento di Elettronica, Politecnico di Milano (Italy)
2.Clinica Neurologica, Università di Milano (Italy)

<S—8—4> **EVALUATION OF ATAXIC GAIT BY AN EXTRA-LARGE FORCE PLATE**

N. Chino, M. Nagata, M. Utsuki and N. Yamazaki
M. D., Dept. of Rehabilitation Medicine, Keio University (Japan)

<S—8—5> **ELECTROPHYSIOLOGICAL ANALYSIS OF WARMING UP PHENOMENON IN MYOTONIA**

Y. Mano, H. Honda and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

8/29 (THURSDAY)

A.M.

S—9 (9:00～10:40) CLINICAL(I)

Moderators:
K. L. Boon(The Netherlands)
R. Suzuki(Japan)

<S—9—1> **THE APPLICATION OF WALKING ANALYSIS TO CLINICAL EXAMINATION**

H. Iwanaga, T. Norimatsu, M. Fujita, N. Matsusaka, J. Kayano, J. T. Chang and R. Suzuki
Dept. of Orthopaedic Surgery, Nagasaki University School of Medicine (Japan)

<S—9—2> **ELECTROMYOGRAPHIC AND KINESIOLOGICAL COMPARISON OF STEREOTYPED, VOLUNTARY MOVEMENTS BY SIGNAL OF ELECTRIC STIMULATION BETWEEN SPINOCEREBELLAR DEGENERATIONS AND PARKINSON'S DISEASE**

T. Muroga
Dept. of Occupational Therapy, Nagoya University College of Medical Technology (Japan)

<S—9—3> **HOW TO EVALUATE PLEXUS LESIONS WITH SURFACE EMG**

H. J. Hermens, K. L. Boon and G. Zilvold
Rehabilitation Centre het Roessingh, (The Netherlands)

<S—9—4> **INVESTIGATION OF MOTOR NERVE CONDUCTIVITY IN AMYOTROPHIC LATERAL SCLEROSIS AND POLYNEUROPATHY; USING DURATION OF COMPOUND ACTION POTENTIAL**

S. Morimoto, Y. Mano, T. Konishi and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

<S—9—5> **INTRAOPERATIVE SENSORY NERVE ACTION POTENTIAL RECORDING AT THE SURGERY OF CARPAL TUNNEL SYNDROME**

S. Tachibana, A. Nagano and N. Ochiai
Dept. of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo (Japan)

● ● ● Coffee Break ● ● ● (10:40～10:55)

S—10 (10:55～12:35) CLINICAL(II)

Moderators:
Y. Blanc(Switzerland)
M. Hasue(Japan)

<S—10—1> **AN INVESTIGATION OF THE EXTENSOR CARPI RADIALIS LONGUS AS AN ELBOW FLEXOR**

D. J. Hobart, R. G. Bloyer, C. W. Hardiman and P. A. Anderson
Dept. of Physical Therapy, School of Medicine, Universty of Maryland (U.S.A)

<S—10—2> **KINESIOLOGICAL STUDY OF POST-TRAUMATIC INSTABILITY OF THE ANKLE TREATED BY SKIN ALLOGRAFT**

Y. Blanc
Laboratory of Kinesiology, Dept. of Surgery, Orthopaedic Clinic, University Hospital (Switzerland)

<S—10—3> **ELECTROMYOGRAPHIC STUDIES OF THE THIGH MUSCLES IN KNEE OSTEOARTHROSIS**

T. Onozawa, Y. Atsuta, I. Yamashita, N. Suzuki and Y. Takemitsu
Asahikawa Medical College (Japan)

<S—10—4> **THE ROLE OF THE QUADRICEPS IN NORMAL AND THE MALALIGNMENT SYNDROME OF THE PATELL-FEMORLA JOINT**

S. Suzuki, Y. Ooi and K. Itoh
Dept. of Orthopaedic Surgery, Jichi Medical School (Japan)

<S—10—5> **ALTERATIONS IN THE DYNAMIC INTRA-ARTICULAR PRESSURE OF THE KNEE JOINT IN DISEASE AND INJURY**

K. Itoh, S. Suzuki and Y.Ooi
Dept. of Orthopaedic Surgery, Jichi Medical School (Japan)

8/29 (THURSDAY)

P.M.

S—11 (13:30～15:10) CLINICAL(III)

Moderators:
R. P. Lehr Jr.(U.S.A.)
Y. Mano(Japan)

<S—11—1> **ELECTROPHYSIOLOGICAL STUDY OF RESPIRATORY FUNCTION IN AMYOTROPHIC LATERAL SCLEROSIS (ALS)**

S. Yanagimoto, Y. Mano, T. Sakakibara and T. Takayanagi
Dept. of Neurology, Nara Medical College (Japan)

<S—11—2> **ELEVATION IN UPPER PART OF TRAPEZIUS MUSCLE IN FSH MUSCULAR DYSTROPHY**

Y. Mano, J. Teramoto and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

<S—11—3> **AN ISOKINETIC ASSESSMENT OF THE LOWER LIMB MOVEMENTS IN ATAXIC HEAD INJURED PATIENTS**

A. Kraus[1], L. Teesdale[1], M. Ashley[1] and R. P. Lehr, Jr.[2]
1.Centre for Neuro Skills, Bakersfield (U.S.A)
2.Southern Illinois University, School of Medicine (U.S.A.)

<S—11—4> **THREE CASES OF LINGUAL BALLISTIC MOVEMENT FOLLOWED BY RIGID-DYSTONIC STATE OF THE TONGUE**

H. Horikawa, M. Konagaya, Y. Mano and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

<S—11—5> **REMARKABLE PSEUDOATHETOSIS OF UPPER LIMBS DUE TO ABNORMALITY IN ATLAS AND AXIS**

S. Morimoto, Y. Mano, N. Ujihira and T. Takayanagi
Dept. of Neurology, Nara Medical University (Japan)

● ● ● Coffee Break ● ● ● (15:10～15:25)

S—12 (15:25～17:05) POSTURE

Moderators:
G. B. J. Andersson(U.S.A.)
H. Iwakura(Japan)

<S—12—1> **DYNAMIC ANALYSIS OF HUMAN ERECT POSTURAL SWAYS**

I. Yamaguchi[1], N. Tajima[1], K. Sato[2] and C. Morisada[3]
1.Miyazaki Medical College (Japan)
2.Research Foundation on Traffic Medicine (Japan)
3.Matsuyama Kinesiology Research Foundation (Japan)

<S—12—2> **MUSCULAR FACTORS INFLUENCING ON THE INTRAABDOMINAL PRESSURE**

M. Fujiwara[1], K. Nakano[1], K. Fukuda[2] and S. Maruo[2]
1.Rehabilitation Center, Hyogo College of Medicine (Japan)
2.Dept. of Orthopaedic Surgery, Hyogo College of Medicine (Japan)

<S—12—3> **ELECTROMYOGRAPHIC FEAUTURES OF IDIOPATHIC SCOLIOSIS**

T. Aoki, K. Yazawa, K. Maruyama, E. Machida, I. Katori and S. Sano
Dept. of Orthopaedic Surgery, Nihon University Shool of Medicine (Japan)

<S—12—4> **IN VIVO MEASUREMENTS OF VIBRATION TRANSMISSION IN THE HUMAN SPINE**

G. B. J. Andersson[1], M. M. Panjabi[2], L. Jorneus[3] and E. Hult[3]
1.Dept. Orthopaedic Surgery, Rush-Pres. -St. Luke's Medical Center (U.S.A)
2.Dept. Orthopaedic Surgery, Sahlgren Hospital (Sweden)
3.Yale University (U.S.A)

<S—12—5> **STUDIES OF THE MOVEMENTS IN SITTING DOWN, SQUATTING DOWN AND STANDING UP —— KNEE JOINT MUSCLE ACTIVITIES AND POSTURE CONTROL IN YOUNG AND AGED PERSONS**

H. Iwakura and K.Yoshida
Dept. of Rehabilitation Meoicine, Teikyo University School of Medicine (Japan)

ABSTRACTS

演題抄録

AUGUST 26 (Monday)

Special Lecture

SOME REFLECTIONS ON MY STUDY OF EMG

Naoichi TSUYAMA
Prof. Emeritus. Univ. of Tokyo

In Japan clinical application of EMG by means of needle electrode was started fairly soon after the 2nd world war and the first assembly of Japan EMG research association was held in December, 1951, under the leadership of late Dr. Toshihiko Tokizane who was the professor of physiloqy of the Brain Research Institute of the University of Tokyo and was really a genious inventive scholar leaving many contributions in the field of EEG, EMG and other brain research.

My study on EMG is much indebted to Prof. Tokizane's guidance and here I should like to recollect some of them.

1. Origin of High Amplitude Motor Unit Action Potential.

It is a well known fact that in chronic nerve diseases, particularly in intramedullary diseases, single oscillation of high amplitude motor unit potential is a characteristic pattern of EMG at volitional contraction. Much controversial theories were presente about the origin of this EMG pattern, e.g. synchronized activity of auterior horn cells abvocated by Buchtal et al, deafferentiation effect to motor unit discharge by Drechsler et al., unmasking of large motor unit, growth

Today it is coneluded that this high amplitude motor unit potential is derived from a growth of motor unit that means increase of innervation ratio as a result of collateral sprouting and reinnervating of axons left intact to those denervated musde fibers.

However, according to my experience, question remains whether the synchronization theory is to be totally denied. The reason is, firstly when we follow this characteristic pattern of single oscillation of giant potential by double channel needling the synchronized pattern does at times, though very short, change to not coinciding discharges, in other words, does de synchronize and they again come back to synchronized pattern, in other words, does resynchronize. This temporary desynchronization can not be explained by a growth of motor unit theory.

Secondly as Marx once suggested, intravenous calcium administration to reduce the excitability of anterior horn cells can induce desynchronization or breaking up of this single oscillation pattern. This fact is also contradictory to the growth of motor unit theory.

Whether we should accept dual origin is yet to be

2. The Interual Variation Analysis.

The interval variation analysis invented by the late Professor Toshihiko Tokizane in 1950 is very useful to detect unmanifested rhythm in motor activity. unit When muscle contraction is very weak, needle EMG shows only a single motor unit firing, and when contraction is gradually strengthened first the temporal summation of the motor unit takes place and then this is followed by a recruitment of different motor units until an interference pattern develops. During the phase of weak contraction at which single motor unit firing is discrete and discernible, the interval between each discharge is measured and numbered in the order and an interval diagram is plotted by putting the number on the abscissa and the interval on the ordinate. This interval diagram describes the rise and fall of the excitatory state of the anterior horn motor cell and can reveal unmanifested or superimposed fluctuation of the motor unit activity. By analyzing this fluctuation pattern, we may elucidate various motor unit activities which is taking place in obscurity, e.g., Babinski's phenomenon in normal subject, respiratory rhythm in limb muscles, tonic neck reflex or other reflectory influences in the skeletal muscles which are unmanifested.

We, as an orthopaedic surgeon, use to perform intercostal nerve crossing to the musculo cutaneous nerve as a sole reconstructive procedure for the whole plexus brachialis injury of root avulsion type which otherwise is irrepirable.

In the early stage of reinnervation after the intercostal nerve crossing to the musclo cutaneous nerve, superimposed respiratory rhythm is clearly seen on the interval variation diagram. With the lapse of time this respiratory involuntary rhythm fades and disappears and is taken over by a smooth voluntary control of the elbow flexor with satisfactory endurance.

3. Portable and Pocketable EMG Apparatus

One of the most useful applications of the surface electrode EMG is that this can give an definite evidence of actual muscle contraction with rough quantitative information.

One of the most useful applications of the needle electrode EMG is that this can show a minimum connection of peripheral nerve fibers which is conveying volitional control. As manual muscle testing is quite misleading when muscle is very weak, the needle EMG is indis-pensable to judge whether the muscle is completely denervated or not.

To fulfill these requirements, we are using portable auditory EMG appratus with surface electrode and pocketable auditory EMG appratus with needle electrode.

The construction of these handy EMG devices will be shown.

4. Quantification of EMG

Quantification of EMG with regard to grading of the muscle contraction strength has been studied in various ways.

Turn counting and amplitude integration method invented by Wilson et al. and rectifying quantification have been used by our department and some results of our study will by shown.

5. Kinesiological Application of EMG

EMG is a very useful weapon in the study of kinesiology and has been applied widely in Japan. Some of the results of our studies will be presented.

AUGUST 27 (Tuesday)

Session 1～4

<S-1-1>

THE LEFT-TO-RIGHT DIFFERENCE IN REACTION TIMES WITH ANKLE JOINT MOVEMENTS

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Department of Physical Education, Iwate University, and Institute of Health and Sport Science, University of Tsukuba*, JAPAN

INTRODUCTION

Many reports about a left to right difference in extremities have been published in recent years, especially about the upper extremity. Nakamura have reported that the left-to-right characteristics in the motor output system have appeared in the simple reaction time.

Moreover, few reports have been published about a left to right difference in the lower extremity. But it is a well known fact about the difference between right and left lower extremity in daily life and sports situations. Some athletes favor the right leg rather than the left leg, and vice versa.

Then, the purpose of this study was to clarify characteristics in the left to right differences in the lower extremity by performed reaction time tasks in which subjects made both plantar-flexion and dorsi-flexion with left and right in both simultaneous and separate tasks as quickly as possible.

METHODS

Twelve healthy male subjects were used for this study. To determine the laterality of preference, each subject was asked to answer the questionnaire. Six of twelve subjects preferred to use the right leg (right group). The other six of those preferred to use the left leg (left group).

Each subject performed plantar-flexion and dorsi-flexion of the ankle joint, repectively, with right and left in both simultaneous (bi-lateral) and separate (uni-lateral). Each subject performed dorsi-flexion of the ankle joint in supine position and plantar-flexion of the joint in prone position with relaxed muscles of the lower legs.

Each subject was informed to react as quickly as possible after the reaction signal through head-phones which occurred at 2-4 seconds after the warning signal. The reaction signal was a frequency of 600 Hz and a duration of 100 msec..

Muscle action potentials were led from both sides of the tibialis anterior muscle and the medial gastrocnemius muscle through pre-amplifier with filter of 10 Hz - 10 KHz. EMG was stored on magnetic tape recorder for later analysis and displayed on digital oscilloscope (Nicolet Inst. Co., 201).

The goniometer was used to pick up angles of the ankle joint.

Premotor time (PMT), reaction time (RT) and motor time (MT) was measured as follows. PMT is defined as the interval time from the reaction signal to the onset of action potential in agonist muscle. RT is defined as the interval time from the reaction signal to the onset of the ankle joint movement. MT is defined as the interval time subtracted RT from PMT.

Each subject performed ten trials for each experimental condition, sixty trials in all. The order of experimental conditions was randomized for the subjects. The inter-trial interval was fifteen seconds. Each subject performed the same experimental conditions in two successive days in which the first day was for practice and the second was for testing.

RESULTS AND DISCUSSION

In the right group, mean PMT for any experimental condition, except the experimental condition of dorsi-flexion with uni-lateral, was shorter in the left leg than in the right leg, as shown in Table 1. In the left group, conversely mean PMT for any experimental condition was shorter in the right leg than in the left leg. Therefore, EMG onset in the preferred leg was slower than in non-preferred leg. These results were the same as those reported by Nakamura and Saito who showed a shorter PMT for the elbow flexion in the non-preferred arm than the preferred arm.

There was no difference between right and left in MT for any experimental condition.

PMT and RT for plantar-flexion showed a significant difference between left and right, but PMT and RT for dorsi-flexion showed no significant difference, the results showing that standard deviation in dorsi-flexion was larger than in plantar-flexion.

There was no significant difference of PMT, MT and RT between simultaneous bi-lateral and uni-lateral movement, suggesting that when simultaneous bi-lateral movement would happen, motor command for movement of one side of the body might not be interrupted the other, as reported in the same results in the upper extremity by Nakamura and Saito.

REFERENCE

Hongo, T., Nakamura, R., Narabayashi, H. and Oshima, T. Reaction times and their left-to-right differences in bilateral symmetrical movements. Physiol. Behav. 16:477-482, 1976.

Nakamura, R. and Saito, H. Preferred hand reaction time in different movement patterns. Percept. Mot. Skills, 39:1275-1281, 1974.

Table 1. Means($\bar{X}$) and standard deviations(SD) of PMT, MT and RT for each experimental condition across each subject group. Each subject group has six subjects. *, **, *** shows the significant difference between right and left in each experimental condition at the level of .05, .01 and .001 respectively, by the result of the T-test.

Subject Group			Plantar-flexion PMT $\bar{x}$ (SD)	Plantar-flexion MT $\bar{x}$ (SD)	Plantar-flexion RT $\bar{x}$ (SD)	Dorsi-flexion PMT $\bar{x}$ (SD)	Dorsi-flexion MT $\bar{x}$ (SD)	Dorsi-flexion RT $\bar{x}$ (SD)
RIGHT	Uni	R	120.1 (6.7)	44.4 (6.5)	164.5 (7.4)	117.3(13.3)	46.6(10.0)	163.9 (9.3)
			**		*			
		L	107.7 (8.7)	45.0 (6.5)	152.7 (7.7)	113.8(17.9)	47.6 (7.2)	161.4(16.9)
	Bi	R	127.4 (5.5)	44.8 (8.8)	172.2(11.0)	122.2 (9.2)	49.0 (9.1)	171.2 (6.8)
			***		*	**		
		L	116.7 (7.9)	44.2 (4.1)	160.9 (4.9)	112.6 (7.6)	51.1 (5.9)	163.7 (8.0)
LEFT	Uni	R	120.2(24.6)	48.6 (5.8)	168.8(23.3)	112.3(13.9)	56.7(10.1)	169.1(19.0)
			*		*	**		
		L	129.7(19.2)	54.2 (9.1)	183.9(25.9)	119.8(15.2)	54.5(13.1)	174.4(25.5)
	Bi	R	122.7(23.0)	48.7 (7.6)	171.4(20.2)	116.6(13.9)	57.1(11.4)	173.6(19.3)
			**			*		
		L	132.6(24.2)	50.2 (8.5)	182.8(30.1)	121.3(15.5)	56.4(20.2)	177.7(32.2)

in milliseconds

<S-1-2>

SPINAL PLASTICITY IN MOTOR CONTROL DISORDERS. THE RESTORATIVE EFFECTS OF POSITIONAL FEEDBACK STIMULATION TRAINING (PFST).

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^Dept. Neurology, Medical Centre of Rehabilitation, Veruno (NO), Italy

INTRODUCTION

In hemiplegic hand, the central tuning on muscular reflexes is altered, with an enhancement of wrist flexor stretch reflexes and the loss of shortening reactions particularly in wrist extensor muscles (Pinelli and Villani, 1984). In long-lasting pyramidal lesions plastic changes may occur at the level of spinal motoneuron synapses; as a consequence a stereotyped functioning of spinal servomechanisms can arise because of "fixed" reflexes. It is obvious the necessity of opposing this synaptic rearrangement and "readapting" the spinal reflex control to a larger range of tuning afferent and descending impulses.

Many Authors suggested the efficacy of functional electrical stimulation in increasing strength and inhibiting antagonistic spasticity, and there was several reports on the therapeutic effects of biofeedback training in stroke patients. Bowman et al. (1979) proposed a new modality of treatment combining the positional feedback and electrical stimulation (PFST) of hand extensor muscles.

Aim of our study was to evaluate the course of plastic changes following a pyramidal lesion and the influences exerted on them by PFST in passive and voluntary wrist movements in a group of hemiplegic patients.

METHODOLOGY

Twenty-seven hemiplegic patients, (18 men and 9 women) between 37 and 72 years of age, were recruited for the study. Fifteen had a right hemisphere lesion and 12 a left hemisphere lesion. The patients were hospitalized for rehabilitative therapy at different times (from 20 days to one year) after the onset of the paralysis. They were treated with conventional physical therapy (PT); 14 out of them were also treated with PFST of wrist extensors for 1 month (2 daily sessions, each lasting 30 minutes).

Before and after PFST or PT, electromyographic, kinematic and dynamometric investigations of wrist flexor and extensor muscles were carried out. The measurements included: 1) muscular strength at maximal voluntary effort (Fmax) during isometric wrist flexion or extension; 2) EMG recordings of stretch reflexes and shortening reactions during passive movements induced by a constant torque, at rest and during 3 different patterns of pre-innervation.

The above measurements were also repeated 3 times at 3-month intervals in the following 9 months.

RESULTS

Basal conditions

In the 20 days following the stroke all the patients (27) showed a total flaccid paralysis of the hand. At the end of this period 8 patients could perform only a weak global synergistic flexor contraction.

This type of movement could be elicited by a collateral activation of the cortico-mesencephalo-spinal system (Kuypers, 1979).

In this early period we did not apply PFST.

Patients with early recovery

Twenty to 30 days after the paralysis, 6 patients, among those performing a weak contraction in basal conditions, showed a rather good recovery in strength (Fmax of wrist extensors $\geqslant$10 N·m). Two of them were treated with PFST and in the following 6 months they exerted a better "modulation" of spinal servomechanisms than the other 6 patients treated only with PT.

The improvement was considered to depend on a persistent facilitation of the cortico-spinal tract induced by PFST.

Patients with late recovery

Thirteen patients presented with severe paresis particularly of wrist extensors (Fmax: 1-5 N m), lasting until the sixth month. Eight of them (including 4 with right hemisphere lesion) underwent PFST 5 to 7 months after the onset of hemiplegia. A stepwise increase (60%-100%) in wrist extensors strength was observed just after PFST and persisted in the following 3 months; however flexor stretch reflexes were still exagered, while shortening reactions remained rather weak. The 5 patients who were treated only with PT showed a slight improvement (30%-50%) in extensors strength.

Obviously in these patients the lesion of cortico-spinal tract did not recover and the activation induced by PFST could prevalently act on the cortico-mesencephalo-spinal system.

Patients with persistent hemiplegia

In 6 patients the paresis persisted rather severe (Fmax of extensors: 0-1 Nm) until 12 months. Four of them were treated with PFST 12-18 months after the onset of hemiplegia; they did not show any significant improvement in strength, but the tuning of extensor reflexes was found to be improved better than in 2 patients not treated with PFST.

In this condition the only central motor system available to PFST effects could be the mesencephalo-spinal system.

DISCUSSION

Our findings suggest that a correct planning of treatment of the hemiplegic hand requires a preliminary classification of the natural course and the modalities of regression of the pathological process.

A prompt recovery of the cortico-spinal function, as we observedin 6 patients, can restore the previous functional arrangement of the spinal servomechanisms without any significant change occurring in the excitability of the alpha and gamma motorneurons.

However if the recovery is delayed, as it was in 13 patients, a prevalence of the indirect cortico-spinal system or even of the mesencephalo-spinal system occurs, leading to an enhancement of descending impulses in accessory pathways while the normal tuning effects are greatly hindered; this modified pattern of discharges acts on degree and sign of excitability of alpha motorneurons responding to the efferent impulses arising from the muscles and from skin receptors. If this new waves of excitement and inhibition persist at a constant rate for a period exceding few days, plastic changes can be induced on interneurons and propriospinal neurons, particularly at a presynaptic level (Wolpaw et al., 1984).

PFST can correct these effects and normalize the functional set of spinal servomechanisms. In hemiplegic hand the most affected function concerns voluntary extension and for this reason PFST must be directed mainly on wrist extensor muscles. The normalizing effect of PFST can be reached when the treatment is carried out within the first six months after the onset of the disease.

In most severe cases without significant motor recovery after 12-18 months, the available voluntary reinnervation presents global syncinetic features which can be due to an activation of the indirect cortico-spinal pyramidal system. In this condition PFST can only partially correct the asymmetrical functional prevalence of flexor motorneurons.

<S-1-3>

MOTOR TIME AND ITS COMPONENTS IN PATIENTS WITH CENTRAL NERVOUS SYSTEM (CNS) DISEASES

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Lesions of CNS cause a variety of disorders in performing voluntary movements. Common features in patients with hemiparesis due to stroke are functional impairment of fast movements and of rapid repititive movements. Patients with Parkinson's disease show bradykinesia as well as tremor-at-rest and rigidity. In patients with spinocerebellar degeneration (SCD), fast movements are more prominently impaired than slow movements. Thus, one of the common features of the lesion in pyramidal tract (PT), basal ganglia, and cerebellum is an impairment of rapid movement.

The measurement of motor time (MT), latency from the initiation of EMG activities to the onset of actual movement, would be a valuable method to examine the delay of initiation of rapid movement. MT is composed of two consecutive phases; the tension lag and the tension-developing phase (Nakamura et al. 1984). The tension lag time (TLT) is defined as a delay of the rise of tension after the onset of EMG activity. MT is determined by three factors; load to be moved, TLT, and the rate of tension development (RTD). The relationship among these three is depicted as MT = TLT + Load/RTD. TLT and RTD are estimated by measuring MTs under loading with different weights on the body segment to be moved. TLT represents the peripheral delay due to a series of physiological and mechanical factors of the muscle. On the other hand, RTD is influenced by the central process of the movement such as the motor unit recruitment and the firing rate. This assumption was supported by our previous study that centrally-acting muscle relaxant Baclofen affected only RTD but not TLT while peripherally-acting Dantrolene sodium affected only TLT but not RTD (Nakamura et al. in preparation).

In this study, we analyzed how different types of CNS diseases affect the central process of the movement, and whether its peripheral component is affected by these pathological states. For this purpose, we measured the components of MT, namely RTD and TLT, of the patients with stroke, Parkinson's disease and SCD.

Method

Seven normal subjects, 9 patients with spastic hemiparesis due to stroke, 6 with Parkinson's disease, and 4 with SCD participated in the study. They sat on a chair with the hip at 90° flexion and the knees at 60° flexion and the heels supported by a horizontal bar. They were asked to extend the knee as fast as possible responding to a tone stimulus. Responding limb was the affected side in those with stroke, and the left in the normal subjects and other patients. MT was measured as the time elapsed from onset of EMG activity of the rectus femoris to the off-signal of a switch attached to the responding heel. Weights of -2, -1, 0, 1, 2 kg were loaded to the mid-point of the leg by pulling forward or backward (Fig. 1). MTs were measured on each weight-loaded. RTD was defined as the coefficient of the linear regression between MTs and weights. TLT was estimated by substituting the weight of the leg and foot into this regression equation.

Results

The overall mean was 0.186 (0.073) kg/msec in the normal subjects, 0.059 (0.018) kg/msec in patients with stroke, 0.077 (0.030) kg/msec in those with Parkinson's disease, and 0.081 (0.027) kg/msec in those with SCD. The overall mean of TLT was 53.3 (7.19) msec in the normal subject, 79.9 (17.04) msec in those with stroke, 47.6 (7.86) msec in those with Parkinson's disease, and 60.2 (12.78) msec in those with SCD. Fig. 2 illustrates the scatter plots of RTD versus TLT for each subject and patient. Compared to the normal subjects, RTD was significantly ($p<0.05$) decreased in every disease group. There was, however, no significant difference of RTD among them. TLT lengthened significantly ($p<0.05$) only in patients with stroke while those with other disease showed TLT within normal range.

Descussion

The present results suggest that the time course of a muscle contraction was altered in patients with CNS disorders, which resulted in prolongation of MT. RTD decreased in all disease process examined here. Although pathophysiological mechanism on decreased RTD were different among diseases, there was no significant difference of RTD reduction. These phenomena suggest that not only pyramidal tract but basal ganglia and cerebellum are involved in programming and executing rapid force generation.

On the contrary, TLT lengthened only in patients with stroke. The effect of contracture which would increase the resistence on the joint-movement should be excluded, because some patients with Parkinson's disease had moderately limited range of motion (ROM) while some of the hemiparetic had full ROM. Moreover, the degree of ROM was not related to TLT. TLT is assumed to reflect the time necessary for peripheral process of a muscular contraction such as excitation-contraction coupling, the rate of cross-bridge cycling and of myofilament relaxation, slack of series-elastic component, and frictional resistance between the musculotendinous and the surrounding tissues (Nakamura et al. 1984). Subtle changes in the sarcoplasmic reticulum of the hemiparetic muscle was observed by electron microscopy (Chokroverty et al. 1976). Accordingly, the lengthened TLT observed in patients with stroke may be partly due to a change in a contractile property of the paretic muscle although invovement of other factors remains for a further study.

References

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Fig. 1

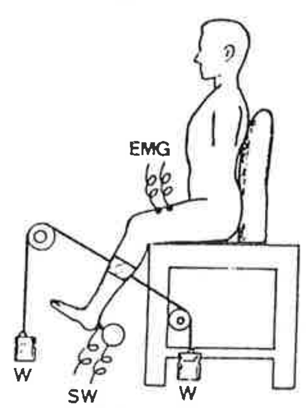
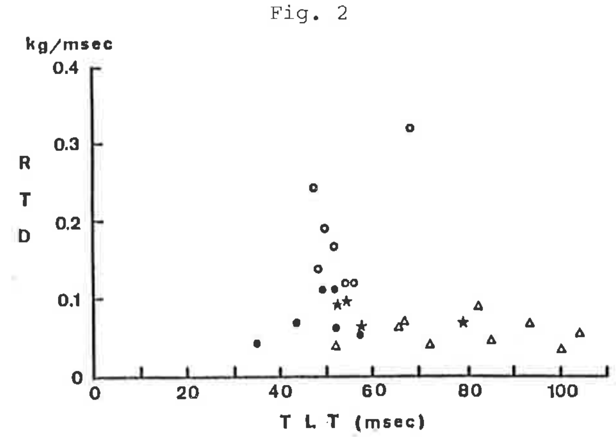


Fig. 2



O: Normal ●: Parkinson's disease Δ: Stroke ★: S C D

<S-2-1>

REACTION TIME OF ELBOW EXTENSION AT DIFFERENT VELOCITIES IN VERTICAL PLANE

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It is generally assumed that reaction time (RT) increases in accord with increase in the number of variables such as velocity and extent of movement that should be controlled (cf.Rosenbaum 1980, Stelmach 1978). Also recent studies suggested that RTs depended upon the movement pattern (Nakamura et al. 1974) and the number of synergic muscles (Taniguchi et al. 1984). However, the effect of neural coordination of movements, i.e., temporal and spatial patterning of muscular activities, on RTs has not been examined in detail.

When a body segment moves in vertical plane, the pattern of muscular activities depends upon the velocity of movement in the gravitational field. For instance, when one adducts the upper arm in the upright position so that it is in line with the pull of gravity, extension of the elbow joint from 90° flexed position is performed by three different modes of muscular activities of the upper arms according to different velocities: faster than free fall due to gravity(BA), free fall(FF) and slower than free fall (RA). Although these movements are similar to each other in kinematic change except the velocity, the movements performed by quite different patterns of muscular activities of the biceps and triceps brachii muscle (Ross et al.1983), and thus the motor program for the movement could be differentiated.

In this study we examined RTs of the three movements and attempted to analyse the effect of different neural commands to be programmed on RTs.

METHODS

Seven healthy men aged from 28 to 49 years participated in the study. All of them were well accustomed to RT studies. The experiment was performed using a specially designed chair equipped with tilting forearm supports. In front of the chair was placed a horizontal bar with a strain-gauge (U3C1-B, NMB) at the level of the forearm supports. Output of the strain-gauge was amplified and fed to an oscilloscope which located about 50 cm before the subject. On the oscilloscope there were two horizontal lines 1 cm apart vertically; the upper one was fixed as a target and the lower one was controlled by DC input from the strain-gauge. The shift of the lower line was adjusted to 1 cm/kg.

The subject sat on the chair with the trunk upright, the shoulders at neutral position, the elbows flexed at 90° and the forearms at mid-position. The right forearm rested on the horizontally fixed forearm support. The left forearm support was fixed at 30° tilted from the horizontal plane supporting the left elbow, so that the subject flexed the elbow actively to keep 90° flexed position.

The subject was asked to press the terminal of strain-gauge vertically upward with the left radial styloid following a ready command and to put together the two lines on the oscilloscope. The subject kept the position at least 3 sec. Then he extended his left elbow in each of the three modes, responding to a tone stimulus given 2 sec after a warning signal. The response modes were BA, FF and RA. EMGs of the left biceps and triceps brachii muscle were taken with surface electrodes and were displayed on a paper oscilloscope with speed of 5 cm/sec. The output of strain-gauge was fed to a computer (PC-9801F, NEC) via A/D converter triggered by electric signal synchronized with the response stimulus, and the latency of the start of tension-decrease was calculated with msec scale (RT). The starting point of tension-decrease was defined as a time at which tension curve intercepted a horizontal cursole extrapolated from the maintained tension before the start of the tension-decrease.

Before the experimental run the subject trained his response movements looking at the EMG records until he could differentiate each EMG pattern of the three modes. In BA the movement started with burst activities with short duration of the triceps brachii, in FF there were no EMG activities of both the biceps and triceps brachii at the start of movement and in RA continuous EMG activities of the biceps brachii decreased gradually (Fig. 1). After the subject learned these three modes, the experimental session was started. The order of trials were randomly assigned for the three modes. Five or more trials were performed for each mode. When the EMG pattern of the response did not coincide with the mode to be made, the trial was discarded from the data. The mean RT of five trials in each mode was used for statistical analysis.

RESULTS AND DISCUSSION

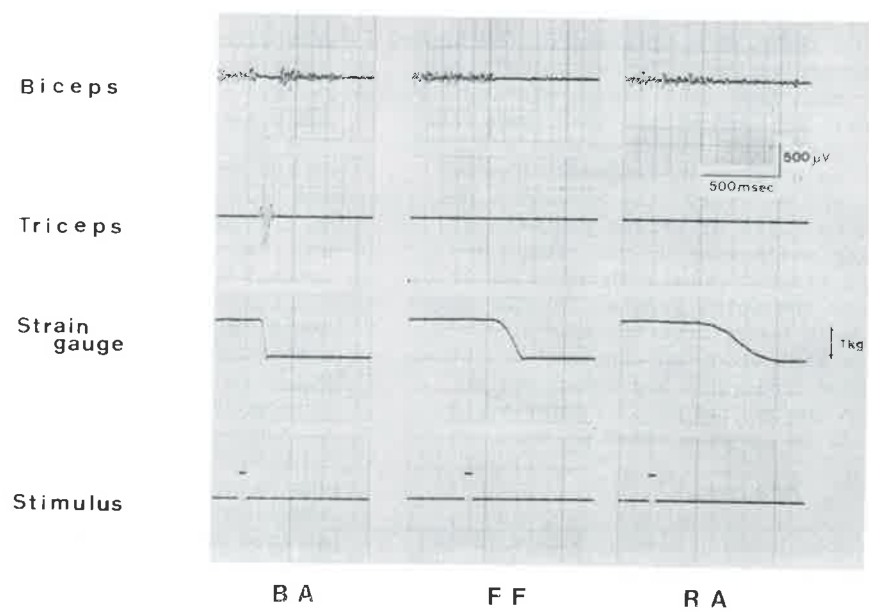
The qualitative results obtained by EMG records during the training session indicated that every subjects could perform BA at once but not the other two modes, which they could control after several trials. Even after several trials there appeared slight or moderate burst activities on EMG of the triceps brachii in FF for some subjects. Thus, FF took more trials until the subjects performed the movement correctly than RA.

For all subjects the shortest RT was obtained in BA (mean: 143.1 msec), followed by that in RA (161.6 msec) and lastly in FF (184.0 msec). Paired t-test revealed a significant difference among them ($p<0.05$).

The present study has shown that the movement mode was a critical factor for the change of RTs when the elbow extended in thesame direction as the force of gravity. The order of RT was the same as that of the easiness to control the movements under EMG feedback during the training session.

RT differences among the three modes would represent the differences of time necessary to central processing for each motor program. The inhibition of antagonistic muscle was not necessary for the initiation of movement in BA, although there appeared mostly the reciprocal inhibition of the biceps brachii at the start of movement. The gradual inhibition of on-going muscle activities of the biceps brachii was necessary in RA, and abrupt inhibition of both the agonist and antagonist was indispensable in FF. The prolongation of RTs was definitely related to the number of the muscles to be inhibited.

Fig. 1



<S-2-2>

THE RELATION OF INTEGRATED EMG OF THE TRICEPS BRACHII TO FORCE IN RAPID ELBOW EXTENSION

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Introduction

The ballistic movement of an extremity is characterized physiologically by a temporal patterning of the electromyographic(EMG) activity, i.e., triphasic pattern in the agonist and the antagonist(Hallett et al. 1975). Recent studies have indicated that the duration of the first burst activity lasting within 100 msec in the agonist is not affected by mechanical perturbations imposed on the moving body segment either prior to or during the burst(Garland et al. 1972, Hallett et al. 1975), nor by the velocity or the force output of the movement(Hallett and Marsden 1979 , Nagasaki et al. 1983). These characteristics have been considered as clear evidence that the first burst activity of the agonist is preprogrammed by the motor centre without modification by sensory feedback from peripheral input. Then what variables does the motor centre control through this activity in the ballistic movement? Experimental investigation into the relation of the first burst to biomechanical variables of the movement would provide evidences on the question. Studying rapid flexion of the interpharangeal joint of the thumb, Hallett and Marsden(1979) demonstrated a linearity between the rectified and integrated EMG(iEMG) of the first burst activity and maximal velocity of the movement, but they did not examine the force outuput. In anisotonic contraction of the biceps brachii muscle for elbow flexion with or without external load, Bouisset et al.(1973) showed a linear relationship between iEMG and mechanical work. In their study, however, the movements were not limited to ballistic movement and the electrical activity was integrated beyond 100 msec up to a time when the velocity became its highest level.

In the present study, the relationships between the first burst activity of the triceps brachii muscle and biomechanical variables such as acceleration, velocity and kinetic energy were examined on ballistic elbow extention.

Method

Five healthy men, aged from 33 to 48 years, participated in the study. The subject sat in front of a table equipped with a horizontally rotating bar and placed his right forearm on the bar. The axis of the elbow joint was aligned with the pivot of the bar, making the shoulder at 90° flexion, 20° horizontal abduction and 90° internal rotation, and the elbow at 90° flexion. Responding to a tone stimulus given 2 seconds after a warning signal, the subject extended the right elbow as quickly as possible. To manipulate the amount of the force output, the trials were performed under three conditions. The subject was instructed to move the bar quickly with large force in Condition A, with intermediate force in Condition B, and with small force in Condition C. The three conditions were assigned at random and ten trials for each condition were performed.

The EMG activity taken from the triceps brachii muscle with surface electrodes were amplified with low cut frequency of 16 Hz. The EMGs were rectified and sampled every 1 msec by a digital computer(NEC PC-8801). The onset of the EMG activity was defined as the time at which amplitude of the EMG first exceeded 100 μV. The recorded EMG activities of the triceps brachii muscle were integrated every 1 msec from the onset of the EMG to 100 msec for each trial(iEMG(100)). The averaged EMG over ten trials were calculated for each experimental condition.

A linear accelerometer(TEAC, 501ER-FB) was attached to the bar 46 cm apart from the pivot of the bar. The accelerometer signal after the onset of the EMG activity was amplified with high cut frequency of 300 Hz and fed to the computer. To obtain a measure of velocity, the data were integrated every 1 msec. The averaged acceleration over ten trials were computed for each condition.

Results

The first burst activity of the triceps brachii muscle had an approximately constant duration and ceased within 100 msec in all conditions for each subject, and thus iEMG(100) was regarded as representing the first burst activity. The amplitude of the averaged EMG increased in the order of the Condition C, B and A. The accelerations started at T1 from 20-40 msec after the onset of the EMG activity and turned to deceleration at T2 after 80-100 msec. Maximal acceleration(Amax) ranged from 0.13 to 10.35 g among the subjects. They increased in the order of the Condition C, B and A. Maximal velocity (Vmax) was obtained by integrating acceleration up to T2. Its range was 0.9 to 10.4 rad/sec through all subjects except one whose range was 0.1 to 7.9 rad/sec. Mean acceleration($\bar{A}$) was computed by dividing the integrated acceleration from T1 to T2 by the time (T2-T1). Square of Vmax was used as an index of maximal kinetic energy.

Table 1 lists the correlation coefficients of the linear regression analysis of each variable to iEMG(100). Although all regressions were significant, the correlation coefficient was the largest in $\bar{A}$ or Amax, and the smallest in $Vmax^2$ through the subjects. Ranks of these correlation coefficients were significantly different among the variables(Friedman's two-way analysis of variance by ranks, $Xr^2=12.12$, $p<0.01$). Consequently, $\bar{A}$ or Amax, that is, the measure with dimension of force was most linearly related to iEMG(100).

Discussion

The present study confirmed our preveous study (Nagasaki et al. 1983) showing that the first burst activity of the triceps brachii muscle in ballistic elbow extension did not change its duration regardless the force output while the amount of the activity corresponded to the force output. Recent studies demonstrated that the duration of the force outuput in ballistic movements also remained constant irrespective of the different force levels(Freund and Büdingen 1978, Nagasaki et al. 1983). Under the neuromuscular constraint of these pre-fixed time-frames, the iEMG (100) was related most linearly to the force output among the biomechanical variables examined in the present study. Considering that the greater the force output, the longer premotor reaction time, i.e., the time for contral processing of the movement organization(Nagasaki et al. 1983), these facts suggest that the motor centre for the initiation of the ballistic movement controls the force output by changing the amount of the first burst activity of the agonist while keeping their durations constant.

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Table 1

Regression analysis of each variables to iEMG correlation coeffient

subjects	$\bar{A}$	Amax	Vmax	$Vmax^2$
1	0.983	0.981	0.973	0.965
2	0.969	0.954	0.960	0.951
3	0.983	0.978	0.974	0.956
4	0.940	0.961	0.881	0.864
5	0.955	0.961	0.931	0.849

<S-2-3>

EFFECT OF PRACTICE IN UNCERTAINTY CONDITIONS ON CONTROL MECHANISMS OF BALLISTIC MOVEMENTS

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While control mechanisms of voluntary movements have been the object of many research undertakings, few studies centered on their modifications with skill acquisition. Traditionally, the results have systematically found an error reduction in the accuracy of movement with skill acquisition, whereas, the modifications of kinematic parameters and EMG patterns remain somewhat obscure. In some instances, an increase of the EMG activity was reported to take place, while an invariance or even a decrease of the EMG activity was found in others (Carrière& Boucher, 1984; Englehorn, 1983; McGrain, 1980). Most studies investigating practice effects used invariant training conditions which could introduce modifications related to the creation of a motor program and an optimization of the operations of the system.

The purpose of this study was to investigate the control mechanisms underlying the correction of ballistic movement perturbed during its execution and the modification of the EMG corrective responses with skill acquisition under event uncertainty conditions.

METHODOLOGY

Subjects were trained to execute a 60-degree ballistic forearm pronation in less than 150 ms. A perimeter containing two light series was located 1.4 m in front of the subject, red lights indicated the movement end position that was to be achieved, whereas, yellow lights (linked to the handle shaft) provided immediate end position feedback. Movement time feedback was provided immediately after the trial by the experimenter. Disturbances of 350 g.cm were introduced by a DC brushless torque motor (Aeroflex TQ 74W-6) simultaneously with the onset of the first EMG burst on 20% of the trials. Bipolar surface electrodes (Beckman miniature Ag/AgCl) were used to record EMG signals of the m. pronator quadratus and briachio radialis. These signals were full wave rectified, integrated and averaged (over 20 trials) following which the amplitude and duration of the EMG responses were quantified. Data acquisition and quantification were insured by Apple II microcomputers. The training period length was determined by the subject's performance (i.e., training continued untill the subject could reach the time and accuracy criteria 95% of the time). A practice session consisted of 100 repetitions of the experimental movement (i.e., 20 perturbed, 80 under normal conditions randomly allocated).

RESULTS

The results show an important decrease in EMG activity particularly in the perturbed trials and in the agonist muscle (Figures 1 and 2). The agonist activity decreased from 313 µV to 170 µV and from 160 µV to 113 µV with practice in the perturbed and normal conditions respectively, while the decrease was from 92 µV to 19 µV and 28 µV to 15 µV in the antagonist muscle. The modifications in the EMG patterns show that even if the subjects were trained in uncertainty conditions they developed an adequate motor program which completely compensated the perturbation. This is refected by the larger overshoot in the normal conditions after training (15^{o} vs 4.5^{o}) while the reverse is true in the perturbed conditions (7.5^{o} vs 0^{o}). Also, the high EMG amplitude in the perturbed conditions prior to training shows that the subject was reacting to the perturbation and changed the motor commands to make the necessary corrections as fast as possible, while the EMG amplitude is not significantly different between the normal and perturbed conditions at the end of training (160 µV vs 170 µV in the agonist and 15 µV vs 19 µV in the antagonist). Finally, the triphasic pattern,

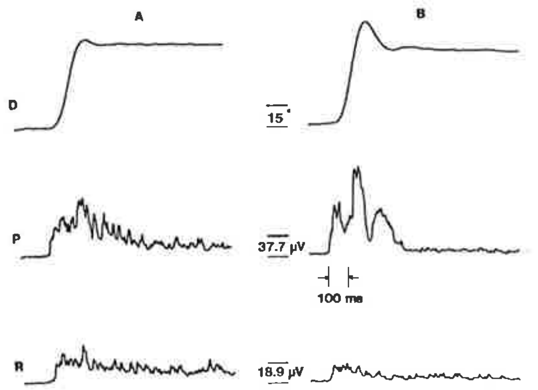

Figure 1. Displacement (D) and EMG signals (P: pronator quadatus; R: brachioradialis) before (A) and after (B) practice in normal conditions.

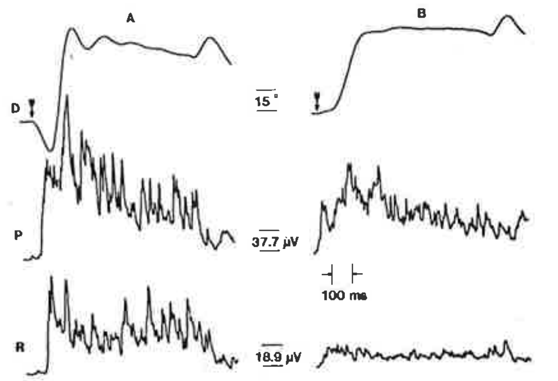

Figure 2. Displacement (D) and EMG signals (P: pronator quadratus; R: brachioradialis) before (A) and after (B) practice in perturbed conditions. ↓: perturbation.

characteristic of ballistic movements, appeared with practice.

DISCUSSION

The results of this study partly replicate those of Carrière and Boucher (1984) who trained subjects in invariant conditions. The myotatic reflex response appears at the beginning of training while the voluntary response overlaps it at the end of training. There was also a reduction in EMG amplitude with practice. In the present study, the changes in EMG pattern seem to reflect modifications in the motor program so that it became adapted to the perturbed conditions. This is reflected by the similarity of EMG patterns in the two conditions and could also explain the increased inhibition period in the normal condition after training (i.e., the increased speed with practice would enhance the unloading reflex). The results also show that the corrections in the motor program involves a feedforward mechanism which allows for a complete compensation of the perturbation when it appears. Hence, the creation of the motor program is combined with a pretuning of the lower centers in order to enhance effectors efficency. The correction in the motor program could be achieved by the adaptative processes proposed by Pailliard (1980), which would result in durable and structural changes in the motor program. These changes are based upon the proprioceptive inputs associated with prior movement repetitions which were at the basis of the structural modifications. The gain changes, reflected by the reduced EMG amplitude, would reflect an optimization of the system operation as suggested by Wiesandenger (1978).

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BALLISTIC FOREARM FLEXION PRACTICE EFFECTS UPON SURFACE EMG SIGNAL CHARACTERISTICS

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Practice effects upon neuromuscular control mechanisms underlying the execution of ballistic movements are traditionally studied through the analysis of temporal components of agonist and antagonist muscle EMG activity (Angel, 1981). Such temporal analyses yield little information regarding changes occurring in the activation pattern of motor unit pools. Whereas, EMG signal characteristic analyses, such as power spectral analysis and interference pattern spike analysis, have been shown to be useful techniques to assess such changes. As suggested by Magora and Gonen (1970), the only characteristic of the motor unit preserved in a full interference pattern is the shape, as demonstrated by its spikes and peaks.

The purpose of this study was to examine the alterations in EMG signal characteristics during skill acquisition.

METHODS

Sixteen college age students (8 men, 8 women) participated in the study. Each student performed 10 maximum speed flexion trials under each of three different loads (0, 4 and 8 times the forearm moment of inertia) on 8 separate practice days. The experimental movement consisted of a flexion of the right forearm from a 15° resting position to a 90° target along the sagittal plane. On every trial, a subject was asked to execute the movement following verbal commands by the experimenter, and volitionally stop the segment as close as possible to the 90° target.

Beckman bipolar surface electrodes (Ag-AgCl) were used to pick up EMG signals from the long head of the biceps brachii (agonist) and the lateral head of the triceps brachii (antagonist) during each flexion trial on 3 of the 8 practice days (i.e., days 1, 4 & 8). EMG signals were differentially amplified and recorded with a two channel Medic electromyograph (Medic Flexline-S, SN V2H4, 2 Hz to 20 kHz response). The EMG signals along with the movement initiation and completion event markers were then stored on a Sony analog recorder to await analog-to-digital conversion (2 kHz rate) and quantification.

The EMG parameters were measured on 4 components of the triphasic pattern distinctive of ballistic flexions of the forearm. Figure 1 illustrates the 4 components: onset of the first biceps EMG burst (C1), end of the first biceps EMG burst (C2), second biceps EMG burst (C3), and triceps EMG burst (C4). On every trial 5 EMG parameters were quantified on all 4 EMG components: number of spikes (Nsp), mean spike amplitude (Amp), mean spike duration (Dur), spike frequency (Fre), and mean number of peaks per spike (P/sp). Within the interference pattern, a spike was defined according to Hirose and Sobue (1972) definition.

Practice effects across days and the inflence of sex and loads were assessed using a factorial analysis of variance model with repeated measures. Data collected on days 4 and 8 were further compared using an intraclass reliability analysis of variance model in order to test for the reproducibility of the parameters monitored.

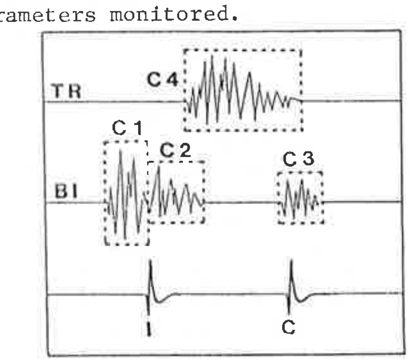

Figure 1. EMG recorded for a typical trial. BI and TR: biceps and triceps EMG; I and C: event markers. (see text for description of C1 to C4 components)

	C1			C2			C1→C2
	Prac	Load	Sex	Prac	Load	Sex	
Nsp	≈	↑17%	≈	≈	↑18%	↑36%	≈
Amp	≈	≈	≈	≈	≈	≈	≈
Dur	↓12%	≈	≈	↓13%	↓5%	≈	↑22%
Fre	↑8%	≈	≈	↑11%	↑3%	≈	↓18%
P/sp	≈	≈	≈	≈	≈	≈	≈

Table 1. Summary of the results from the analysis of variance. Significant increase (↑), decrease (↓), and no significant changes (≈).

RESULTS AND DISCUSSION

Reliability of the EMG parameters collected on C3 and C4 was deemed too low to warrant further analysis. Reliability values for the EMG parameters for the agonist EMG burst components C1 and C2 ranged from fair to good (intraclass R= .48 to .87). These results replicate the ones reported by Boucher and Flieger (1985) on the reliability of the mean power frequency measured under the same conditions.

Table 1 presents a summary of the results from the analysis performed on all EMG parameters collected on the C1 and C2 components. In both C1 and C2, the spike frequency increased with practice, whereas, it increased with loads only in C2. As expected, the effects were the exact reciprocal for the mean spike duration as compared to the spike frequency. A drop in spike frequency, accompanied with an increase in spike duration, was also assessed from the beginning to the end of the agonist EMG burst (between C1 and C2). Finally, no statistically significant differences were found in both the number of peaks per spike and the mean spike amplitude in any condition.

The shift from higher to lower frequencies between the static (C1) and dynamic (C2) components of the agonist EMG burst corroborates the mean power frequency data reported earlier by Boucher and Flieger (1985), as well as single motor unit data presented by Desmedt (1981). The stability of the number of spikes and the spike amplitude, accompanied by significant variations in both the spike duration and frequency, would tend to demonstrate that a firing rate modulation mechanism is active with practice, and is responsible for an increase efficiency of the agonist muscle in the production of the movement. If more or less fast twitch motor units were recruited and/or motor unit synchronization would occur with practice one could expect the number of spikes as well as the spike amplitude to change. Such modifications were however not monitored in the present study.

Finally, the low reliability of all EMG parameters measured in the antagonist EMG burst (C4) and the lack of consistency in the occurrence of the second agonist EMG burst (C3) remain a puzzling question which warrants further investigation.

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<S-3-1>

ELECTROMYOGRAPHIC STUDY OF RUNNING IN CHILDREN OF VARIOUS AGES

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We recorded EMGs of running in persons ranging from small children just beginning to run to adults. This study was partially longitudinal and partially cross-sectional. From the results we inferred some ideas on how muscle activity of running develops.

Methods

The longitudinal portion of this study involved 12 children who, when first seen, were 1 year 4 months to 4 years of age (Goto et al 1979). They were followed electromyographically at intervals of 2-12 months over periods of 5-10 years.

The cross-sectional part of this study involved recording EMGs on the following subjects.

GROUP NAME	AGE RANGE	NUMBER OF BOYS	NUMBER OF GIRLS
TODDLER	1-3	6	6
PRESCHOOL	4-6	15	5
SCHOOL	7-11	15	10
ADULT	20-26	20	10

Surface EMGs were recorded using silver disk electrodes 5 mm in diameter, shielded cables, and an 18 channel pen-writing system of biological amplifiers. Sensitivity was set to 6 mm/0.5 mV, the time constant to 3 msec, and paper speed to 6 cm/sec. We recorded activity from the tibialis anterior, gastrocnemius, vastus medialis, rectus femoris, biceps femoris, gluteus maximus, sacrospinalis, and rectus abdominis. In some of the subjects we also recorded from the anterior and posterior portions of the deltoid.

The subject sprinted with an all out effort for 15-50 m, the distance depending on the subject's age. The cables were bound together at the subject's lumbar area and carried from behind by another person in such a way as to minimize the load on the subject.

We needed to clearly distinguish between stance and swing phases in order to definitively determine when the subject was running, so we made foot contact switches and hooked them into the 18 channel system via D.C. amplifiers to include a basogram with the EMG recordings.

We also used a 16 mm cinecamera to record running form from a lateral view. The camera ran at 32-64 frames/sec and filmed an area where the subject would be running at top speed.

Results

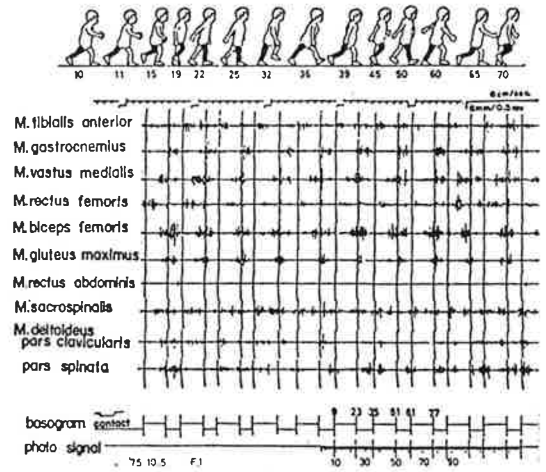
In adult sprinting, the rectus femoris displayed strong activity to raise the thigh early in swing phase. About the middle of swing phase the vastus medialis (knee extensor) and biceps femoris (hip extensor) became dominant, and before the foot reached the ground the gastrocnemius was showing strong activity. The rectus abdominis displayed two bursts per cycle, occurring in the latter half of stance phase for each foot (Matsushita et al 1974).

In children just beginning to run, usually after one and a half years of age, more often than not the rectus femoris (thigh raiser) did not manifest *conspicuous* activity. Likewise, the gastrocnemius (ankle plantarflexor) failed to be *strongly* active just before ground contact, as it fails to do in childhood walking. These features contrast with adult sprinting.

Other patterns contrasting with the adult form included a lack of strong activity in the rectus abdominis and of reciprocal activity between anterior and posterior fibers of the deltoid associated with arm swing.

Some of the children showed marked activity of the gastrocnemius prior to ground contact and of the rectus femoris just after toe off, two characteristics found in the adult pattern.

The airborne phase was extremely brief, and considerable variation of muscle discharge patterns from step to step was one salient feature among these novice runners.



EMGs and running form of a 1 year 4 month old child. This was the first time we saw definitive running in this child. The basogram trace was low when the right leg (indicated in black in the topmost figures) was in contact with the ground. The numbers beneath the topmost figures correspond to the numbers in the photo signal trace.

At two years of age, the sacrospinalis began to show two large bursts of activity, one at the beginning of ground contact and the other at the end.

At three and a half years of age, a large proportion of the children showed marked activity of the gastrocnemius shortly before ground contact. Activity of the rectus femoris became more marked after toe off than at the time ground contact began, so the thigh lift resulting from hip flexion became more vigorous.

Children at this age also manifested strong activity in the rectus abdominis when either foot was in the latter half of stance phase, and the anterior and posterior fibers of the deltoid displayed mutually reciprocal activity in conjunction with vigorous arm movements.

We could see a definite triplet of burst dishcarge patterns, first with the posterior deltoid coming on early in stance phase, next the rectus abdominis late in stance, and then the rectus femoris at the very beginning of swing. We consider the possibility that the swinging movement of the arm may, through descending interlimb reflexes, have evoked the subsequent activity of the other two muscles. The posterior deltoid would have moved the arm back, facilitating strong thigh flexion at the beginning of swing phase; and the anterior deltoid would have swung the arm forward to induce strong thigh extension prior to foot contact. These activities could not only have sped up the limb movements, but also have effected longer step lengths. We thus believe that the arm movements can contribute greatly to increased speed. We found that, up to three and a half years of age, step length increased at a greater rate than body height.

Characteristics especial to early childhood running diminished during further development, but did not completely disappear until about seven years of age, when muscular activity in the arms, legs, and trunk worked in clearly reciprocal patterns, and both muscle discharge patterns and running form greatly resembled the adult paradigm. Ground contact was no longer made with the heel of the foot so much as with the whole plantar surface or with the forefoot.

We thus see that changes in the way muscles work during early child development accord with movements that bring about increases in step length and step frequency, enhancing speed.

Conclusion

From these results we can see at about three or four years of age a metamorphosis in running from an exaggerated form of walking to active flexion and extension of the limbs. The child does not acquire an adult-like pattern, however, until about seven years of age.

Changes in muscle activation patterns as well as other aspects of physical maturation related to expanding the capacity of basic movements are the principal determinants of improved running speed up to about seven years of age. Improving speed thereafter depends more on the development of muscular strength and power.

Supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan.

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<S-3-2>

NEUROMUSCULAR CONTROL OF FORCE OUTPUT OF ANKLE EXTENSORS DURING STANCE PHASE IN HUMAN RUNNING

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Shuji Suzuki, Koji Kaiya and Shiroh Watanabe (Kyorin University, Japan)

The interrelationship of electromyographic (EMG) activity, change in muscle length of the soleus (Sol) and lateral gastrocnemius (LG) muscles, and their torque production during human running were studied.

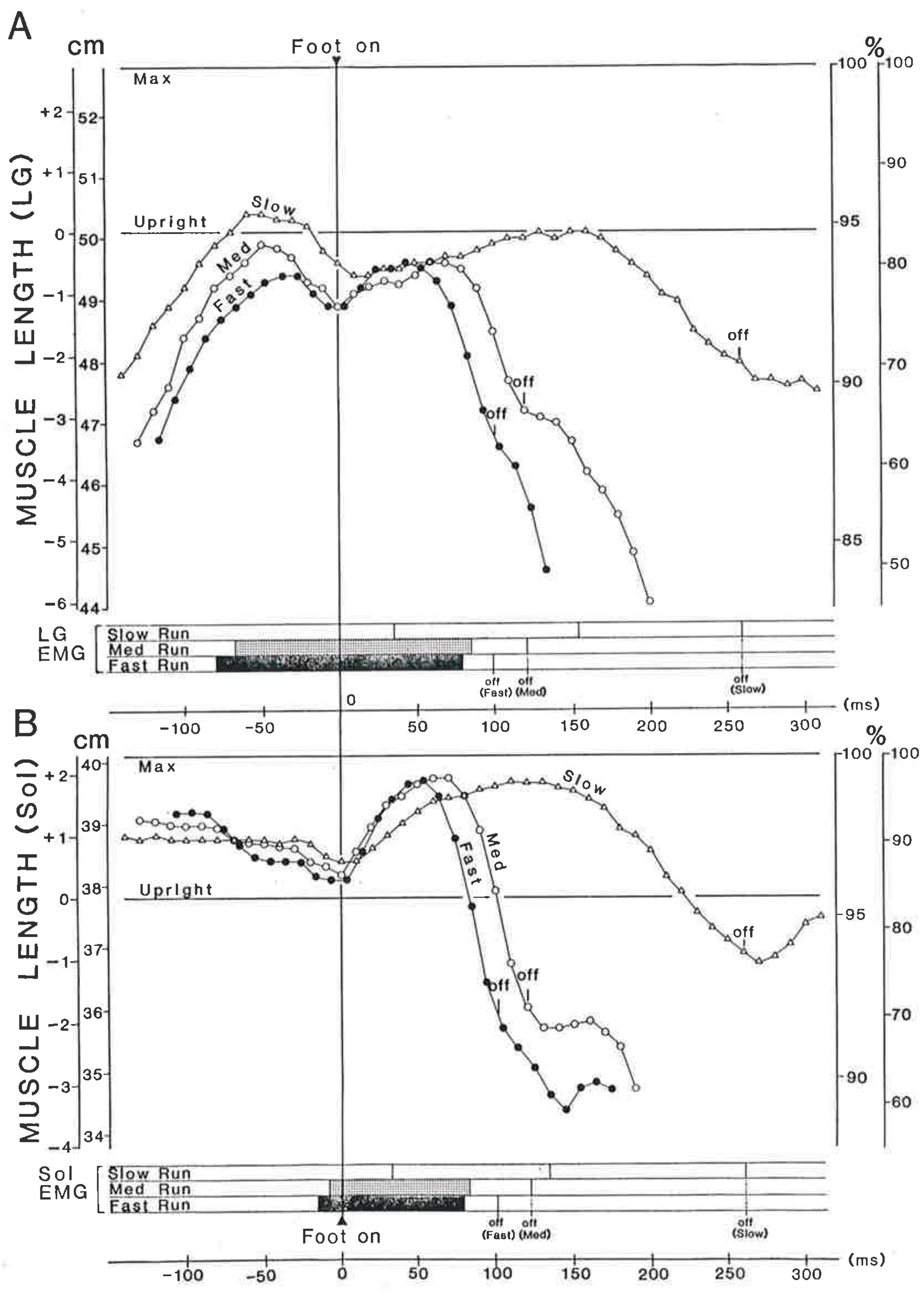
The subjects were asked to run at several self-selected constant speeds ranging from a jog to near maximum sprint on the track which was equipped with a force plate. EMG activities from the Sol and LG of the right lower extremity were recorded telemetrically. The right lower extremity movement was filmed at the rate of 97-99 f/s (shutter time : 0.8 ms) with a 16 mm motor-driven camera (Photosonics 1PL), positioned 30 meters from the subject. In sequential film frames, the meaningful anatomical points were marked, and then analyzed by computer (SPORTIAS MOTION ANALYZER, GP-2000). The length changes in Sol and LG musculotendinous units were estimated by means of Goslow's trigonometric equations, slightly modified. During running in each trial, three orthogonal components of the resultant ground reaction force were measured by the Kistler force platform. Then the resultant muscle torque about the ankle joint was derived by combining the ground reaction force data with the kinematic and body segment parameter (Chandler et al, 1975) data.

In Figs. A and B, the relationship between the EMG activity and the length changes of a sprinter's LG (A) and Sol (B) at three different running speeds are shown. The record of the subject, a top-class sprinter of Japan, was 10"38 for 100 meters. As speed was increased (705 to 505 ms in cycle time) the EMG initiation of Sol and LG tended to appear earlier. A remarkable shift forward of the onset occurred in LG. This EMG initiation appeared about 80 ms and 20 ms prior to foot contact in the LG and Sol, respectively, at running speeds near maximum. In general, at speeds of 500 to 600 ms in cycle time, most EMG initiation appeared from 80 to 120 ms prior to foot contact in the LG, and from 40 ms prior to to 10 ms after foot contact in Sol. In the LG muscle, the quantitative increase in EMG activity before foot contact became greater as speed increased, and the change was especially significant in the top-class sprinter.

Muscle length of LG during the extension (E_1) phase was observed one time to reach full extension, then shorten just prior to foot contact. Muscle length curves became steeper as speed was increased, but the peak muscle length became shorter. However, in the Sol muscle during the E_1 phase, comparatively small decreases in muscle length were seen as speed was increased. After the foot touched the ground, the EMG activities in both Sol and LG were enhanced during the early stance phase and disappeared at nearly the muscle's maximum length in the stance phase, especially at slow running speeds. As speed was increased to near maximum, the timing of the EMG activities in both muscles prolonged, and the activity ceased as the muscle length shortened.

The resultant muscle torque about the ankle joint of the same top-class sprinter had two positive peaks during the stance phase. The first torque peak was observed 25 ms after foot contact, and reached a maximum torque of 170 N·m while eccentric contraction occurred in the muscles. The 2nd peak occurred 21 ms after the first peak, and reached 146 N·m as the muscle contraction changed from eccentric to concentric. The first peak during eccentric contraction did not temporally vary in any other of the subjects, but the 2nd peak, where the change from eccentric to concentric contraction occurred, was not constant.

These phenomena observed during the E_1 and early stance phases suggest that the timing of the initiation phase and the quantitative values of EMG activity during running may be correlated to the changes of the muscle stretch activity.



<S-3-3>

ELECTROMYOGRAPHIC STUDY ON RUNNING

- HOW STEP LENGTH AND STEP FREQUENCY CHANGE -

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Running speed is a function of both step length and step time, so we can not only change running speed by altering step length and step frequency, but also alter these two variables while maintaining the same running speed.

In this study we examined the activities of muscles in relation to step length and step frequency to identify factors that may be important in sprinting. We looked at how activities of various muscles changed as the runner spontaneously adjusted to faster running speeds and also as the runner consciously changed step length and step frequency while running at constant speed.

Methods

The subjects were 10 adult men, capable of sprinting 100 m in 10.8-12.5 sec. Each subject ran on a treadmill, the speed of which was increased from 150 to 450 m/min in 50 m/min increments. Also, at 300 and 400 m/min the runner was directed to extend his step length, and again to increase his step frequency.

We recorded EMGs of 7-9 leg muscles, 2 trunk muscles, and 2 arm muscles, using 10 mm diameter surface electrodes, a Miller circuit to integrate EMGs for some muscles, and 16 mm cinematography to film a lateral view of the subject's running form.

Results and Discussion

Effect of Changing Running Speed

Step length increased with running speed, reaching a peak (194.1 $\pm$ 11.2 cm, mean $\pm$ s.d.) at 400 m/min. At 450 m/min step length decreased slightly.

Step frequency hardly rose between 150 and 250 m/min (160-170 steps/min), climbed gradually to about 200 steps/min as running speed increased to 400 m/min, and ascended markedly between 400 and 450 m/min, reaching 232.7 $\pm$ 11.4 (mean $\pm$ s.d.) steps/min.

Step length accounted for more than half the increase in speed at 150-350 m/min, but between 350 and 400 m/min at least half of the increase in running speed became due to step frequency instead. Beyond 400 m/min, step frequency accounted entirely for increase in running speed in some subjects.

Figure 1 shows EMG activity of one subject for each of the seven running speeds. In this subject, the increase in running speed from 350 to 400 m/min could be attributed about equally to step length and step frequency, so we considered the EMG activity at 400 m/min to represent muscle activity in running.

At 400 m/min, the *tibialis anterior*

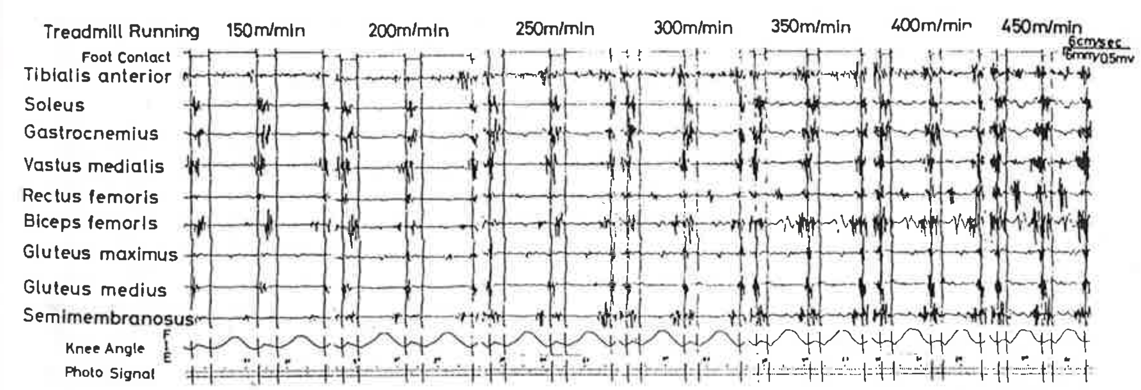

Fig.1 EMGs of running a various speeds (foot contact trace is low when the right leg is contact with the ground).

displayed a biphasic discharge sequence during swing phase to dorsiflex the foot. The *gastrocnemius* became active before ground contact and maintained activity throughout stance phase, working to raise the heel and to propel the body forward at push off. The *vastus medialis* was active prior to ground contact into the start of stance phase, working to brace the shank and help absorb shock. This muscle did not work in the propulsive phase of latter stance. The *rectus femoris* was slightly active just prior to ground contact and became very active at the start of swing. This muscle appeared to assist the vastus medialis as the foot contacted the ground. In swing phase, the rectus femoris worked with the *gluteus medius, tensor fasciae latae*, and *adductor longus* to flex the hip. The *biceps femoris* showed activity before the foot reached the ground until the end of stance phase, and the *gluteus maximus* worked in parallel, though starting later and finishing earlier than the biceps femoris.

Only at or above 400 m/min do we see the gastrocnemius become active prior to ground contact. This activity is unnecessary at slower running speeds, but requisite for fast speeds.

Muscles displaying increases in activity that corresponded to the increase in step length up to 400 m/min were the gastrocnemius, biceps femoris, and gluteus maximus, all of which are located on the back of the leg.

Some of the muscle activity associated with the marked increase in step frequency beyond 400 m/min came from the vastus medialis, biceps femoris, and gluteus maximus before ground contact. Not only did these discharges become larger, but they also began earlier. In addition, the rectus femoris, gluteus medius, and tensor fasciae latae became more active in the early part of swing phase to flex the hip forward quickly.

Effect of Conscious Changes

Figure 2 shows EMGs of a different subject running at 400 m/min while going in a comfortable manner, consciously increasing step length, and consciously increasing step frequency.

Increasing step length induced greater activation of the gastrocnemius, whereas increasing step frequency reduced such activity. Stronger push off by the ankle appears to be involved in enhancing step length. The biceps femoris and gluteus maximus, both hip extensors, became more active when the runner increased step length, but in some subjects the biceps femoris did not show such a change although activity in the gluteus maximus increased markedly. Thus, these two muscles may work together in a complementary manner.

The vastus medialis increased activity just before ground contact when the runner increased step frequency, whereas activity in the rectus femoris did not change much when the foot struck the ground. This latter muscle did, however, markedly increase activity just after toe off.

Step Length and Integrated EMG

Correlations were examined between changes in step variables and integrated EMGs of some of the muscles. The following were notable correlations between integrated EMG activity of the muscle and increase in step length: soleus (0.923), gastrocnemius (0.886), vastus medialis (0.657), biceps femoris (0.739) gluteus maximus (0.875), and rectus femoris (-0.621). The last correlation, strongly negative, suggests a corresponding positive correlation between activity of the rectus femoris and increase in step frequency.

Conclusion

Step length reaches its limit by activity of the ankle plantarflexors and hip extensors during ground contact. Step frequency is increased by activity of hip flexors during swing phase and of hip and knee extensors before stance.

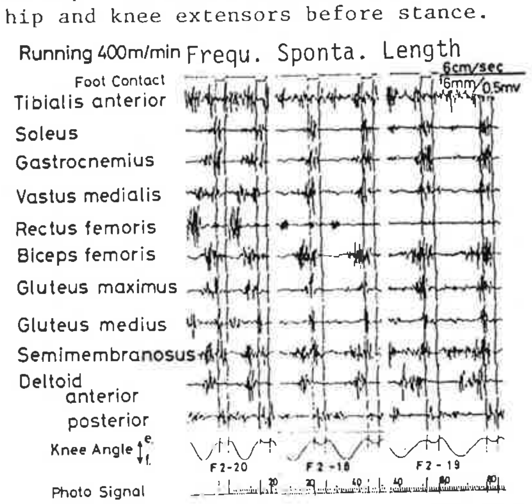

Fig.2 EMGs of running at constant speed with three different step lengths.

<S-3-4>

THE EFFECT OF ANKLE-TAPE ON LOWER LIMB MUSCLE ACTIVITY.

P. BOELENS, T. LOOS NIJMEGEN - HOLLAND.

In sportsmedicine taping techniques are regularly used for injury prevention and as part of therapy of injuries. Taping has an important mechanical effect on the joint mobility and joint stability.

In this report we have investigated the possible neurophysiological effects on surface EMG recordings by taping the lower limb muscles.

METHOD.

In 29 healthy subjects the surface EMG was recorded of the peroneus longus, the tibialis anterior, the soleus and the vastus medialis muscles on the left side.

The test situations were:

1. Standing on two legs;
2. Standing on the left leg;
3. Standing on the left leg with additional external force (2 kg.) applied at the left hip height.

The subjects were instructed: "to maintain balance" during each trial. The activity of the right peroneus longus muscle was recorded instead of the left vastus medialis muscle in the test situation of standing on two legs. The same test situations were repeated in 15 subjects after application of three tape straps on the skin of the left peroneus longus muscle.

The reverse order was followed in 14 subjects.

For the surface EMG recordings were used two Myomed 432 (twochannel myofeedback devices Enraf Nonius Holland), connected to an Apple II microcomputer, which used a moving average method to plot adequate curves of each muscle during the trial of 4.48 seconds.

The arbitrary units of microvolts calculated by the microcomputer were used by comparing the average values per position and per muscle and also the maximum values in all subjects with the Wilcoxon test.

RESULTS.

During standing on two legs the activity of the left peroneal muscle was increased in the taped condition. The right peroneal muscle showed a neutral result, while the other muscles did not show a consistent pattern. These results were not significant. The activity of the left peroneal muscle in the taped condition was significantly increased in both test situations while standing on the left leg. In most subjects the soleus and tibialis activity was also significantly increased.

DISCUSSION.

A description of the facilitation mechanisme of muscle activity by stimulation of skin receptors is to be found in most physiology textbooks.

Hagbarth reported the facilitation of the peroneal muscle under static conditions just by stimulation of the skin overlying the muscle. Horstink emphasized that stimulation of the skin causes reflectory muscle contractions. The data in this report support the hypothesis, that tape applied over a muscle facilitates its stabilisation action. This facilitation can be important in preventing injuries, because there is a loss in mechanical stability of tape after 10 minutes.

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<S-3-5>

DEVELOPMENTAL CHANGES IN MUSCLE ACTIVITY FOR WALKING UP AN INCLINE

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N Kazai (Bukkyo University)

In daily life we often walk not only on level surfaces, but also on stairs and slopes. Walking on a slope differs from walking on stairs in that one can freely choose and alter step length on a sloped surface, but not on stairs. This makes an inclined surface more useful for studying small children than stairs. Inclines are also frequently used for muscle strengthening and gait training in sports and rehabilitation. We have encountered little EMG literature on adults walking up slopes, and none at all on children, so we decided to examine muscle activity during uphill gait in subjects ranging from small children to adults.

Methods

The slope of the incline was set to 15 degrees.

One hundred subjects, from one and a half year old children (well able to walk) to adults, participated in this study. Some of the children we followed for over five years. We recorded EMGs using an 18 channel system of biological amplifiers, and silver disc surface electrodes. The subject's movement was photographed with a 16 mm cinecamera, contact switches were placed on the feet, and electrogoniometers were used at hip, knee, and ankle joints. Analog signals from all these devices were recorded together with the EMGs on the 18 channel system.

We recorded EMGs from the following muscles in the subject's right limbs and trunk: tibialis anterior, gastrocnemius (lateral head), vastus medialis, rectus femoris, biceps femoris, gluteus maximus.

Results

Adults

During the early part of stance phase in adults, as both knee and hip extended, we found strong maintained discharges in the vastus medialis and gluteus maximus, both uniaticular muscles. The biarticular biceps femoris also displayed strong activity, but not its antagonistic biarticular counterpart, the rectus femoris. This suggests that a greater load was being borne by the hip than by the knee. Later in stance the gastrocnemius emitted a strong burst of activity for push off, and in most cases the vastus medialis and rectus femoris were also active at this time, indicating strong extension at the knee. We do not see this active knee extension in the latter half of stance phase in normal adult gait on level surfaces at natural speeds.

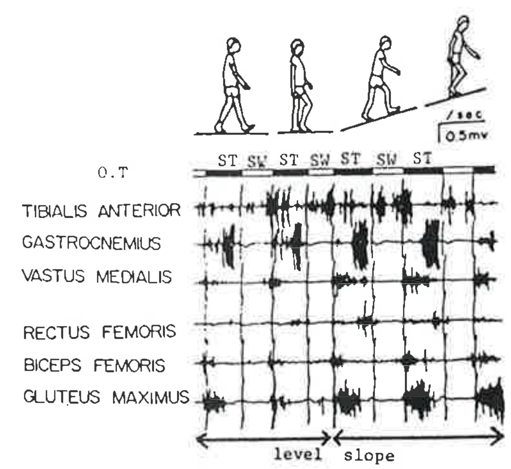

Figure 1. EMGs of an adult walking on a level surface and up a 15 degree slope.

One and a Half to Two Years of Age

In children between one and a half and two years of age, strong activity was noted at the beginning of swing phase in the rectus femoris, as the thigh was raised. In the latter half of swing phase the vastus medialis became strongly active to extend the knee. Our observations on the walking form confirmed the presence of active hip flexion in the first half of swing phase and of knee extension in the second half.

The gastrocnemius became active just at the beginning of stance phase and remained so throughout stance phase. This suggests a rapid transfer of weight onto the limb as stance began. The antagonistic tibialis anterior was usually maintaining activity at this time as well, presumably to help stabilize the ankle for enhanced balance.

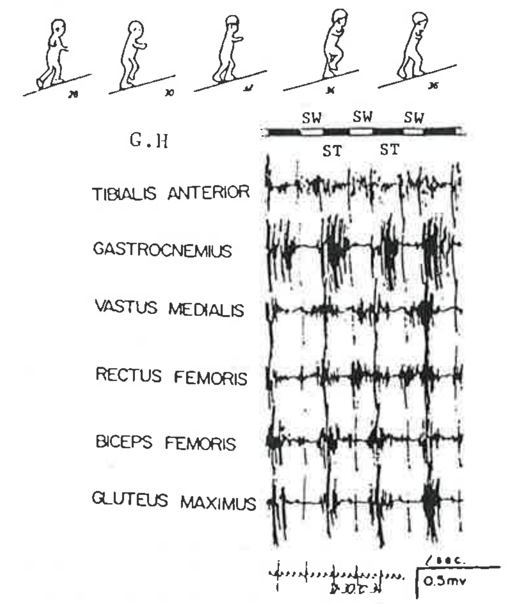

Figure 2. EMGs of a 1 year 8 month old child walking up a 15 degree slope.

Early in stance phase, the vastus medialis, rectus femoris, biceps femoris, and gluteus maximus were all strongly active. The presence of cocontraction between the rectus femoris and biceps femoris suggests that the load was shared between hip and knee extensors. As stance continued the biceps femoris remained active, but not the rectus femoris, suggesting a relative shift in emphasis to hip extension. This differed from the stronger knee extension that the adults displayed late in stance, as noted above.

Three Years Old

Among three year old children the rectus femoris displayed less activity early in swing phase than among two year olds. Activity in the vastus medialis, which began in the midst of swing in the youngest walkers, tended to appear later in swing phase among the three year olds. The gastrocnemius failed to be strongly active at the time of floor contact, but came on later in stance for push off, as in the adult pattern.

Throughout stance phase we saw tonic activity in the vastus medialis, biceps femoris, and gluteus maximus, but the rectus femoris become silent just after foot contact. We attribute this silence to anterior inclination of the trunk, which increased the requirement for the hip extensors to propel the body up the incline more than the knee extensors. Continued activity of the biceps femoris into the latter half of stance and failure of the rectus femoris to become active at that time differed from the adult pattern described above.

Maturation

In a few of the six year old children the vastus medialis and rectus femoris showed activity toward the end of stance phase, so that the knee was strongly extending as the ankle was actively performing push off.

By eight years of age most children displayed this pattern.

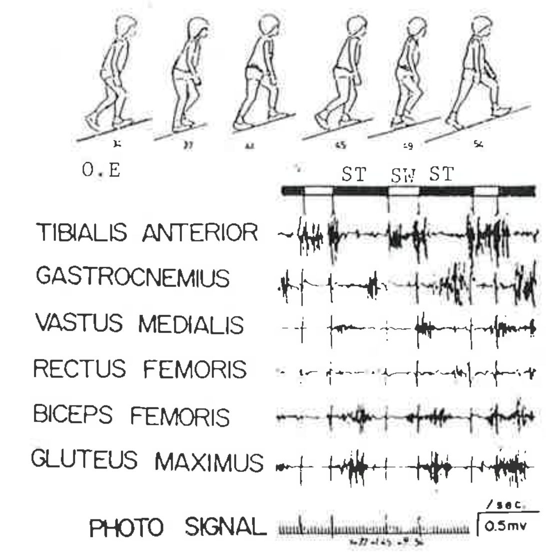

Figure 3. EMGs of a 6 year 1 month old child walking up a 15 degree slope.

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<S-4-1>

ELECTROMYOGRAPHIC OBSERVATIONS ON THE DEVELOPMENT OF INDEPENDENT WALKING IN INFANTS

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We frequently noted cocontraction of mutual antagonists among leg muscles as the child first began to walk, and we interpreted the cocontraction to indicate a lack of stable equilibrium. A very few cases, however, displayed adult-like patterns from the very beginning of independent walking, suggesting that the pattern adults use may already be inherent in a baby who is just starting to walk for the first time.

In the present study we followed EMG activity in five children from the time they first walked independently until they displayed adult-like patterns, that is, until three or four years of age. We sought evidence to further clarify whether or not babies beginning to walk already have the basic mechanism to generate an adult-like pattern, and we also wished to reconfirm our previous observations on normal infant walking (Okamoto and Kumamoto 1972, Kazai et al 1976). In addition, we extended to over 10 years our longitudinal observations on another four children whom we had followed from first walking to achieving adult-like muscle activation patterns. To this we supplemented cross-sectional data from another 200 subjects from infants to adults.

Swing Phase in First Steps

Note in Figure 1 the strong burst from the rectus femoris as the hip began to flex. In most cases, we saw the vastus medialis active at this time, as well as the gastrocnemius (lateral head) and the biceps femoris. A look at the gait pattern shows that the biceps appeared to be flexing the knee. The gastrocnemius may have been contributing to the knee flexion as well, but it may instead have been restraining the active dorsiflexion that was taking place. The vastus medialis may have been activated by a stretch reflex mechanism during this knee flexion.

In the latter half of swing phase, the vastus medialis and gastrocnemius showed strong activity with the knee extending and the ankle plantarflexing. All of this activity in swing phase resembled the pattern of muscle activation seen when an older child or an adult runs fast.

Stance Phase in First Steps

As the foot contacted the floor, the tibialis anterior and gastrocnemius continued a strong cocontraction pattern that began during swing. This cocontraction may help stabilize the ankle to compensate for inadequately developed balance function. Meanwhile, at the hip and knee, the vastus medialis, rectus femoris, biceps femoris, and gluteus maximus contracted together if the baby could take only two or three steps, but the activity of the rectus femoris died out as the baby became able to take more steps. Activity of the rectus femoris was associated with holding the trunk upright over slightly flexed legs, whereas this muscle displayed less or no activity as the baby began to lean the upper body forward over the slightly flexed legs. The rectus abdominis, inactive in adult gait, also displayed bursts not only in swing phase but also in stance.

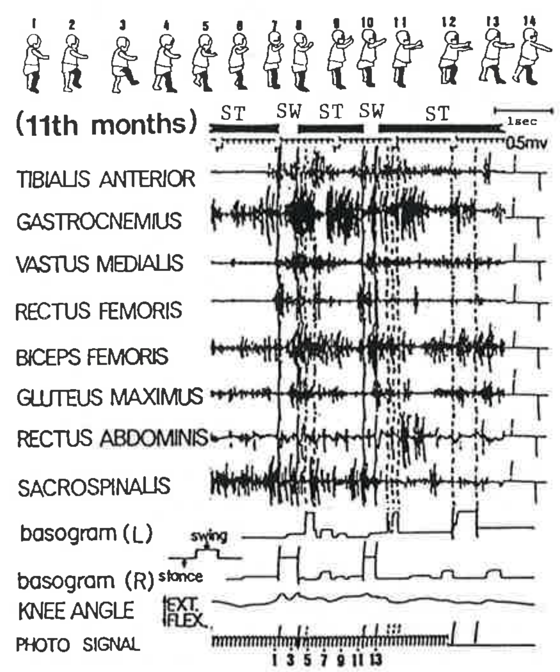

Fig.1 EMGs of a baby who succeeded in taking four independent steps for the first time.
ST:stance phase SW:swing phase

Adult Pattern Present from Start?

Even within such an early stage, signs of decreasing cocontraction in conjunction with a forward migration of the originally upright trunk were associated with a more adult-like pattern. This suggests that elements of the adult pattern already reside in the baby who is just beginning to walk independently. Most novice walkers fail to display an adult pattern at the beginning because of poorly developed muscle strength and equilibrium function. These deficiencies give rise to instability, and so excessive muscular activity results in a pattern that looks more like an adult running fast than walking.

The First Few Weeks

One week after independent gait began, activities of the tibialis anterior and rectus femoris became sparser during stance, the strong bracing action at the ankle apparently decreasing, and the upper body began to lean forward over still slightly flexed legs. A few babies, presumably because of the posture assumed and the speed of walking employed, showed adult-like patterns.

At two to four weeks of walking experience, the baby could generally take 20 steps and used a reciprocal pattern between the tibialis anterior and gastrocnemius. The vastus medialis showed less activity during stance phase, associated with a straightening of the legs and thus less load on the knee. The tibialis anterior failed to show any burst of activity just prior to foot contact in some cases, unlike the adult pattern, In these instances, the foot was not inverting during plantarflexion as it had been before when the tibialis anterior had been active.

Subsequent Development

The "running pattern" that originally characterized swing phase began to disappear between one and two months of independent walking.

Between two and three months the "running pattern" and activity of the rectus abdominis went away completely, suggesting a considerably more stable equilibrium. The lack of activity in the tibialis anterior just prior to foot contact continued to be seen in a number of subjects, so this feature may be considered one pattern peculiar to early walking in babies. During stance the biceps femoris and gluteus maximus manifested maintained discharge patterns, associated with a forward leaning trunk.

Up until about the end of two years of age the baby propelled the body forward with a pumping action of the thigh as the trunk leaned forward, rather than by strong push off at the ankle as seen in adult gait. After the foot contacted the ground, a quick shift of the body to the forefoot, a subsequent pattern characteristic of gait in small children, appeared.

At about three years of age, however, the continuous activity of the biceps femoris and gluteus maximus, associated with forward inclination of the trunk, began to dwindle as the trunk started to assume a more upright position. Activity of the gastrocnemius in the first half of stance phase disappeared, but condensed into a strong burst during the latter half of stance, similar to the adult pattern, to effect a strong push off by the foot. These findings enabled us to reconfirm one idea drawn from our previous work, namely that at about three years of age, the child walks with a muscle activation pattern that begins to look similar to the pattern seen in adults. In our previous work, we had found that almost all children demonstrated adult-like patterns by seven years of age, so we have set seven years as the age at which the muscle activation for gait should be fully mature.

Supported by a Grant-in-Aid for Scientific Research, The Ministry of Education, Science and Culture, Japan.

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ELECTROMYOGRAPHIC STUDY ON PRIMITIVE AUTOMATIC WALKING AND SUPPORTED VOLUNTARY WALKING IN INFANTS

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If a baby up to two or three months old is supported by the axillae and the trunk is inclined forward, this should induce a stepping pattern called "primitive walking" (McGraw 1940). In our earlier work (Okamoto and Goto 1982) we found that, as babies first begin to walk, the leg muscles display cocontraction of mutual antagonists, but a few of the activation patterns resemble those of walking adults. In the present study, we studied infants from 20 days to 11 months, none of whom could yet independently walk. We recorded EMGs as they walked by primitive walking or by voluntary supported walking to see what muscle activation patterns of adult walking might already be inherent in the movements of babies.

We studied seven babies, whose ages were 20 days, and 2, 3, 6, 7, 9, and 11 months. We followed the 20 day, 6 month, 7 month, and 11 month old babies at monthly intervals up to the times they became able to walk.

EMGs were recorded on an 18 channel pen-writing system of general-purpose biological amplifiers, and also on a 14 channel optical recording visigraph. We used small silver-silver chloride surface electrodes 5 mm in diameter to detect activity from the eight muscles listed in Figure 1, and photographed the walking from front and side views with video or cinematic cameras.

Voluntary Walking Requiring Support

In babies who could not yet walk independently, even in the 6 month old baby (Figure 1), activation patterns of the tibialis anterior and gastrocnemius during walking in a walker showed similarity to adult walking patterns.

Giving the baby unstable support induced cocontraction patterns characteristic of babies who are just beginning to walk independently. In the latter part of swing phase, the baby displayed vigorous knee extension and ankle plantarflexion, just like that seen in a sprinting adult. If given adequate support, however, the baby walked with discharge patterns that looked more like those of a toddler who has been walking for at least three months.

When the upper body was supported in an erect posture as the baby walked, the rectus femoris became active around the time the foot contacted the floor, but activity in the antagonistic biceps femoris was in the process of decreasing, as in an adult walking pattern. When the trunk was supported in an anteriorly inclined posture, activity in the rectus femoris was minimal, a pattern not seen in adults.

From this we see that babies not yet able to walk can display some adult walking patterns of muscle activation, but only under certain circumstances of stability. Such babies usually do not encounter these circumstances because their muscular and equilibrium systems have not yet matured enough to create the required stability. They thus typically demonstrate wide variations from the adult theme.

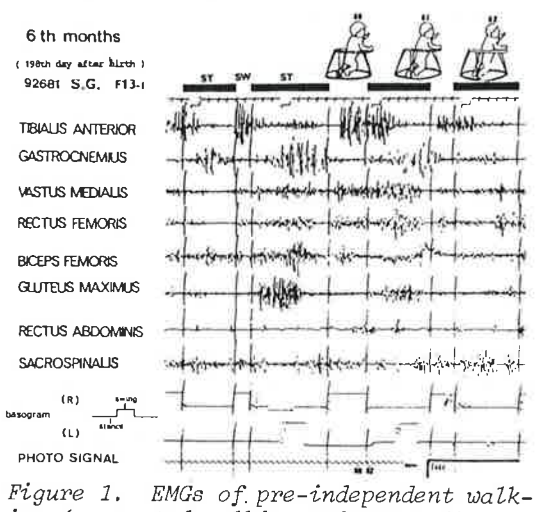

Figure 1. EMGs of pre-independent walking (supported walking using a walker).

Primitive Walking

In primitive walking (see Figure 2 for a representative example), the movement itself was much less orderly than in adult gait. The infant quickly raised the thigh to start swing phase, and the inertia thereof brought the knee into extension, but gravity brought the leg back down. The limb then typically slowly extended further down until the forefoot or entire plantar surface of the foot contacted the floor. In a few cases, foot dorsiflexion failed to accompany the quick thigh flexion, with the result that the foot dragged forward along the floor.

Stance phase, considerably longer than swing, had posturing that involved knee flexion at some times and knee hyperextension at others. This irregularity contrasts sharply with the consistently slight knee flexion that adults use in gait to absorb shock and progress smoothly forward.

At the very beginning of swing phase, the biceps femoris, rectus femoris, and tibialis anterior became active almost simultaneously to flex the hip and the knee and to dorsiflex the foot. In only a few instances did the vastus medialis and gastrocnemius also exhibit activity, resulting in a muscle activation pattern suggestive of what we see in a baby walking independently for the first time.

Just before the foot reached the floor, the vastus medialis, rectus femoris, and gluteus maximus usually became active to extend the hip and the knee. Simultaneous activity from the biarticular rectus femoris and biceps femoris at this time sometimes showed an adult-like pattern, and sometimes not, as we could see in the supported walking mentioned above.

Digitigrade gait was the rule during primitive walking. We can see this also in a baby who first begins to walk independently. For the novice independent walker, the gastrocnemius is already strongly active as the toes reach the floor, but in the present study on primitive walking, we were unable to find such activity from the gastrocnemius until the foot actually contacted the floor. This negative finding stands in clear contrast to what Forssberg (1980) described in an independently conducted EMG study on primitive walking.

We saw many instances of cocontraction of mutual antagonists in stance.

The muscle activation patterns in primitive walking, except for the lack of ankle muscle activity just prior to floor contact, resembled our findings (above) for unstable supported walking of non-independently walking babies. These patterns are further suggestive of muscle activity in a baby just beginning to walk for the first time, and somewhat resemble the activity seen in a fast running adult.

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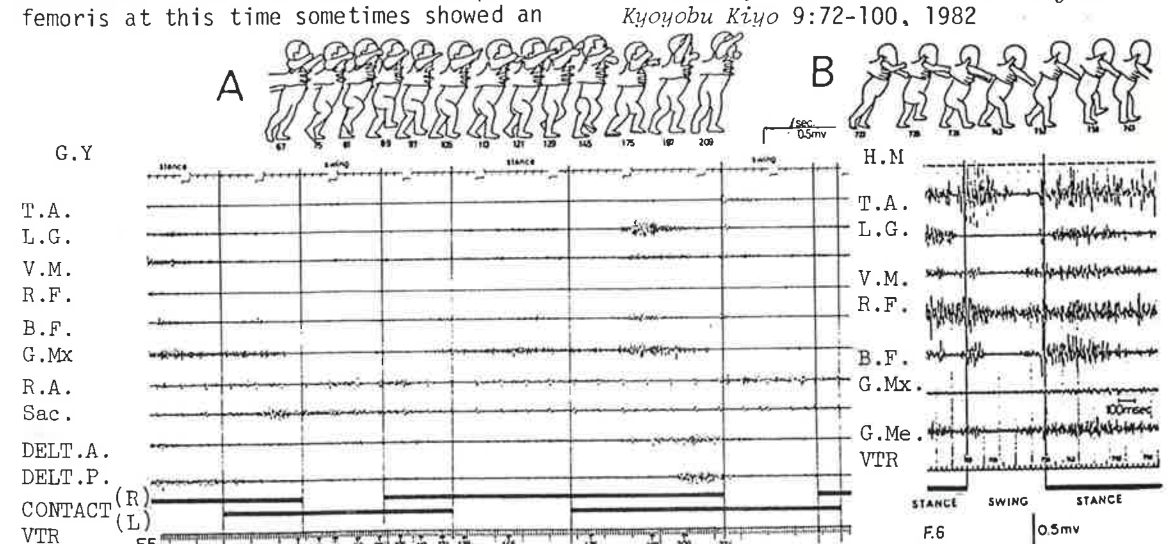

Figure 2. EMGs of primetive walking: **A** *50th day after birth* **B** *59th day after birth*

<S-4-3>

EVALUATION OF THE EFFECT OF PHENOLISATION BY MEANS OF A QUANTITATIVE FOLLOW UP STUDY

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ABSTRACT

Phenolisation of peripheral nerve ends (motor points) is described as a means for achieving a reduction of spasticity.
Sixteen hemiplegic patients were treated for a spastic equino-varus foot after a period of at least six months succeeding the C.V.A. This time span eliminates effects due to improvement of the neurologic disorder.
The results were evaluated by means of surface EMG, gait-analysis and a clinical function test of the leg.
Short term results, as expressed in the 'M response' immediately after phenolisation, showed a significant (substantial) reduction of activity.
Long term results as obtained by the clinical function test of the leg, differed.

A preliminary report on the long term effects, after evaluation of EMG and gait-analysis data over a one year period after the phenolisation, will be presented on the ISEK congress in August 1985 in Tokyo.

<S-4-4>

Gait Analysis of Postoperative Club Foot

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Introduction

Since 1973, 80 cases of congenital club foot in children were treated in Nagasaki University Hospital using Turco's method (postero-medial release). The clinical results of the post-operative congenital club foot children were mainly checked by a routine method by examing the range of motion (ROM) of the ankle joint and roetogenographic changes of the foot (such as talocal-caneal angle, tibro-calcaneal angle and talus-1st metatarsal angle).

Recently, the authors have been trying to evaluate the clinical results of the postoperative club foot children from the viewpoint of the ground reaction force. The purpose of this study is to find out whether there are some parameters in ground reaction force for the assesment of the clinical results.

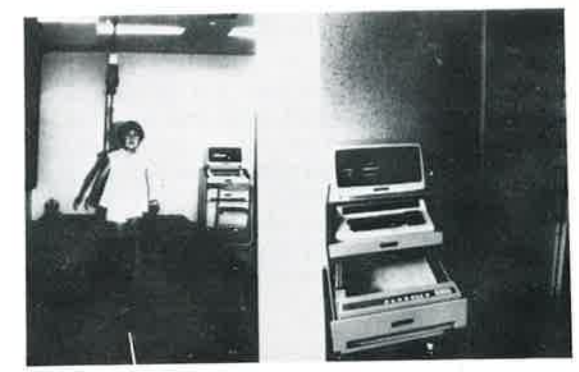
Patients and Methods

29 patients with congenital club foot, which comprized 14 bilateral cases and 15 unilateral cases were studied. The age range of the patients was 6 to 13 years old, and at least 3 years had passed from the date of operation. The normal subjects included 36 children between the age of 6 and 10, and 40 adults. The age distribution of the subjects is shown in Table 1.

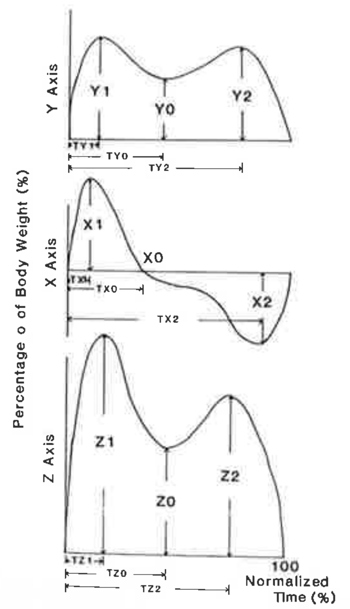
NORMAL		CONGENITAL CLUB FOOT		
AGE	TOTAL	BILATERAL	UNILATERAL	TOTAL
6.0	6	1	4	5
7.0	8	2	2	4
8.0	9	3	2	5
9.0	8	1	1	2
10.0	5	7	6	13
ADULTS	40			
TOTAL	76	14	15	29

Every subject was asked to walk on the walkway, in the center of which two large-sized force plates were embedded. In this experiment 10 to 15 trials (at least 20 steps by each foot were measured) were undertaken and the ground reaction force was normalized by by computer (PC-9801 F, NEC, Tokyo)

Figure 1 shows the experiment and the authomated gait lab system.



The normalized reaction force is shown in Figure 2. The Y axis is the lateral component of ground reaction force (G.R.F.), The X axis is the forward-backward component and the Z axis is the vertical component. Y1, X1 and Z1 are the value of the peak point in the phase of deceleration. Y2, X2 and Z2 are the same in the phase of acceleration, and Yo, Zo is the valley between the restraining period and the prospelling period. Xo is the turning point from the phase of deceleration to the phase of acceleration of the forward-backward component.
TY1, TYo, TY2, TX1, TXo, TX2 and TZ1, TZo, TZ2 is the time refered to in Y1, Yo, Y2, X1, Xo, X2 and Z1, Zo, Z2. (The measurement of the G.R.F. is studied by Dr. Noguchi in our department and presented in a paper to the International Society of Biomechanics in 1983)



The G.R.F.data was fed in to the computer accompanied with the data of the clinical results and other clinical factors such as dorsiflexion and plantar -flexion of the ankle joint, the ability of tip toe gait and the measurements of the roentogenogram, so as to examine the correlation between G.R.F.and the clinical factors.

Results

The values of the peak point in the phase of acceleration of the forward-backward component (X2), was in high positive correlation to the clinical results, plantar-flexion, tip top gait and talus-1st metatarsal angle.

The same point in the phase of acceleration of the vertical component (Z2) was also in high positive correlation as X2 was,except for the talus-1st metatarsal angle.

Y2 (lateral component) was found in high negative correlation to the clinical results, and talus--1st metatarsal angle, but only in the bilateral club foot group.

The time of the turning point from the phase of deceleration to the phase of acceleration in the forward-backward component (TXo) was in high positive correlation to the clinical results, dorsiflexion and tip toe gait. (tahle 2)

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CORRELATION TABLE

		C.R.	D.F.	P.F.	T.T.G.	T-1stM
X2	B	*		*	* *	*
	U	***		***	***	***
Z2	B	* *		*	* *	
	U	***		○	* *	
Y2	B	- *				-**
	U					
TXo	B	***	***		***	
	U	***	***		* *	

B: bilateral club foot   U: unilateral club foot

C.R.: clinical results   *** $p < 0.01$

D.F. dorsiflexion   ** $0.01 \le p < 0.02$

P.F.: plantar flexion   * $0.02 \le p < 0.05$

T.T.G.: tip toe gait   ○ $0.10 \le p < 0.20$

T-1stM: Talus-1stMetatarsal angle

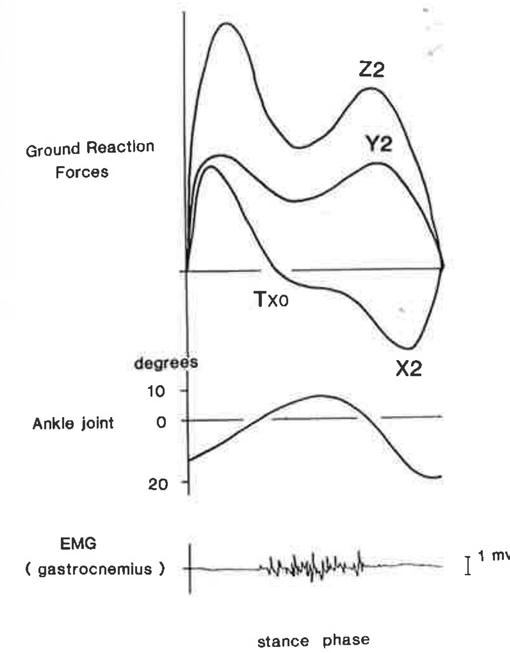
Discussion

From the results atated above and refer to Figure 3. (Figure 3 shows the simultaneous records of the ground reaction force with the movement of the ankle joint and EMG of the gastrocnemius muscle in the walking cycle), we can understand that when the plantar-flexion of the ankle joint is small (or limited) the ability of the tip toe gait will be poor and the vector of the sagital plane at the time of push off in walking will be small. In other words, X2 and Z2 will become smaller, while the dorsi-flexion of the ankle joint is small (or limited), the gait pattern will tend to be that of a stumping gait and the time of the phase of deceleration will become short. In other words the value of TXo will become smaller.

In addition, the greater the adduction of the anterior portion of the foot, the smaller the forward-backward component of G.R.F.(X2) will be at the time of push off. On the other hand the lateral component (Y2) will became smaller.

3

In this study, the measuring point X2, Z2, Y2 and TXo of the ground re-action force are found to be available in the clinical assessment for post-operative congenital club foot patients.



AUGUST 28 (Wednesday)

Session 5～8

<S-5-1>

MYOELECTRIC PROFILE OF ELECTRICALLY STIMULATED MUSCLE AND ITS RELATION FORCE

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Introduction

Recording, processing, and assessing the myoelectric signal (MES) of an electrically stimulated muscle is required for several clinical and research purposes, e.g., evaluating the gait of hemiplegic or paraplegic patients with functional electrical stimulation (FES) assist devices, and assessing FES exercise on reversal of muscle atrophy. Our interest in using the MES of a stimulated muscle as the feeback parameter of a closed-loop FES control system motivated the study described here. One of the most difficult problems in recording and processing the MES of an electrically stimulated muscle is the contamination of the signal with stimulus artifacts. Furthermore, the FES system we have developed consists of a dual electrode system delivering stimuli at 30 pps and at 600 pps to make induction of fused contraction and recruitment possible. Under such conditions the MES is contaminated with artifacts due to two stimuli, one of which is of high frequency. Indeed, when the MES trace is examined during the onset of high-frequency stimulus on the background of low-frequency stimulus, the MES compound action potentials are completely abolished. Our objectives, then, were to develop a technique for eliminating stimuli artifacts from the MES, and to process the signal so that its relationship to the developed muscle force is revealed.

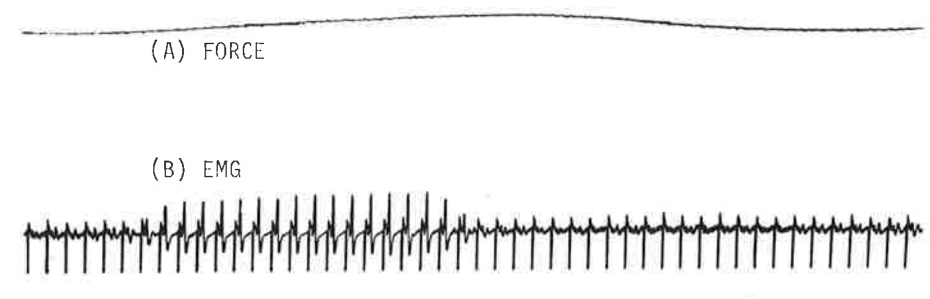
Methods

The soleus and gastrocnemius muscles of six adult cats anesthetized with chloralose were used as the experimental model. Two wrap-around electrodes were placed on the sciatic nerve and connected to their respective stimulators. Muscle force was measured with a Grass Ft-10 transducer attached to the severed calcaneal tendon under isometric conditions. EMG was recorded via fine stainless-steel wire electrodes inserted in the muscle with a hypodermic needle. Differential and preamplifiers provided gain up to 10,000 with 110 db common mode rejection ratio. A Chebyshev low-pass filter with a corner frequency of 550 Hz and eight poles was used to eliminate the artifacts due to the high-frequency stimulus of 600 Hz fundamental and all higher harmonics. Muscle force and EMG were recorded simultaneously with Gould 260 polygraph and HP FM tape recorder. The raw EMG was processed by two techniques, envelope detection and RMS value. The instantaneous median frequency was also calculated.

Results

Figure 1 shows the myoelectric profile during simultaneous low-frequency and high-frequency stimulation. Although all the artifacts due to the high-frequency stimulus are no longer present, the signal is still contaminated with artifacts from the low-frequency stimulus. To eliminate these remaining artifacts, we studied the effect of stimulus amplitude on artifact magnitude. As long as the low-frequency stimulus amplitude did not exceed three times suprathreshold amplitude, the resulting artifact consisted of a "notch" less than 1% of the compound action potential amplitude. The effect of such a "notch" is negligible if quantification of the EMG is contemplated. All further experiments consisted of low-frequency stimulus calibration at 1.5 times suprathreshold to insure artifact suppression while evoking the maximal available force from the muscle.

Figure 2 shows simultaneous recording of muscle force, EMG, envelope detected EMG, and RMS value of the EMG. The time constant of the envelope detection integrator was 180 ms.



FIGUR 1
Shows the force(A) and EMG (B) when recorded with a Chebyshev low pass filter at corner frequency of 550 Hz. The negative spikes are low frequency stimulus artifacts.

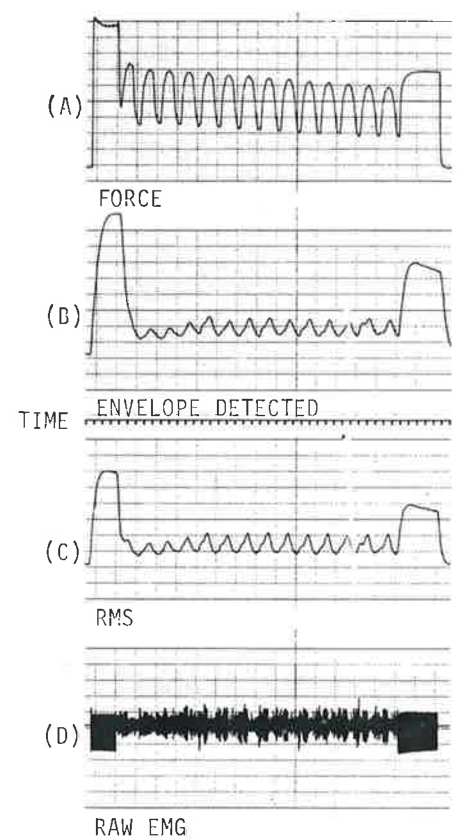


FIGURE 2
Showing (A) Force,(B)Envelope detected EMG,(C)EMG RMS value,and non-contaminated EMG (D).

Conclusion

Noncontaminated EMG was shown to be available for processing when stimulus amplitude was set below 3-time suprathreshold and a low-pass Chebyshev filter with eight poles was used.

The myoelectric profile of a stimulated muscle during recruitment consists of monotonic, large-amplitude compound action potential with gradual decrease in amplitude and desynchronization as the large motor units are deactivated.

Envelope detection and RMS values of the rectified show linear relationships to the force with the exclusion of fatigue. The RMS trace, however, tends to emphasize some of the EMG features that may be advantegeous if accuracy is required.

Calculation of the EMG median frequency provides a good estimation of the force, while accounting for muscle fatigue.

Supported by the American Paralysis Association

<S-5-2>

RELATION BETWEEN MUSCULAR FUNCTIONS OF THE QUADRICEPS FEMORIS AND MAXIMUM WALKING CAPACITY

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INTRODUCTION

Recent studies on spacial and temporal distribution of muscular activities during gait have shown that the activities could be divided into two modes, tonic and phasic. Also relation of muscle strength such as the quadriceps femoris muscle, both isokinetic and isometric, to walking capacity was suggested. However, there is no correlation between fast isokinetic and isometric strength (MVC) [Hamrin et al.,1982: Renstrom et al.,1983]. Thus, there remains a question how these two modes of muscular activities are related to the walking capacity such as velocity.

Motor time (MT) is a functional measure of muscle as reflecting rapid force generation of the muscle [Irie et al.,1983]. Clinically prolonged MT of the quadriceps femoris indicates the degree of walking disability in spinal paraplegics [Nakamura and Sajiki,1985]. In this study we examined MT and MVC of the quadriceps femoris to the walking capacity such as velocity, step length and walking rate, in healthy adults and attempted to solve the question above mentioned.

METHODS

Twenty men aged from 22 to 39 years participated in the study. The age, height and weight were recorded as personal variables.

1) WALKING CAPACITY. The subject walked as fast as possible on flat floor for 15 m. The time and the number of steps for 10 m were measured after walking velocity became steady. The subject performed the task three times. The trials with the shortest time was used as data from which the velocity (m/sec), step length (m) and walking rate (steps/sec) were calculated.

2) MEASUREMENT OF MT. The subject with closed eyes sat on a specially-designed chair with trunk upright, the hips flexed at 90° and the knees at 60°, and the heels were supported by a horizontally fixed metal bar. A metal knob was attached to the left heel. The metal knob and bar made a switch, signalling precise off time when the left heel left the bar. The subject was asked to extend his left knee as fast as possible. responding to a tone stimulus given 2 sec after a warning signal. EMG of the left rectus femoris was taken with surface electrodes and displayed with the off signal on a memoscope (ATAC 210,Nihonkoden), which was triggered by electric signal synchronized with the sound signal. The latency between the initiation of EMG activities and off signal was measured with msec scale on the memoscope (MT). After several trials the experimental session was started. The trial intervals were 10 to 20 sec and more than 10 trials were performed. The mean of 10 trials was used for statistical analysis.

3) MEASUREMENT OF MVC. The posture of the subject was as same as that of MT measurement. A strain gauge (U3B1,NMB) was vertically backward attached to the distal part of the left leg via wire and belt. DC output of the strain gauge was displayed on a X-Y recorder. The subject extended isometrically his left knee as forceful as possible about 3 sec. He tried three times with intervals more than 1 min. The maximum force among the three trials was used as his datum. The length between the lateral joint space of knee and the belt was measured, and the maximum torque was calculated (MVC,kg·m).

RESULTS AND DISCUSSION

1)DETERMINANTS OF THE MAXIMUM VELOCITY. There were significant correlations between the step length, walking rate and weight, and the velocity in Table. Multiple regression analysis indicated

	VELOCITY	STEP LENGTH	WALKING RATE	AGE	HEIGHT	WEIGHT	MVC	MT
VELOCITY								
STEP LENGTH	.565**							
WALKING RATE	.473*	-.457*						
AGE	.060	.107	-.018					
HEIGHT	.086	.006	.095	.196				
WEIGHT	-.433*	-.511*	.093	.237	.421*			
MVC	.109	.049	.087	.283	.398*	.557**		
MT	.161	-.300	.524**	.057	.202	-.040	-.111	

Table. Correlation matrixes among the variables. n=20 *:p<0.05 **:p<0.01

that the light weight and great MVC were significant factors for the velocity, VELOCITY= 6.232 -0.051×(WEIGHT) +0.056×(MVC) [r^2=0.364, $p<0.05$]. The velocity was positively related to the step length and walking rate in Table. Regression equation, VELOCITY=-3.374 +3.344×(STEP LENGTH) +1.156×(WALKING RATE) [r^2=0.996, $p<0.01$], showed that the long step length and high walking rate were significantly related to the fast velocity.

2) DETERMINANTS OF THE STEP LENGTH AND WALKING RATE. There was negative correlation between the step length and walking rate (r=-0.457, $p<0.05$), suggesting that the longer the step length became, the lower the walking rate in Table. Human could separately manage his step length and walking rate during daily activity. When he accelerates the velocity, both the step length and walking rate increase simultaneously (Larsson et al.,1980 : Grillner et al.,1979). However, at the maximum velocity his step length and walking rate would reach at a predetermined value. Regression equation for the step length and walking rate was STEP LENGTH= 1.060 - 0.018×(WEIGHT) +0.119×(MVC) -0.008×(MT) +0.892×(HEIGHT) [r^2=0.560, $p<0.05$], WALKING RATE= 1.514 +0.033×(MT) [r^2=0.274, $p<0.05$], respectively. The light weight, great MVC, short MT and long height were factors for the long step length. Only the long MT was significantly related to the high walking rate. These results suggest that MT determines both the step length and walking rate at maximum velocity.

Sutherland et al(1980), studing developmental change of walking during early childhood, reported that the increase of velocity in elderly children was mainly attributed to the increase of step length and the walking rate did not increase but rather decreased. Regarding the subject with the long step length as showing a matured walking pattern, there was close similarity between our results and their report, that is, the negative correlation between the step length and the walking rate at the maximum velocity.

In conclusion, muscular functions of the quadriceps femoris contributing walking capacity were interpreted as follows:

1) the greater the MVC became, the faster the velocity, and

2) the shorter the MT, the more mature the walking pattern.

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<S-5-3>

FOOT MUSCLE ACTIVITIES AND FOOT MOVEMENT DURING WALKING WITH FOOTWEARS

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INTRODUCTION

It has been found, from our data, that the foot movement caused by arch movement was restricted during stance phase of a walk with footwears such as the tennis shoes. EMGs, force plate data and foot movement were analysed simultaneously, to investigate muscle activities during walking with footwears. The purpose of this study is to clarify the difference between muscle activities during walking with footwears and those with barefeet.

METHOD

EMGs of M.gastrocnemius(M.g.), M. extensor hallucis longus(M.e.h.l.), M. extensor digitorum longus(M.e.d.l.) and M.tibialis anterior(M.t.a.) were recorded. Force plate data and foot movement recorded by a 16mm high speed camera were used to monitor the phase of a walking cycle. Four kinds of footwears (tennis shoes,rubber sandals,Japanese Geta and Setta) and barefeet were used in the experiment, and the subject walked with 4 speeds (60,80,100,120m/min.).

RESULT

The discharge of M.e.h.l. was completely restricted during walking with all footwears. It corresponds to the restriction of the great toe movement with footwears, comparing to those with barefeet.

The activities of M.t. and M.e.d.l. were activated and their contraction times were elongated during walking with all footwears, comparing to those with barefeet.

The start of contraction of M.g. was apt to be postponed during walking, especially with tennis shoes.

It is concluded that the foot muscle activities are affected greatly by putting on the footwears.

<S-5-4>

PATHOLOGIC GAIT DIAGNOSIS WITH THE RATIO MEASURMEENT COMPUTER AVERAGE ELECTROMYOGRAPHIC PROFILES

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Smoothly joint movement were decided by control of antagonistical muscles activity,therefore antagonistic muscles by E.M.G. inspected about integrator during free walking from able-bodied subject and patient. The action potincal of the E.M.G. were integrated each antagonistic muscles, and struck an averag the ratio between extensor and flxsor muscles of integrating action potincal, because the simple integrating action potincal with E.M.G. indicated individual defference.

The purpose of this reseach is to demonstrate the use of ratio measurement computer-averaged E.M.G. pattern, as a diagnostically valuable implemet for the assessment of pathologie gait, also emphasized the need for statistically reliable E.M.G. profiles of the able-bodied population to serve as a reference for comarison with patients E.M.G.

Method and Results.

The electromyographc technique described apply equally to both able-bodied subjects and patients.

Five muscles (TIB.ANT. GASTROC. REC. FEM. VAST.LAT. BCEP.FEM.)and footswich signal were recorded at any time using a biotelemetetry system in conjunction with an E.M.G. and ratio meusurement conputer. Surface electrodes were placed over the middle of the muscle belly, footswitches taped to the heel, Ist metatarsal head,5th metatarsal head,and toe of the subject or patients sole.

The E.M.G. signals were transmitted 4 channel F.M. biotelemetry system.

The ratio measurment computer operate on integrate for the action potencal of the E.M.G. by biotelemeter between each muscles,and point out the ratio each muscles integretig action potencal.

The deta of ratio were decided to one phase of each selected strides and were determined at the average of I0th measurements.

An objict were 20 students in our school and all patients were hemiplegia with C.V.D.were I8 patients.

Data of subject patterns were observed that ratio of the lower limbs muscle, gastrocnemus/tibialis anterior 80%, rectus femoris/biceps femoris 50% Increment of cadence were inspected more than ever activty of tibialis anterior so ratio were lowering 40%.

Data of patients patterns indicated variation,ther were decided for condation of foot sole contact.

That is to say gait of patients were observed abnomal patterns,pes equinus pes valgus pes vulgus flat foot,there were differentiated each muscles function.To confirm of this mthode be used assessment of rehabilitation treatment and muscles function for antagonistic muscles.

<S-5-5>

COMPRESSION OF EMG DATA

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INTRODUCTION

This work describes the joint effort of two groups of researchers in the field of electromyography, to compare different data compression strategies. As a result, an efficient protocol is proposed to be adopted in EMG data compression.

In particular the objective of this research is to show that the mean and the median frequency can be retrieved by an autoregressive (AR) model. By using an AR model the computation time will be reduced considerably which makes the application of microcomputers an attractive alternative.

The Power Spectrum was computed for the same EMG signals by using the following methods:

- . Fast Fourier Transform (FFT)
- . Maximum Entropy Spectral Estimation (MESE)
- . Autoregressive spectrum estimation by Recursive Least Squares (RLS).

A good agreement was found for the mean frequency in all cases.

The final protocol that is proposed uses the MESE algorithm; this was selected because no committment is made to unavailable data and it is efficient as for the computing time.

DESCRIPTION OF THE METHODS USED

Traditional Method

The Power Spectral Density Estimation, or simply the Spectrum, based on the direct approach via the FFT operation on the data is called the Periodogram.

Many of the problems of the periodogram estimation technique can be traced to the assumption made about the data outside the measurement interval. The finite data sequence may be viewed as being obtained by windowing an infinite length sample sequence with a rectangular function. The use of only these data implicitly assumes the unmeasured data to be zero which is usually not the case. This commitment to unavailable data leads to the phenomenon of leakage. Although this can be reduced by appropriate windowing, other disadvantages still remain:

- . the frequency resolution is limited by the available data length independent of the characteristics of the data or the signal to noise ratio, and
- . some sort of averaging is necessary to obtain statistically consistent estimates.

Maximum Entropy Spectral Estimation Method

This method (Burg, 1968) suggests that the estimated autocorrelation function should be predicted beyond the data-limited range. The principle used for this prediction process is that the spectral estimation must be the most random, i.e., must have the maximum entropy of any power spectrum which is consistent with the sample values of the autocorrelation function. The objective is to add no information as a result of the prediction process.

Subsequently, it has been shown (Van den Bos, 1971) that the MESE method is equivalent to the least square fitting of an autoregressive model to the process.

Autoregressive Spectrum Estimation Method

An autoregressive model is a stochastic model in which the current value of the process x_t is expressed as a finite linear summation of previous values of the process and an unknown innovation of the process n_t.

It is assumed that n_t, for all t, is a linearly independent stochastic variable, with zero mean and a certain variance. Being n_t totally unknown, x_t can be predicted only approximately from a linearly weighed summation of its past values. The difference between the actual value x_t and the predicted value $\hat{x}_t$ represents the estimation error, also known as the residual. In the method of least squares fitting of the model, the parameters a_k are obtained by minimizing the mean or total squared error.

SUBJ	FFT+/- S.D.	MESE (P)	RLS (P)
1	79.5+/-11.9	72.1 (4)	69.5 (3)
2	80.3+/-12.2	66.6 (4)	66.5 (4)
3	102.6+/- 8.8	105.2 (4)	105.1 (4)
4	73.9+/-14.1	66.5 (4)	66.3 (4)
5	80.9+/-11.0	84.3 (4)	82.5 (3)
6	97.4+/-28.2	81.2 (4)	80.8 (4)
7	108.8+/-14.3	120.5 (3)	120.8 (3)
8	118.2+/-22.4	99.5 (4)	102.6 (6)
9	83.9+/-21.3	69.3 (5)	68.9 (5)
10	151.8+/-49.1	145.4 (4)	142.5 (4)
11	62.8+/-14.6	54.8 (5)	56.6 (6)
12	63.8+/-12.5	62.2 (5)	59.8 (4)
13	63.8+/- 8.4	58.7 (5)	60.6 (6)
14	76.1+/- 9.4	67.4 (5)	66.4 (4)
15	79.3+/-10.5	67.5 (5)	65.7 (4)
16	94.4+/- 5.7	97.6 (5)	97.5 (5)

Table I: Comparison of the mean frequency estimated with the three different methods.

IMPLEMENTATION OF THE METHODS

A data base of 16 normal cases was considered to test the relative efficiency of the illustrated methods. The signals were measured by concentric needle electrode from the biceps brachii during voluntary contraction in the range of 20% 30% maximum voluntary contraction by using a Medelec MS6. The test was carried out under isometric non-fatiguing conditions with the arm flexed at 90° and the forearm in complete supination to avoid synergic contraction of the agonist muscle . The EMG signal was sampled at 5 kHz after low-pass filtering with a phase equalized 4th order Butterworth filter with 2 kHz cut-off frequency to prevent aliasing phenomena. Twelve blocks of 2048 samples were considered, because of the requirements of the FFT method mentioned before, that is stationarity and resolution. Whereas all blocks had to be used for estimation of the spectrum by the FFT algorithm, one only was selected for the other two algorithms by the following procedure: the variance of each record was calculated, the mean of these variances λ^2 was taken as a reference; processing was carried out for the block with the highest variance in the range 1 to $1.5\lambda^2$.

A system call was introduced into all the programs in order to quantitatively compare access time to the CPU of the VAX 750 system.

From the estimated spectrum the mean and median frequency was computed (ISEK, 1980).

RESULTS AND DISCUSSION

From our results the mean frequency appears to be a more robust parameter than the median frequency.

With reference to Table I the results can be summarized as follows:

- the order of the adopted model is less than or equal to 5, and
- the values of the median frequency estimated by the MESE and RLS methods show a very good agreement with the results of the FFT in all cases but 2 and 15. When the resolution is improved by adding 2048 zeroes to the data, also cases 2 and 15 show a good agreement.

On the basis of these results and because of the reduced computation time (about 10 times faster than the traditional method) adoption of the MESE algorithm is suggested for computation of the mean frequency. The efficiency of the proposed protocol allows to state that application of microcomputers is an attractive alternative.

ACKNOWLEDGMENTS

The authors are grateful to Professor K.L.Boon, whose contributions and financial support made this project possible.

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<S-6-1>

Position and movement detectors in composition of wrist joint afferents in the cat

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The terminal branch of cat's deep radial nerve contains only afferent fibres innervating the wrist joint and deep tissues (Zalkind, 1971,1972, Tracey, 1979). For the present investigation the dorsal wrist joint nerve in the anesthetized cats was prepared for shradding into 3-5 thin filaments. The afferent discharges from each filament were recorded by the use of a variety of stimuli: direct local pressure on the capsula, an increase of the intra-articular pressure by means of injection of warm saline into the joint, after a change in different static positions, during passive movement in both directions starting from the "intermedial" angle 120° as well as during a small "active" movement initiated by electrically indused twitches of flexors or extensors.

In the majority of filaments several units were observed simultaneously but in some cases only a single unit response could be recognized. Their action potentials were recorded as plots of instantaneous discharge rate versus time.

In the course of the steady-state indentation a lot of previously silent units were made active. The likewise effect followed by the after-discharge occured as the intra-articular pressure was increased. Many more afferents were recruited during small "active" movements in comparison with their amount caused by the passive movement of the same amplitude.

By the response to passive stepwise movements both rapidly-adapting (RA) and slowly adapting (SA) receptors were revealed. The former generated 2-5 spikes with the rate up to 600 pps at the beginning of fast movements. There were 2-3 RA units in some filaments. As soon as the joint had been maintened at a new position the SA receptors showed obvious differences in a course of adaptation and thus were subdivided into movement detectors (MD) and position detectors (PD). The MD could not fire tonically more than 0.5-5 sec, sometimes they responded only with the movement. Nevertheless long-lasting responses on indentation and intra-articular pressure indicate their SA origin.

When the wrist was progressively extended or flexed the discharge rate of the MD units increased. A phasic burst reached the maximum as either of the extreme positions was approached and while a range of the movement increased. The number of recruited units and the duration of their adaptation rose as the angle came nearer to its extreme value.

The PD units generated the spike train lasting more then 30 sec if the wrist was fixed at one of the extreme positions. The minority of units exhibited a rather wide "working range"-30-40°, including the "intermedial" range. If a stepwise stretch was started from an extreme position a pause in afferent discharge could be found. The slopes of "joint angle-discharge frequency" relation of the PD units were nonlinear. No units responding to the whole range were obtained. The maximal afferent discharge was recorded during the rotation of the wrist and when it was held in the extension position.

The representation of the wrist joint afferents in SI and SII was examined. The focuses of the maximal evoked potentials had a square about 1 mm^2 . The joint afferent projections were superimposed with those of muscle and skin afferents (Zalkind, 1981).

During the clinical examination a palpation of a joint and muscle region causes no disturbance in the position sense despite the fact that it might excite many capsular and muscle afferents. It appears that c.n.s. has to "open the inputs" for the significant afferent signals at the moment. The filtering processmay be performed differenly for the passive and active movements.

In the cat the detaction of the "intermedial" range hardly plays an important functional role. The wrist joint is mainly used in quick movements which start with an extended position. Even a slight displacement in this range may cause a lot of unites to change their discharge characteristics including the RA units.

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<S-6-2>

ELECTRO-MECHANICAL RESPONSES DURING AND FOLLOWING ELECTRICALLY INDUCED MUSCLE CONTRACTION FROM LOW OR HIGH FREQUENCY STIMULUS

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INTRODUCTION

The underlying mechanisms of muscle fatigue have been attributed to various parts of the final common path : decreased central excitatory drive, neuromuscular transmission failure and impairment of contractile machinery. Recently, a number of attempts have been made to determine the various sites of muscle fatigue during maximally stimulated contractions.

Muscle stimulation at appropriate frequencies and for short periods of time can produce similar force outputs as voluntary contractions, although the recruitment patterns are quit different. These maximally stimulated contractions serve as an index of muscle contractility and are independent of central drive.

The present study was designed to repeat earlier human experiments with a synergistic muscle group. The results support the hypothesis that force fatigue during high frequency stimulation can be largely accounted for by failure of electrical transmission due to the reduced muscle membrane excitability. In addition electrophysiological responses with respect to the evoked potential amplitude, conduction velocity and EMD(electrical mechanical delay) changes during high frequency fatigue of 50 Hz or 80 Hz.

METHODS

Experiments were performed on the triceps surae muscle of seven male subjects who ranged in age from 20 to 24 years. Each subjects was fully informed about the possible risks and nature of experiments and signed the informed consent. Amplitude and conduction velocity of the evoked action potential during and after electrical stimulation were measured. Each subject was seated on an insulated, straight-backed chair with wide belts crossing his chest and abdomen to tightly fix his body. The force of the isometrically contracting triceps surae muscle was recorded during 20, 50, and 80 Hz nerve stimulations.

The posterior tibial nerve was stimulated with a small surface electrode by the methode of deVries. A brief train of squre pulses (300 μs duration, 80 V amplitude) from a stimulator was delivered through an isolation unit with a felt-tipped exploring electrode. The stimulus intensity was further increased by 10 to 20% to ensure the supramaximal stimulation.

For force recording, a piezo-type transducer was placed between the base metal plate and the force lever plate. The force signal was amplified through a charge amplifier. For surface compound mass action potential (M-wave) recording, silver silver chloride electrodes (7 mm diameter) filled with conducting jelly were applied over the muscle belly.

All EMG signals were fed through high impedance preamplifiers with 200 dB

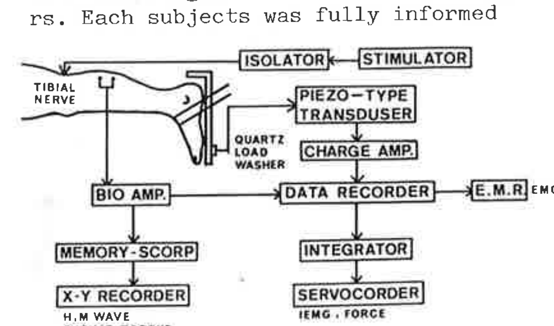

Fig.1 Experimental shema of E. Stimulus

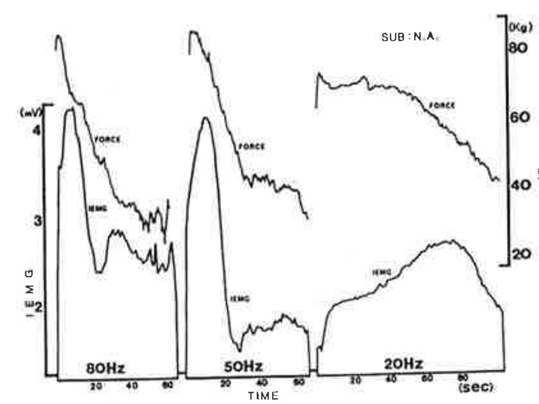

Fig.2 Force and IEMG Reduction

common mode rejection ratio and amplified.

RESULTS and DISCUSSION

The muscle was stimulated via the posterior tibial nerve at a constant frequency. Figure 2 shows the integrated EMG and mean force values during stimulated contractions. At 20 Hz stimulation, the force remained fairly constant. At higher frequencies (50 and 80 Hz), which were required to match the force of the max. contraction in unfatigued muscle, a marked decline in force was evident. After 20 sec of high frequency stimulation, significantly less force was generated than after a similar period of low frequency stimulus. At this stage of the high frequency force fatigue, considerably greater force was developed at 20 Hz stimulation.

The surface EMG M-waves in response to different stimulation frequencies are presented in Figure 3. At 20 Hz, there was a gradual increase in the amplitude during the first 20 to 25 sec of stimulus. During 80 Hz tetani, a marked slowing and prolongation of the waveforms were demonstrated along with a gradual increase in the amplitude at the beginning. Thereafter a very rapid decline in the amplitude became evident. It is clear that the initial action potential amplitudes were almost identical, but thereafter marked changes in the amplitude were seen with higher stimulation frequencies.

Rest and following EMGs potentials were recorded from the triceps surae. The recordings of the following evoked potentials after stimulus showed similar changes as seen with rest EMG recordings. The absolute magnitude of changes in the force relaxation time, M-wave conduction time, and EMD were appeared with high or low frequency stimulation. These data suggest that both EMG signals showed essentially the same pattern of the amplitude recovery and relaxation after high frequency

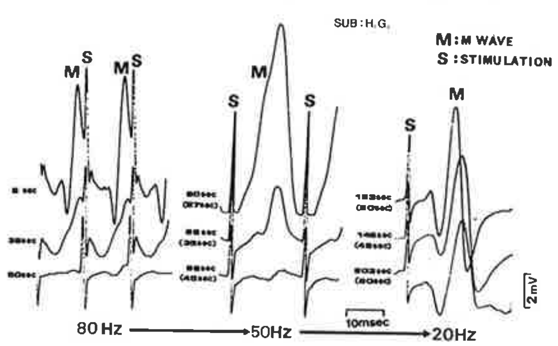

Fig.3 Action Potencial (M-Wave) Changes

tetani, with the extent of lag time being more pronounced in the muscle. Furthermore, the slowing of action potentials was greater for this triceps surae muscle, particularly during 80 Hz stimulation. The origen of high frquency fatigue resides solely on the time-dependent cationic exchange in order to maintain the muscle membrane excitability.

For motor units participation in the muscle contraction, Power Spectrum Analysis were caliculated by the digital computer as seen in the upper part of Figure 4. Other motor units except stimulus frequency appeared in the fresh muscle as 170 and 200 Hz. But in the fatigued muscle these frequency were elased sudently. It has been postulated that so-called high frequency fatigue is a result of insufficient time available for the sodium pump to restore the Na^+ and K^+ exchange during the passage of each stimulus impulse. This reduction of extracellular Na^+ or accumulation of K^+ may reduce the muscle membrane excitability sufficiently during high frequency tetani to account for the excessive loss of force.

SUMMARY

The force and evoked action potentials obtained from surface electrodes were recorded continuously during stimulated contractions of the triceps surae at 20,50, and 80 Hz. Excessive force and potencials loss during tetani contractions were accompanied by a marked reduction in the amplitude and conduction time (prolongation).

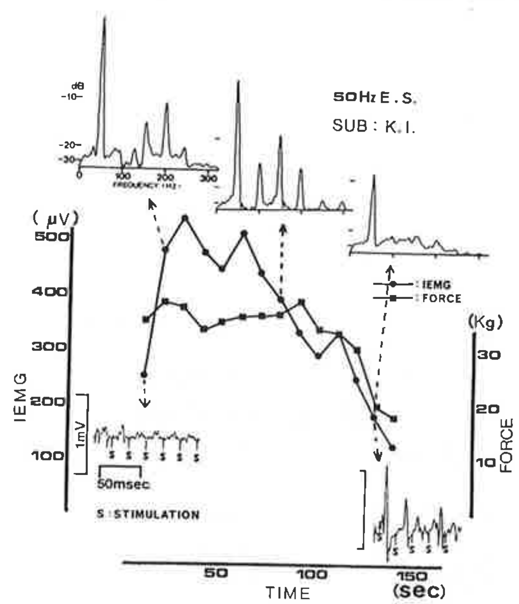

Fig.4 Power spectrum and IEMG Changes

CHARACTERIZATION OF FAST EDL AND SLOW SOLEUS MOTOR UNIT ACTION POTENTIALS

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INTRODUCTION

The shape of motor unit action potentials (MUAP's) is in its essence determined by three groups of parameters (Griep et al., 1982). First, the action potential data at fibre level. Second, the geometrical arrangement of endplates and fibres in a motor unit. Thirdly, the conductivity properties of the tissue between the active fibres and the recording electrode.

We have shown (Wallinga-de Jonge et al., 1985), that in in vivo preparations the intracellular action potentials of fast twitch glycolytic (FTG) extensor digitorum longus (EDL) and of slow soleus fibres differ significantly, especially in the slopes of the de- and re-polarisation phases. We now checked whether the MUAP's of FTG EDL and slow soleus motor units are different or not. This is an interesting aspect for the characterization of motor units.

In EMG-recordings with wire electrodes in voluntary active muscles the MUAP's are often separated of each other. The shape of the AP of each active MU can be analyzed. It is easier to study these MUAP's than the mechanical activity of the MU. Characterization, e.g. based on the contraction time in the twitch pattern of the MU, demands averaging of several hundreds of responses and is not sufficient for unambigious classification (Burke, 1974 and Clamann and Robinson, 1985).

METHODS

(1) Animal and muscle preparation

The measurements were carried out in vivo, on the right m. extensor digitorum longus (EDL) and right m. soleus in the hind limb of the rat. The rats (Wistar; male; 3-4 months old; 0.30-0.35 kg) were anesthetized intraperitoneally with pentobarbital sodium. EDL and soleus muscles were used in separate experiments in different rats. The muscle was in vivo at 35 $\pm$ 1°C as described before (Wallinga-de Jonge et al., 1985). All experiments were performed at optimum twitch length of the whole muscle.

(2) MU stimulation and typing

Single motor units were stimulated with the epimuscular stimulation method of Griep et al. (1980). The typing occurred as described by Wallinga-de Jonge et al. (1985). EDL-MU's were fast twitch glycolytic (FTG) and all soleus-MU's slow.

(3) Electrodes and recording systems

The EMG electrodes were trimell coated Karma wires of 25 µm diameter. The signals were preamplified (input impedance 10^{12} Ω//3 pF). The bandwidth of the EMG recording system was 0.1 Hz - 30 kHz (-3 dB).

(4) Signal processing

Amplification of the force signals and the EMG's was used for good dynamic range in A-D-conversion. The sample frequencies used were 10 and 100 kHz resp. The 10 bit samples were stored on hard disc in a PDP 11/03 computer system.

RESULTS

(1) Characteristics of MUAP's

An example of a MUAP-registration is shown in Fig. 1.

In our experiments with normal muscles and with the electrodes inserted half way the tendon and the end plate region the recordings normally are triphasic. In soleus units five phases are not exceptional. In both unit types aberrations of triphasic shapes occur when one or a few single fibre contributions predominate. Only three-phasic patterns are analyzed now.

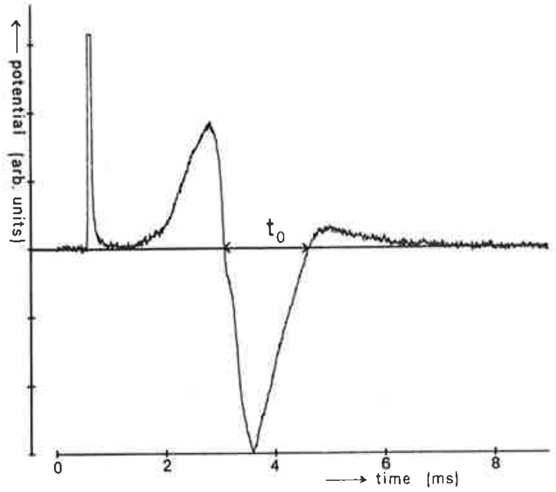

Fig. 1. A triphasic MUAP of a slow soleus unit (exp. RED 004.513 EMG 1). Recording starts 0.5ms before the stimulus. The characteristic, t_0 is indicated.

(2) MUAP's of FTG EDL units and slow soleus units.

The mean values and the standard deviations of t_0 of the two unit populations are indicated in table I.

	FTG-EDL units	slow soleus units
mean (ms)	0.74	1.34
s.d. (ms)	0.13	0.31
n	12	53

Table I. Mean values and the standard deviations (a measure of dispersion around the mean) of t_0 for two MUAP populations. The number of MUAPs in the populations are indicated with n; the significance level of the difference is very high ($\alpha < 0.1\%$).

CONCLUSIONS

The present paper describes one aspect of the MUAP shape of two types of MU's, the FTG EDL and the slow soleus MU's. It is found that the duration of the negative phase is significantly different in these two MU types. Data about other MUAP-characteristics will be presented at the congress.

Whether the MU type within a single muscle can be derived from their MUAP-patterns is under study.

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<S-6-4>

THE CHANGES OF EVOKED SPINAL POTENTIALS ON PARTIAL BLOCKING OF SPINAL BLOOD FLOW IN CATS.

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One of the causative factors of the spinal disfunctions would be a loss or lessen of blood flow in the spinal cord which might be ensued by tumors, O. P. L. L. and trauma. The present study was undertaken to investigate the correlation between blood flow and function of the spinal cord by mean of evoked spinal potentials in cats.

(Methods)

Twenty five cats were studied in this paper. Laminectomies were done from C7 to Th8 or 9 levels under intra-trachial anethesia, and stimulating electrodes were placed on C7 dura mater as well as recording electrodes at Th8 level. After these procedures, Thracotomy were performed to obstruct the intercostal blood flows which lead to ischemic or avuscular condition in the spinal cord. These vascular clipping technic were performed on from third to eight intercostal arteries. The amount of blood flow in the spinal cord were measured at the level of Th8 in each speciemens. The electrical responses were investigated before and after clipping of the arteries. Five cats were examined as a control materials without clipping of the arteries and others were with clipping.

(Results)

In the group with partial blocking of blood flow, the amplitude pattern of the first and second responses were quite variable. After clipping of the inter costal arteries, the amount of blood flow were 40 percent reduction in the spinal cord during clipping of the arteries.

On the contrary, the latency of the first and second potentials were delayed more than normal ranges within 20 minutes after clipping, especially the latency of the second potential was delayed very significantly.

<S-6-5>

AUGMENTATION OF THE EVOKED SPINAL POTENTIAL CAUSED BY COMPRESSION ON THE SPINAL CORD

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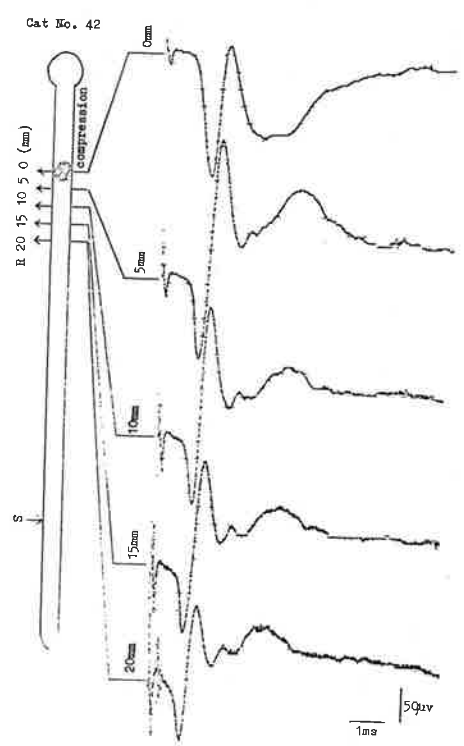
Recently, spinal evoked potential has been used for cord monitoring during operation for the purpose of detecting its injury in the early stage to prevent it from irreversible change. The amplitude of the potential is the most practicable indicator of the conductivity of the cord in the monitoring. A reduction in amplitude is frequently caused by conduction block in spinal tracts, and on the contrary an augmentation of the potential has been regarded as a sign of recovery in conductivity of the cord. Consequently, an important problem to be solved is whether such an augmentation of the potential is always a favorable sign of recovery or it may suggest a risk of spinal cord damage in some occasion. The first purpose of this paper is to describe the augmentation of the evoked spinal potential around the site of mechanical injury on the spinal cord. So far as we know, this phenomenon has not been described by any other literature till now. The second purpose is to study the mechanism of such augmentation, e.g. was it caused by a change of neuronal activity in the cord, or by a change of the volume conductor around the neural tissue duing to deformation of the spinal cord. The conductive spinal potential was evoked by epidural stimulation of the cord and measured around the site of subacute or acute compression as well as transection of the cord in cat. To confirm the possible mechanism, the change in amplitude of the evoked potential of the peripheral nerve was measured with transecting the nerve in situ and compared it with that in electrically isolating paraffin pool.

As results, augmentation of the evoked potential could not be always a favorable sign of recovery. It might be an early sign of spinal ischemia and subacute spinal cord injury, or it may exist near the site of mechanical cord injuries. Therefore, these exceptions must be beared in mind when spinal evoked potential is used as a tool to evaluate conductivity as well as viability of the spinal cord during operation.



<S-7-1>

SYNCHRONOUS MOTOR UNIT FIRING AT REGULAR INTERVALS PRECEDING RAPID VOLUNTARY MOVEMENT AND ITS RELATION TO MOTOR PREPARATION

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INTRODUCTION

It has been reported that, when a rapid voluntary contraction is performed following a slightly sustained contraction, the surface EMG during the sustained contraction changes to a rhythmic slower wave, with a periodicity of 20-30 msec, a few hundred milliseconds before the rapid contraction, and that the amplitude of the slower wave increases frequently (Tanii, 1984).

The aim of the present study was to determine whether the slower wave involves a synchronization of motor unit activity (experiment 1) and relates to motor preparation (experiment 2). The electroencepharogram (EEG) was measured to study a relationship between the slower wave and motor preparation. A slow negative potential in EEG preceding self-paced movement (readiness potential) is associated with the preparation to perform a specific movement, rather than with generalized preparatory processes.

METHODS

Experiment 1. Four male subjects were studied. A rapid extension of the trunk from a moderately bent angle of 50° in the sagittal plane was performed spontaneously (self-paced movement) and in response to a reaction signal (reaction movement). A weight of 10 kg or 15 kg was lifted simultaneously with the trunk extension from the platform in front of the subject as quickly as possible. The elbows were straightened during the experiments. In the reaction movement a warning signal (S1) was delivered 2 sec before the reaction signal (S2). The delivery of S1 was after the subject held a forward bent posture. The signals were delivered through an earphone.

Bipolar surface EMG and motor unit potentials were simultaneously recorded from the erector spinal muscle at the L4 level. A tungsten needle electrode was inserted into the muscle in the center between paired surface electrodes attached to the skin 2 cm apart above the muscle. The S1 and S2 signals and a signal from a hip-joint goniometer were also recorded.

Experiment 2. Eight male subjects participated. A rapid self-paced push of a belt with the wrist was performed powerfully following a slightly sustained push in sitting position on a chair. Then, the elbow was flexed at 110°. Force level of the sustained push was about 20% of the maximal voluntary force.

Bipolar surface EMG was recorded from the triceps brachii muscle. The EEG was recorded by Ag/AgCl electrode placed on the scalp at CZ of the 10-20 systems. The electro-oculogram was recorded simultaneously with the EMG and the EEG.

RESULTS

Experiment 1. The slower wave was observed in two subjects. Motor units fired synchronously at regular intervals of 20-30 msec during the slower wave. However, each motor unit was not recruited at the regular intervals. The synchronous firing at the regular intervals corresponded to projected EMG signals in the slower wave. Background discharge in action potentials from the needle decreased with the synchronous firing of motor units (see Fig. 1).

In the reaction movement of Fig. 1, the slower wave accompanying an increase of the amplitude appeared about 220 msec before S2 and broke with a decrease of the EMG amplitude about 120 msec before S2. Such an earlier appearance of the slower wave was observed very often in one of the two subjects. Subdivisions indicating maintenance of the slower wave appeared in the EMG after the break of the slower wave and corresponded to motor unit potentials which appeared at irregular intervals.

In other trial a large motor unit spike which appeared during the slower

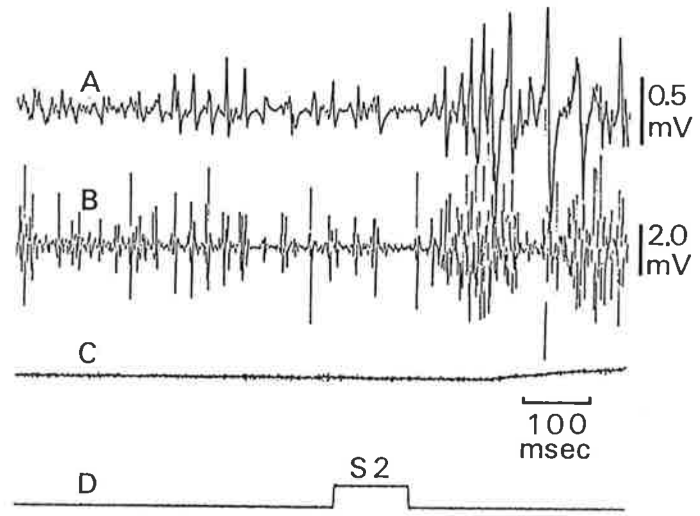

Fig. 1. Correspondence of synchronous firing of motor units at the regular intervals to projected EMG signals in the slower wave. A, action potentials recorded by surface electrodes. B, action potentials recorded by needle electrode. C, signal from the hip goniometer. D, reaction signal.

wave corresponded to the most projected EMG signal in this wave.

Experiment 2. A negative shift of the EEG potential by visual inspection was observed often in three subjects. Slowing of the surface EMG was recorded from them 250-800 msec before the EMG burst in the rapid push, including the slower wave. The slowing for one of the three subjects appeared often simultaneously with the negative potential. The slowing accompanying the negative potential was observed also in other two subjects.

Fig. 2 shows a typical recording of a concomitant slower wave with the negative potential. The amplitude of the slower wave did not increase. The slower wave was followed by the silent period prior to movement. The results indicate that the slower wave is related to motor preparation.

DISCUSSION

In the experiment 1, the results show that the regular periodicity of the slower wave is due to the synchronous firing of motor units at the regular intervals and suggest that the slower wave involves a synchronization of motor units. It is thought that the increase of the amplitude of the slower wave is due to an increase of the synchronized motor unit activity. The decrease of the background discharge during the changes of the motor unit activity suggests depression of spinal motoneurones during the slower wave.

In the present study it was suggested that the synchronous firing of motor units at the regular intervals occurred in connection with motor preparation for the rapid movement.

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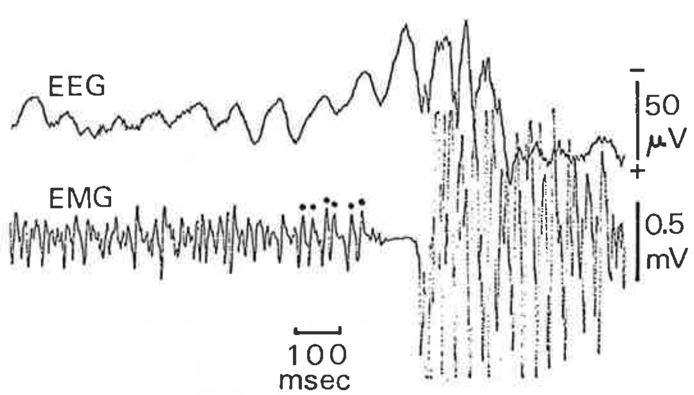

Fig. 2. Concomitant slower wave with negative potential in EEG preceding the rapid push movement.

<S-7-2>

THE COMMON DRIVE CONCEPT OF MOTOR UNIT CONTROL

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Introduction

To understand the strategy (or strategies) which the nervous system uses to control motor units for the purpose of generating and modulating the force of muscles, two central questions arise: 1) Is there a strategy or are there rules which govern the process of motor unit recruitment? 2) Is there a strategy or are there rules which govern the behavior of firing rates of motor units? The first question has received considerable attention. Notable contributions have been made by Henneman and his colleagues. The second question has not engaged a comparable level of excitement; possibly due to the technical complexity of the experiments necessary to address it. The occasional reports in the literature indicate that the firing rates of active motor units increase proportionally with increasing force output. This implies that increased excitation to the muscle motoneuron pool increases the firing rates of all the active motor units.

Experiments

The commonality in the behavior of the firing rates was studied in detail by De Luca et al (1982a,b). A new method, called the Decomposition Technique was used to separate the EMG signal into the constituent motor unit action potentials. See Mambrito and De Luca (1984) for details. We observed the behavior of the firing rates of up to eight concurrently active motor units in the deltoid, FDI, FPL, EPL, TA, ECU, ECRL Muscles during various types of isometric contrations. The contractions were performed under various conditions: attempted constant force, linear force increasing and force reversals. In all cases the direction of pull remained constant during a contraction.

Results and Discussion

The EMG signals were decomposed without any errors. The firing rates of the individual motor units were calculated as a function of time. The firing rates of the concurrently active motor units were cross-correlated. All the cross-correlation functions had values ranging from 0.6 to 0.9 and presented essentially no time shift. This indicates that the modulation in the firing rates occur essentially simultaneously and in similar amounts in each motor unit. It was also noted that the firing rates of earlier recruited motor units always maintained a greater firing rate than that of later recruited motor units. This behavior was rank ordered. Given that the initial (or minimal) firing rates of motor units at recruitment are considerably similar, it follows that the higher force-threshold, faster-twitch motor units will always have lower firing rates than the lower force-threshold, slower-twitch counterparts. This arrangement indicates a peculiarity of motor unit control during voluntary contractions. That is, the firing rate behavior is not complementary to the mechanical properties of the motor units. Higher threshold motor units tend to have shorter contraction times and twitch durations, and thus require higher firing rates to produce fused contractions. De Luca et al. (1982a) calculated that in some cases, the faster-twitch motor units never achieved a fused contraction during voluntary effort. This behavior provides a basis for the concept that in man, the full force generation potential of the muscle fibers may not be normally utilized during voluntary contractions. Conceivably, it may be held in abeyance for occasional dramatic displays of force.

Similar behavior of the firing rates has also been observed to exist in an agonist-antagonist set of muscles simultaneously. In one of our recent studies involving the FDL and the EPL, the sole controllers of the inter-phalangeal joint of the thumb, we noted that during voluntary stiffening of the inter-phalangeal joint, the firing rates of motor units in two muscles were highly correlated with essentially no time shift. During random flexion-extension isometric contractions of the inter-phalangeal joint, the firing rates of the antagonist motor units were negatively highly cross-correlated. This implies the existance of an ordered modulation of the firing rates of motor inits in two muscles; when the firing rates increased in one it decreased in the other and visa versa.

Conclusion

These studies described a unison behavior of the firing rates of motor units, both as a function of time and force. This property has been termed the Common Drive. Its existance indicates that the nervous system does not control the firing rates of motor units individually. Instead, it acts on the pool of the homonymous motoneurons in a uniform fashion. When two antagonist muscles are activated simultaneously to stiffen a joint, the nervous system views them as one unit and controls them in a like fashion. In this case, the homonymous motoneuron pool consists of the motoneuron pools of both muscles. A demand for the modulatin of the force output of a muscle may be represented as a modulation of the excitation and/or inhibition on the motoneuron pool. This is the same concept which comfortably explains the recruitment of motor units according to the Size Principle.

The accompanying figure represents a schematic expression of the concepts of the Common Drive and the Size Principle as well as other interactions between motor units involving the stretch reflex and renshaw recurrent inhibition.

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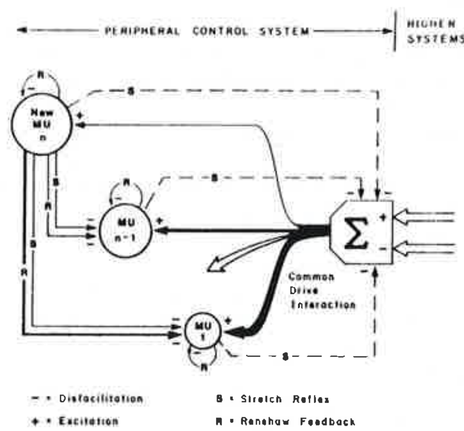

<S-7-3>

THE BLINK REFLEX, CLINICAL OBSERVATION UPON THE LATER RESPONSE R_2, ESPECIALLY CONSENSUAL R_2 IN THE INTRACRANIAL LESIONS.

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Introduction

An unilateral electrical stimulation to the supraorbital nerve elicits the early response R_1 of orbicularis oculi muscle on the ipsilateral side to the shock and the later response R_2 on both sides. In case of the brain stem lesion R_1 is usually abolished or reduced. In some cases of supratentorial lesions, abolishment or reduction of R_2 might be seen. When vibration (vibratory stimulation by Hagbarth) is given to the upper extremity some influences could be observed in the later response R_2 in such case. This study deals with analysis of the blink reflex activity especially consensual R_2 in the normal control, in case of supra and infratentorial lesions.

Materials and Methods

Electrical stimulation of 0.5 msec. duration square wave is given to the supraorbital nerve, and the blink reflex of R_1 and R_2 to the shock are recorded with two pairs of surface electrodes placed at the infraorbital regions (right and left). The later response R_2 with or without vibration to the upper extremity was observed.

The materials used in this study are 44 cases as a total, namely, 10 normals, 5 thalamic hemorrhages, 5 cases of tumor situated in the thalamus, 1 case of infarction within the thalamus, 5 cases of pons glioma and 18 cases of Parkinsonism.

Results

1) Normals :

Early response R_1 on about 10 msec. latency could be recorded ipsilaterally to the shock, and the later response R_2 on about 30 msec. latency could be recorded on both sides (direct and consensual responses).

When 100 Hz. vibration (Hagbarth's aparatus was used) was given to the upper extremity ipsilateral to the side electrically stimulated, the response R_2 of both sides (right and left) showed a certain augmentative change in the activity of direct R_2 and consensual R_2.

2) Thalamic lesions :

a) Hypertensive thalamic hemorrhage :
5 cases were examined in this study. Electrical stimulation to the supraorbital nerve contralateral to the lesion elicited the early response R_1 on the contralateral side to the lesion.

Vibration given to the upper extremity contralateral side to the lesion made no augmentative change in the response R_2 of contralateral side to the lesion. A certain change could be observed in the R_2 on the other side (ipsilateral side) but no R_1 could be seen. Vibration to the ipsilateral upper extremity to the lesion made some changes in the responses R_1 and R_2.

b) Tumor situated within the thalamus:
5 cases were tested in this study. Electrical stimulation to the contralateral side to the lesion elicited the early response R_1 but almost no later response R_2 (on the contralateral side to the lesion).

Vibration to the upper extremity on the contralateral side to the lesion made no augmentative change in the amplitude of R_2 response on the contralateral side to the lesion. Whereas the R_2 response on the ipsilateral side showed some augmentative change in the amplitude.

Electrical stimulation to the ipsilateral side to the lesion elicited R_1 and R_2 responses on the ipsilateral side.

Vibration to the upper extremity ipsilateral side to the lesion made some augmentative change in the amplitude of R_2 response.

c) Infarction within the thalamus :
Only one case was examined in this study

R_1 and R_2 responses were recorded in this patient by electrical stimulation. Vibration in this case, some augmentative change could be seen in the both sides. In this case thalamic function is thought to be still kept.

3) Tumor around the thalamus :

5 cases were tested in this experiment. Electrical stimulation to the contralateral side to the lesion elicited the R_1 response. Some cases whose thalamus affected by the pressure from the tumor did not show R_2 response, in which case destructive change could be considered in the thalamus.

The patients without destructive change in the thalamus usually showed R_2 response. Stimulation to the ipsilateral side to the lesion showed both R_1 and R_2 responses usually. Vibration to the upper extremity of the patients in this group showed some augmentative changes in the R_2.

4) Pons glioma :

5 cases were examined in this experiment. Electrical stimulation to the ipsilateral side to the lesion did not show neither R_1 nor R_2 on this side. Vibration given to the upper extremity of this side did not give any influence upon R_1 and R_2 responses. However the contralateral side stimulation elicits both R_1 and R_2 responses which are augmented by vibration given to the same side.

5) Parkinsonism :

18 cases were examined. Almost of these Parkinsonian patients but 2-3 cases respond to the electrical stimulation with R_1 and R_2. They also responded to vibratory stimulation to the upper extremity. The patients with severe rigidity or akinesia could not respond to vibratory stimulation given to the upper extremity.

Discussion

It is well known that in case of the brain stem lesion R_1 is usually abolished or reduced. However it is usually unknown that in case of supratentorial lesion, especially in case of the thalamic lesion R_2 is reductively changed or abolished. In this study R_2 was observed, and Hagbarth's vibratory aparatus was used. Vibratory stimulation given to the peripheral receptors makes some influences in the reflex activities in the spinal cord and brain. In this study it's influence upon R_2 activity

was observed. Afferent impuses from the vibratory sense organ are brought to the thalamus through the dorsal column in the spinal cord to the VL nucleus in the thalamus. And some parts of the impulses from the blink reflex performed at the orbicularis oculi muscles are thought to come up to the brain cortex through the VL nucleus. Therefor some influences are brought to their reflex activities.

In the normal person in this study augmentative change in the amplitude of R_2 could be seen directly and consensually. And in the case whose thalamus affected destructively by the tumor or hemorrhage in the thalamus shown in this study did not demonstrated almost no change in the response R_2.

Conclusion

The blink reflex especially the later responses (direct and consensual) R_2 were observed in cases of normal, supra and infratentorial lesions. Generally later response R_2 could not seen in case of wide spread destructive change in the supratentorial brain tissue.

Vibratory stimulation (Hagbarth's vibration TVR) was used for seeing the change in the direct and consensual later responses R_2.

5 cases of thalamic hemorrhage, 2-3 cases with destructive change caused by brain tumor or infarction within the thalamus showed no augmentative change in R_2 response,or very poor augmentative change. In this study through this examination upon the blink reflex especially upon the later response R_2, some motor dysintegration or dysfunction in the central nervous system in the supra or infratentorial lesions could be investigated.

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<S-7-4>

INFLUENCE OF THE PONTINE ATROPHY TO AUDITORY BRAIN STEM RESPONSES IN SPINOCEREBELLAR DEGENERATIONS

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INTRODUCTION

Auditory brain stem responses (ABR) have been widely applied to a variety of neurological disorders to evaluate the brain stem function. ABR of the patients with spinocerebellar degenerations (SCD) have been also recorded, but the general agreement on the abnormality of it has not been acquired. One reported the prolongation of latencies, the other stated that there was no significant difference between the patients and normal subjects. And lately some reports stated that the changes of volume conductor influence the formation of evoked potentials. So we tried to study the abnormality of ABR in patients with SCD and the influences of pontine atrophy on the latency and the amplitude of each wave.

MATERIALS AND METHODS

ABR were studied in 24 patients with SCD, 15 men and 9 women, ranging in age from 33 to 68 years (mean, 51.3 years) and age and sex matched normal subjects. The patients were divided into the two groups according to their clinical features. The first group, comprising 11 patients, was cerebellar form. And among them 6 had the neurological symptoms of olivopontocerebellar atrophy. The second group, 14 patients, was spinocerebellar form. 7 patients were the hereditary cases. ABR were recorded from the electrodes placed at Cz and mastoid process. Click stimuli were given through the bilateral earphone with intensity of 70 dB, and 2048 responses were averaged with an analysis time of 10 msec. Peak latencies of wave I, III and V, and interpeak latencies of I-III, I-V and III-V were measured. In order to study the influence of pontine volume on the ABR, we measured the area of the posterior fossa and of the pons, using the computed tomogram and calculated the pontine volume index (PVI) by the following formula:

$$PVI(\%) = \frac{\text{area of the pons}}{\text{area of the posterior fossa}} \times 100$$

Then we studied the correlationship of the latency, interpeak latency and the amplitude ratio to the PVI.

RESULTS

Latencies and interpeak latencies of SCD and normal subjects were as follows:

	SCD	normal subjects
I	1.78 ± 0.25	1.73 ± 0.29
III	3.96 ± 0.28	3.83 ± 0.28
V	5.85 ± 0.32	5.74 ± 0.34
I-III	2.18 ± 0.28	2.10 ± 0.26
I-V	4.07 ± 0.32	4.01 ± 0.30
III-V	1.90 ± 0.31	1.91 ± 0.31 (msec)

No significant difference was found at latencies and interpeak latencies between the patients and normal subjects. 3 cases out of 4 with prolonged interpeak latency of I-III were hereditary SCD. The PVI of SCD were ranging from 4.3 to 12.0 (%). One patient with olivopontocerebellar atrophy showed the remarkable atrophy of pons (PVI = 4.3%) but his peak latency and interpeak latency were within normal range. But the significant relationship existed between the amplitude ratio III/I and PVI ($P < 0.05$), while no relationship was found between the amplitude ratio V/I and PVI.

COMMENTS

We observed no significant difference between the patients and normal subjects in the each latency and interpeak latency. There was no correlation of the pontine atrophy to the each latency and interpeak latency. But the amplitude ratio III/I increased with the advance of the pontine atrophy. From these findings it is suggested that the decrease of pontine volume causes the increase of the amplitude ratio III/I and that the changes of amplitude of ABR reflect the current density changes of surrounding tissue of the auditory tract. And these data were compatible with the idea that the changes of volume conductor influences the formation of evoked potentials.

<S-8-1>

COMPARISON OF WIRE AND SURFACE ELECTRODE RECORDINGS BETWEEN AN ANTAGONIST PAIR OF MUSCLES

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INTRODUCTION

Myoelectric activity of a muscle may be observed with surface electrodes as a summation of action potentials from a number of motor units, or with wire electrodes which can subcutaneously differentiate single motor unit activity in a muscle. In cases other than medical purposes electromyographic (EMG) recordings are almost exclusively attained from surface electrodes. The greatest advantage of using surface electrodes is convience. They are useful in cases where simultaneous activity is being studied in a fairly large group of muscles where a "global" pickup is desired (Basmajian, 1978). However, signals from surface electrodes are often influenced by attenuation, propogation in the tissue, or cross-talk from adjacent muscles (Zipp, 1982). Basmajian (1978) condemns the use of surface electrodes in studies reporting the presence or absence of activity in certain postures where precision is desirable. As a result, researchers must face many practical and technical considerations in the application and interpretation of EMG.

Condon (1983) observed the Integrated EMG (IEMG) and motor pool excitability of ankle extensor muscles related to stretching technique effectiveness. Using a Hoffmann reflex, she observed profoundly depressed motor pool excitability of the soleus (Sol) muscle during contraction of the pretibial muscles implementing a stretching method by which the target muscle is contracted and then stretched during contraction of the antagonist muscle. These findings supported the principle of reciprocal inhibition. But, paradoxically, the Sol IEMG (using surface electrodes) was greater during tibialis anterior (TA) contraction than when the Sol muscle was only passively stretched without any contraction. Apparently, either reciprocal inhibition was not operating at the muscle level, or it was masked.

Because surface electrodes were used in the previous study, it is possible that cross-talk, propogated between electrode pairs may have produced the apparently paradoxical results. The present study intended to examine and compare the neuromuscular activity from simultaneous recordings using both surface and wire electrodes from the tibialis anterior and soleus muscles during the performance of the antagonist-reversal stretching technique.

METHODS

The subjects were 6 males (between 19 and 34 years old) who were in good health and without any known neurological disorders. Each subject was seated comfortably with his preferred foot secured to a pedal which allowed plantar- - or dorsi-flexion of the foot. A light in front of the subject, indicated to the subject when to begin and end each isometric contraction. A steel cable secured the foot pedal during the contraction. Electromagnets released the pedal at the end of each trial. Two interval timers regulated the light and electromagnet durations. A spring attached to the distal end of the foot pedal applied stretch to the soleus muscle and was maintained at a constant tension with a tensiometer connected in series with the spring.

Procedures

Experimental Protocol. A maximum isometric contraction was established prior to any trials. This level was monitored during the trials and the subject received feedback of his force level by a tensiometer. Each trial was performed 15 times. Sufficient rest was given between trials to reduce subject fatigue.

Electromyographic Recordings. Bipolar fine wire electrodes, with 2mm of insulation cleaned from the tips, were inserted into the medial soleus (Sol) muscle and the tibialis anterior (TA) muscle. The skin surface was prepared for application of the Beckman, Ag-AgCl, bipolar, 1 cm diameter paired surface electrodes, filled with Beckman electrode paste (electrolyte). The surface electrode pair was separated vertically 2 cm apart between the recording and reference disks directly adjacent to the inserted electrode. The electrode placement was approximately at the motor point for each. Acceptable electrode impedence was less than 5 K ohms. The EMG signals were amplified through BAK differential amplifiers, simultaneously viewed on an oscilloscope (Tektronix 5111a) and recorded on FM tape by a Hewlett Packard 8 channel recorder. Noise output from the amplifier and tape recorder was less than 5 uV rms, resulting in a signal to noise ratio greater than 100:1.

Stretching Technique: The stretching technique consisted of prestretching the soleus muscle until it was at its maximum length. The subject then contracted the soleus for a six second period, followed immediately by contraction of the pre-tibial muscles (primarily the tibialis anterior) for an additional three seconds.

RESULTS

The EMG recordings were very similar among the six subjects and produced very consistent pattersn over each of the 15 trials. Comparison between the surface EMG recordings showed what appeared to be the suppression of recipricol inhibition, as in Condon's (1983) studies. A low level of activity appeared in the soleus recording during maximum contraction of the tibialis anterior following contraction of the soleus. However, the tracings from the wire electrodes showed no activity in the soleus during tibialis contraction (See Figure 1). Since the surface

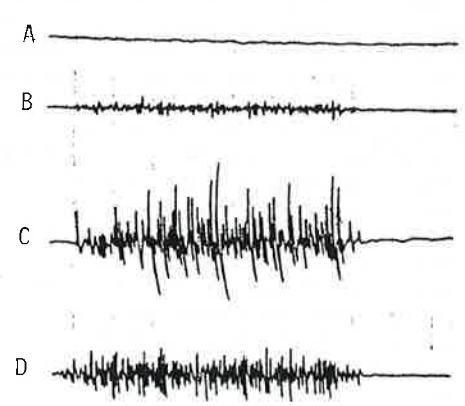

Figure 1. EMG recordings from surface and wire electrodes of the Soleus (Sol) and Tibalis Anterior (TA) muscles during dorsiflexion. A) wire Sol; B) surface Sol; C) wire TA; D) surface TA.

electrodes were placed directly over the wire electrodes, the source of the activity from the surface electrodes was other than the soleus muscle. Recordings from the Sol and TA surface electrodes were further amplified on the oscilloscope and observed at a 10 msec/cm sweep speed. The patterns of the two recordings were nearly identical, indicating that the Sol surface electrodes were picking up the myoelectric activity from the TA.

DISCUSSION

Surface electrodes are much more commonly used by researchers because of their convenience, comfort, and availabiity. However, it was concluded from this study that the activity observed from the surface electrodes of the stretched muscle during antagonist contraction was a result of electrode cross-talk. Although it is not possible to conclude cross-talk occured in other studies, it is apparent that EMG recordings, where surface electrodes are used, must be carefully considered.

Condon (1983) found greater IEMG values, and suppressed motor pool excitability levels in the stretched muscle during antagonist contraction than when the muscle was only passively stretched. The results of this study suggest reciprocal inhibition was suppressed or not operational during the Antagonist-Reversal procedure.

An alternate explanation is that the observed signals from the surface electrodes in the stretched muscle were a result of cross-talk as was demonstrated in the present study with the aid of indwelling electrodes. The source of the cross-talk in this study was the antagonist muscle. This was determined by simultaneously comparing raw EMG patterns between antagonist muscles amplified to similar levels and observed at a high sweep speed on an oscilloscope. This procedure is suggested for future EMG studies which use surface electrodes and when the specificity of individual muscles might be influenced by adjacent muscle contractions.

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<S-8-2>

A SIMPLE PROCEDURE TO CUT DOWN ARTIFACTS IN SURFACE ELECTRODE RECORDINGS

- HOW TO PAINLESSLY LOWER SKIN RESISTANCE -

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Over many years the first author has been recording multiple channel EMGs during vigorous activities, using surface electrodes attached to long cables. Movement of the cables during the activity and noise from nearby A.C. line current often gave rise to artifacts in the EMG recording, thereby contaminating the results for both qualitative and quantitative analyses. We believe that an investigator may unwittingly be accepting noisy data if, while analyzing processed (e.g., rectified and averaged) EMG data, he or she has no access to the unprocessed EMG of the same time. The investigator can solve this problem by recording unprocessed EMG on one channel and processed EMG on another, or by recording unprocessed EMG on analog tape or into a digital computer and doing the processing later.

The kinesiologist should critically examine unprocessed EMG data for artifacts, even when using equipment that allegedly assures reasonably noise-free data. Even if input impedance to the amplifier is extremely high, the benefits of reducing skin resistance merit attention. In most older EMG systems as well as in some of the currently available models, input impedance is low enough that skin treatment becomes requisite to obtain an acceptably noise-free base line.

One way we tried to solve this problem was to put a field-effect transistor close to the electrodes to build up the input impedance to the amplifier, but any quick jarring of the transistor produced a sizable artifact.

Another way to attenuate artifacts is to reduce interelectrode resistance. Some of the older EMG textbooks suggest reducing interelectrode resistance by cleansing the skin with alcohol, but this is not feasible if less than 30K ohms is to be considered acceptable.

A more recent method to further lower this resistance is to abrade the skin with sandpaper or with a nylon scrubbing pad. This hurts. Sanding also leaves a redness of the skin that in some cases may take over a month to subside. Repeating an electromyographic recording on consecutive days at the same electrode site is out of the question if the site must be sanded again. We know of a case in which resanding resulted in keloid formation.

A small battery powered drill has been used as an improvement over sandpaper, because the area of the abraded skin surface is considerably reduced and the instrument can do the job lightly and quickly. Still, the basic problems of pain and skin trauma remain.

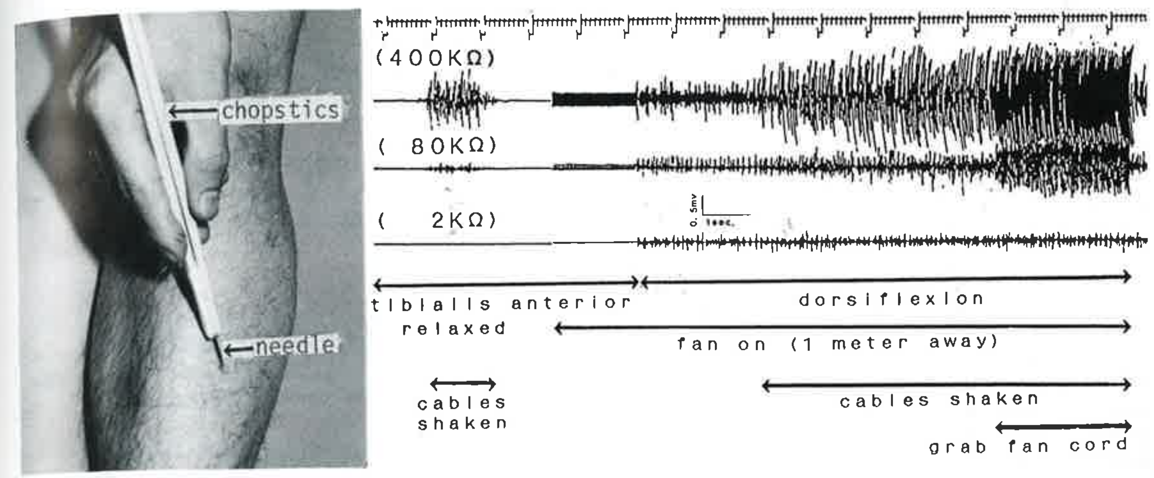
Some companies market electrode paste that is supposed to lower skin resistance, but using such a paste by itself fails to produce any adequate effect.

The first author, however, stumbled upon a technique that effectively lowers skin resistance, causes no appreciable pain, and damages the skin so little that recordings on consecutive days are possible.

The technique involves using a simple stylus. The stylus in the left side of the figure is a sewing needle bound by thread between a pair of disposable wooden chopsticks. A fine stylus from an art supply store would also be satisfactory. Such an instrument can also be found among surgical instruments and in anatomical dissection kits. A medical syringe needle, with the syringe attached as a convenient handle, can also be servicable if used with care.

Technique

The investigator lightly applies the needle to the subject's skin, and with a sideward motion flicks off a tiny piece of surface skin. The novice may want to do a few flicks at each electrode site, confident that the resistance will be adequately lowered by at least one of the flicks. With exper-



ience, the investigator can learn just how lightly to apply the needle to sufficiently lower the resistance with a single painless stroke.

The investigator should first cleanse the area with alcohol and then mark the locus with a felt-tip pen. Pulling the skin sidewards to put the skin of the locus in tension enables a light stroke to be more effective than when the skin is slack. A close examination of the ink spot left by the felt-tip pen reveals exactly where the needle flicked the skin. Repeating this procedure to the same ink spot on consecutive days results in no cumulative damage to the skin. The investigator may want to camouflage the needle with a doll or other toy when using the needle on a child.

Effectiveness

Reducing skin resistance at the two recording electrodes is of course absolutely necessary, but additionally treating the locus of the reference electrode in the same manner enhances attenuation of artifacts.

The three traces of data in the figure were simultaneously recorded from the tibialis anterior. Other than the interelectrode resistances indicated, conditions among the neighboring sets of electrodes were uniform. The skin was cleansed lightly with alcohol for the uppermost tracing, cleansed vigorously with alcohol for the middle recording, and lightly flicked with a needle for the lowermost tracing. The electrodes were attached to long cables unshielded for the first meter from the electrodes. As the figure shows, shaking the cables produced EMG-like waves on the pen recordings of the channels with high interelectrode resistances. Turning on a fan one meter from the subject produced noticable baseline noise in the upper two traces. Even when the subject held the A.C. power cord to the fan in his hand while the electrode cables were being shaken, the activity of the tibialis anterior remained uncontaminated in the lowermost trace.

Electrocardiograms typically have floating base lines, and may become difficult to interpret if the subject is performing a step test, running on a treadmill, or revolving a shoulder wheel. Not so, however, when the resistance at each electrode site is lowered. All electrocardiographic leads may then be left in place and no significant movement artifact appears.

We have used this technique for over ten years, consistently obtaining clear EMGs in more than 500 subjects, from a 20 day old infant to a 90 year old man. Because a flick of the needle removes no more than a tiny piece of epidermis, autoclaving the needles is not strictly necessary. We have encountered no known cases of infection or injury from this procedure. Using and autoclaving surgical styluses on a routine basis, however, may be appropriate in clinical environments or in other situations involving special circumstances of liability or risk.

<S-8-3>

COMPARED STATISTICAL EVALUATION OF CNEMG MEASUREMENT PROTOCOLS

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INTRODUCTION

For the parameters of the EMG signal to be reliable in the assessment of the pathological conditions of the muscle, statistical stability is essential. Therefore, it is mandatory to establish the minimum number of sites which are required to obtain information of diagnostic relevance.

When the EMG signal is obtained by means of a concentric Needle Electrode the minimum number of sites generally adopted ranges: (1) from 20 to 25 for the single Motor Unit Action Potential (MUAP) (Buchthal,1957); (2) from 10 to 15 for the interference pattern at recruitment (Willison,1964; Hayward and Willison,1977; Fuglsang-Frederiksen et al.,1984).

The aim of this work is to identify, by means of quantitative analysis, the minimum number of sites which are necessary when the EMG activity is measured at increasing force levels (from 20% to 30% and from 30% to 40% of maximum voluntary contraction (MVC)).

MATERIAL AND METHODS

Material

Six volunteers (1 female, 5 males aged 22 to 32 years) were examined. None of the subjects had symptoms or signs of neuromuscular disease. Informed consent was obtained from all subjects.

Method

.*The force* of the elbow flexion was measured at the wrist with the joint at 90° by means of a dynamometer. The forearm was kept in full supination in order to avoid activation of the synergistic muscle. The maximum voluntary contraction (MVC) of the biceps brachii was measured before inserting the needle electrode.

Stepwise increase in force from 20% to 30% MVC and from 30% to 40% MVC was studied.

.*The electrical activity* was recorded by concentric needle electrode (0.07 mm^2 up-take area) using Medelec MSS electromyographer. The signal was fed to the Apple IIe microcomputer through the parallel interface CI6.

In order to obtain a total number of 16 sites, 4 derivation points were isolated for every needle insertion as shown in the figure. For each derivation point the following signals were recorded: (1) single MUAP; (2) compound activity at 20% MVC; (3) compound activity at 30% MVC; (4) compound activity at 40% MVC.

The gain of the amplifier was in most cases: (1) for the single MUAP: 200μv/div; (2) for the compound activity at 20% and 30% MVC: 500μv/div; (3) for the compound activity at 40%: 1000μv/div.

.*Processing of the EMG signal* was carried out as follows: (1) for the MUAP a cut-off frequency of 16kHz was selected following the requirements of package "CI5.Analytical 1" which computed average values of potential duration amplitude and number of phases; (2) for the compound signal at 20%-30%-40% MVC the cut-off frequency was lowered to 3.2kHz in order to sample at 10 kHz.

Use of the memory extended card was necessary in order to acquire 35 traces of 1024 points corresponding to 100ms each, which were stored into 5 coded files indexed from 0 to 6.

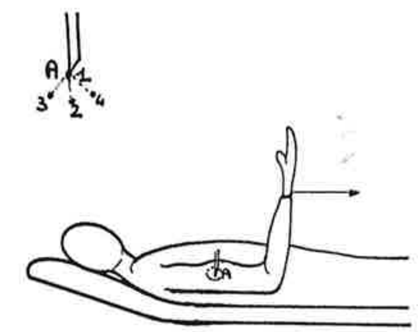
Time Domain analysis was carried out yielding the following parameters:

- number of turns (T)
- mean amplitude of the rectified signal (A)
- number of zerocrossing (ZRCS).

RESULTS

i) Mean and variance of duration and amplitude were computed over the 16 average potentials measured from the 16 derivation points.

ii) for each derivation point parameters T,A,ZRCS were computed averaging over 35 epochs, for the compound EMG



Ā needle·insertion
1-2-3-4 derivation points.

iii) these mean values were again averaged over the 16 derivation points.

iv) variations of the values described under ii) were considered for changes in the contraction level from 20% to 30% MVC and from 30% to 40% MVC.

The preliminary results show that the variance of the parameters is lowest when variations at recruitment are considered.

The number of derivation points to be adopted for statistical stability of the parameters can be noticeably reduced in this case.

ACKNOWLEDGMENTS

The kindness and efficiency of Mr. Nicholas Bettles Service Engineer of Medelec Ltd, England are thankfully acknowledged.

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<S-8-4>

EVALUATION OF ATAXIC GAIT BY AN EXTRA-LARGE FORCE PLATE

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Ataxic patients tend to walk with various forms of "staggering" gait. It is extremely difficult to evaluate the staggering pattern by a conventional small force plate since ataxia is a sum of dynamic changes of gait for some distance.

The purpose of this research was to investigate the ambulation form of the ataxic patients by using an extra-large force plate (10.8 meters in length and 1.2 meters in width).

The subjects were instructed to walk on the extra-large force plate in an ordinary speed.

The "staggering index" was set by discrepancy of the aimed ambulation line through the computer analysis(Figs. 1, 2). The data were also used in evaluating the five walking indexes such as coefficients of valiance step length and cadence, step width, smoothness and staggering index as well.

The results showed each patient had deficit in the scores specific to its etiological entity.

It is concluded that the present method will throw light on studing ataxic gait quantitatively and qualitatively so that one can deal with pathophysiology and training modality of abnormal gait.

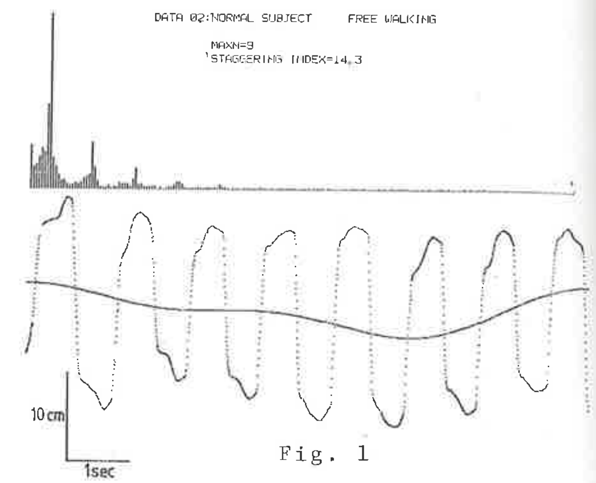

Fig. 1

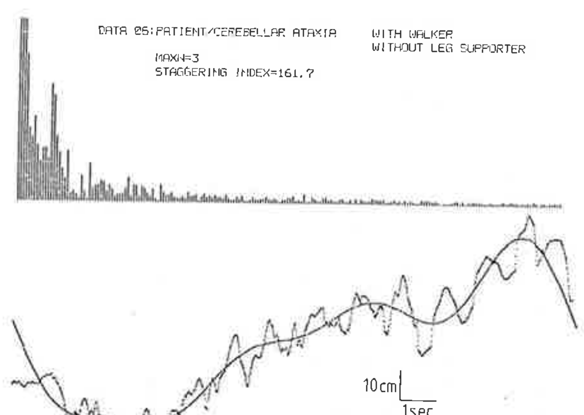

Fig. 2

<S-8-5>

ELECTROPHYSIOLOGICAL ANALYSIS OF WARMING UP PHENOMENON IN MYOTONIA

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INTRODUCTION

Myotonia is a phenomenon in which a failure of the muscle to relax takes place immediately after voluntary contraction has ceased and in which regional muscular contraction occurs for a several seconds after percussion on the muscle. It is believed that this phenomenon in the muscular relaxation process is attributable to abnormalities of prolonged after discharges due to disorders in the muscular cell membrane. Its pathophysiology, however, is still incompletely understood. The degree of myotonia has the influence from many physiological factors and it shows fluctuations in some moment. The main reasons of these fluctuations are in the changes of physiological factors like temperature, effect of previous movements etc. In the past many of these factors to be influenced to the myotonia have been reported based on the subjective observation without objective data. In this paper, we attempt to evaluate the degree of the myotonia in repetitive exercise, in cold exposure and in warm exposure, by recording this abnormal prolonged after discharges using the surface EMG.

MATERIALS AND METHODS

The subjects were four patients with myotonic dystrophy (three males and one female), aged 30,33,41 and 42, respectively (the mean age: 36.5). Surface EMG recordings were undertaken in these patients. The surface electrodes were attached on the thenar and the hypothenar muscles, and polygrams were recorded. The patients were instructed to grip as strongly as possible for five seconds. In addition, percussions were given on the thenar of each patient by the tip of a hammer. The conditions for the occurrence of after discharges following grip and percussion and their duration were studied in the following states: the forearm and hand were cooled down to the skin temperature of 15°C to 20°C by covering with ice bag; the forrarm and hand were heated to the skin temperature of 40°C to 45°C by covering with a hot pack. And the percussion and grip were repeated several times in the settled intervals.

RESULTS

On the surface EMG recordings, prolonged after discharges following grip and percussion were recorded with 30°C - 33°C skin temperature.

Repeated grips and repeated percussions: prolonged after discharges following grip and percussion recorded on the surface EMG recordings were decreased by repeated grips or repeated percussions in every 20 seconds. After 2 or 3 trials, abnormal after discharges were disappeared or became short duration. This tendency was marked when the grip was repeated, moderate when the percussion with the tip of a hammer was repeated. When the repetition was tried in more than 5 minutes delay, no decrement was noted.

Effects of cooling and heating: Grip myotonia and percussion myotonia were markedly aggravated after the hand and forearm were cooled down to the skin temperature of 15°C to 20°C with ice bag. On the recordings of after discharge, the increase in the amplitudes and the prolongation in the duration were marked. The after discharges following grip and percussion were reduced by repetition, even when the hand and forearm were cooled. The after discharges following grip and percussion became less marked or disappeared after the hand and forearm were heated to the skin temperature of 40°C to 42°C with a hot pack. Inthe patients, the after discharges were completely disappeared. In the patients in whom after discharges were disappeared, muscular discharge patterns were normal during voluntary muscular contraction induced by grip.

DISCUSSION

There are several studies on the effect of cooling the myotonic muscles. It is said that cold nonspecifically aggravates all types of myotonia, or merely accentuates the paradoxical myotonia. In paramyotonia, however, cold induced muscle stiffness is accompanied by cessation of myotonic discharges, which myotonia in the recessive type of myotonia congenita or myotonic dystrophy is not aggravated by cooling. There is controversy in the reported results. In our study, the after discharges following grips and percussions became marked when the part of the body of the patients with myotonic dystrophy was cooled.

It is known that the amplitude of miniature endplate potential in normal person is increased by cooling. Ricker et al. found that muscle action potential was also increased by cooling of the muscle. It has been believed that muscular movements in normal persons are reduced by cooling. In myotonic dystrophy, muscular movements are also reduced by cooling with increased amplitude of muscular action potentials and with abnormal prolonged after discharges. The increase of muscle action potential is supposed to be caused by the effect of cooling directly at the muscle cell membrane, not the effect on the contractile apparatus. The abnormal prolonged after discharges following grips and percussions are also supposed to be the result of hypothermia of the muscular cell membrane. The mechanism, however, is not clearly understood. The tranport of ions in the muscular cell membrane is believed to be changed as the result of a decrease in the temperature.

Contrary to the case of cooling, after discharges following grip or percussion are markedly improved by heating of the muscle. Therfore, temperature has completely the opposite effects on myotonia according to its degree. This tendency was marked in the all four patients with myotonic dystrophy who were the subjects of our study.

It is interesting finding that even during cooling the repetitive exercise improve the myotonia. The repetitive exercise might warm the muscle membrane as the warming of the muscle does it. The improvement by warming and repetitive movements seems to be the same physiological base, and these might be called warming up phenomenon together.

AUGUST 29 (Thursday)

Session 9～12

<S-9-1>

THE APPLICATION OF WALKING ANALYSIS TO CLINICAL EXAMINATION

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INTRODUCTION

Recently gait studies have progressed remarkably, but performing gait analysis with patients is difficult because of various physical problems. To overcome these problems a step by step approach was undertaken using serial photographs.

The authors have reported that the frame frequency of 1/24 of a sec. and five walking cycles were sufficient to analyze human gait at the 8th ISB in 1981 and the 5th ISEK in 1982.

In the joints of small angular changes it is difficult to evaluate the gait only by the mean patterns of angular changes, while the normalized patterns of angular changes were performed.

The purpose of this paper is to examine the efficiency of the normalized patterns of angular changes. Special attention was given to the small angular changes, especially those of the shoulder girdle and pelvis.

MATERIALS AND METHODS

Five normal adults and patients with osteoarthritis of the hip, knee or ankle, hemiplegia, Parkinson's disease and spinal disorders were enlisted for this study. The examinees were asked to walk five in trials, and their serial photographs were taken by a stick picture camera and then the frame frequency of 1/24 of a sec. was fixed.

Angular changes of the shoulder girdle, shoulder joint, elbow joint, hip joint, pelvis, pelvic tilt, knee joint, ankle joint and metatarsophalangeal (M.P.) joint of the foot were measured from serial photographs.

To calculate the standard deviation of the different walking cycle Cramer's rule was applied.

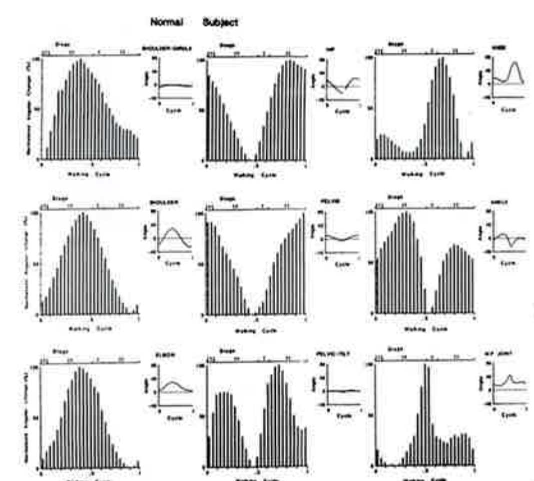
The mean patterns and normalization of the angular changes of five walking cycles were calculated and illustrated on a computer (PC-9801, NEC, TOKYO).

RESULTS

In the normal subjects, the normalized patterns of angular changes of the shoulder girdle, shoulder and elbow joint were of the convex type, but the pelvis and hip joint were of the concave type (Fig.1).

In relation to other joints, the ankle joint and M.P. joint of the foot showed a two peak pattern, but the ankle joint showed a higher peak in the first half of the walking cycle.

The knee joint showed a smooth lower curve in the first half of the walking cycle and a higher one in the latter half of the walking cycle.



[Figure 1]

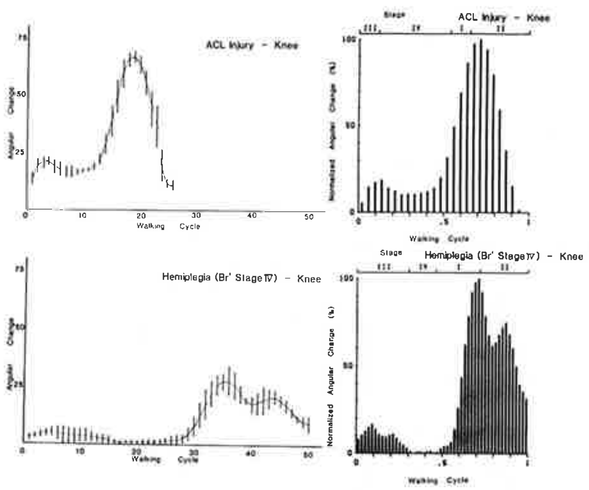
In the patients except one with hemiplegia, the shoulder, elbow, hip, knee, ankle joint and M.P. joint of the foot showed a similar pattern to the normal subjects.

On the other hand, the shoulder girdle and pelvis showed various patterns.

DISCUSSION

In the joints of large angular changes, it is relatively easy to evaluate the gait by both the mean patterns of angular changes and the normalized patterns, but in the joints of small angular changes it is difficult to evaluate the gait only by the mean patterns of angular changes. For this reason, the authors concentrated on the small angular changes, especially those of the shoulder girdle and pelvis.

The normalized patterns of the knee joint in patients with anterior cruciate ligament insufficiency and hemiplegia were shown in Figure 2.



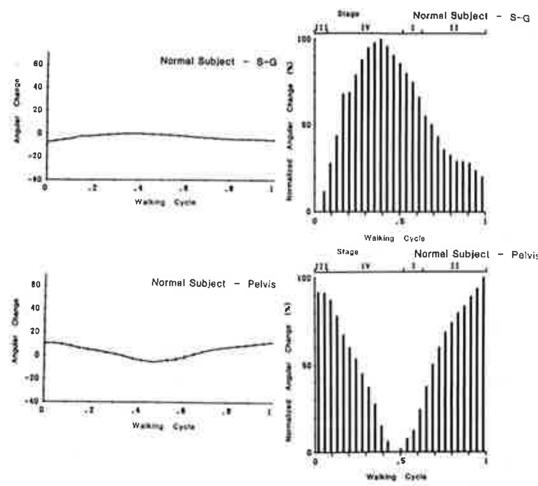
[Figure 2]

The normalized patterns of the hemiplegic patient are deep in color compared with the one of the patient with anterior cruciate ligament insufficiency. This means an elongation in the duration of the walking cycle. Because the abscissa is printed in constant length, an elongation in the duration of the walking cycle increases the bars (frames).

Consequently, in the abscissa, it is easy to recognize an elongation in the duration of the walking cycle and a cadence.

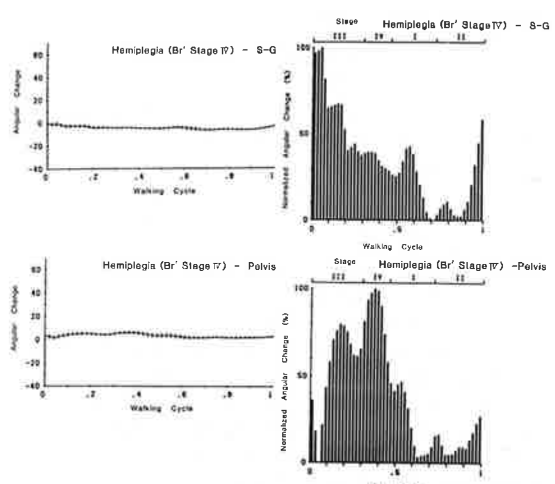
The transverse rotatory movements

of the shoulder girdle and pelvis of the normal subjects were shown in Figure 3.

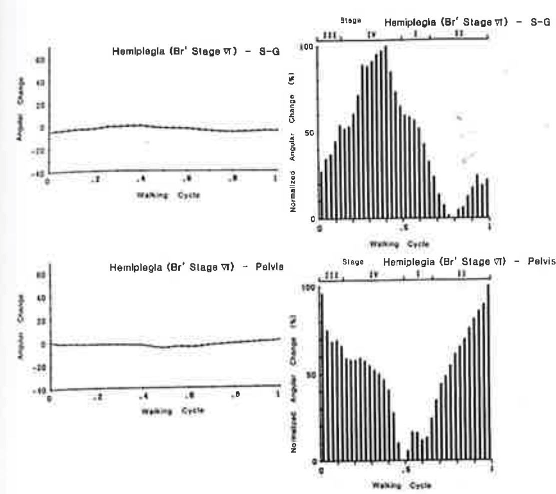


[Figure 3]

It can be seen that the shoulder girdle and pelvis twist in an opposite direction to each other, producing coiling and recoiling of movement of the trunk during each walking cycle.



[Figure 4]



[Figure 5]

The transverse rotation of the hemiplegic patients (Br' stageⅣ and Ⅵ) were shown in Figure 4 and 5. In both patients , the mean patterns of the rotations of the shoulder girdle and pelvis were very small. In the normalized patterns, the patterns of the angular changes were scaled up so that it is easy to recognize the characteristics of the rotations of the shoulder girdle and pelvis. In the hemiplegic patient at stageⅣ, the rotations of the shoulder girdle and pelvis twist in almost a same direction, but in the other hemiplegic patient, the rotations twist in an opposite direction like the normal subjects.

Consequently, in the ordinate, it is easy to recognize the rotations of the shoulder girdle and pelvis, which is very important to indicate the recovery stage of hemiplegia.

CONCLUSION

The characteristics of the normalized patterns of angular changes are as follows;

(1) In the abscissa, it is easy to recognize an elongation or a shortening in the duration of the walking cycle and a cadence.

(2) In the ordinate, it is easy to recognize the rotations of the shoulder girdle and pelvis of very small angular changes.

<S–9–2>

ELECTROMYOGRAPHIC AND KINESIOLOGICAL COMPARISON OF STEREOTYPED, VOLUNTARY MOVEMENTS BY SIGNAL OF ELECTRIC STIMULATION BETWEEN SPINOCEREBELLAR DEGENERATIONS AND PARKINSON'S DISEASE

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Introduction

The cerebellum plays an important role in initiation and coordination of voluntary movements. Contribution of cerebellar system to this movement was rapid movement and its accuracy.
Objective evaluation to cerebellar ataxia and parkinsonian motor disturbance was done using a method by which accuracy grades as well as EMG-latency of stereotyped voluntary movement and reaction time in the upper limb were analysed, comparing motor disorders between spinocerebellar degenerations(SCD) and Parkinson's disease(PD) and normal controls. This simultaneous recordings of latency in EMG-discharge, reaction time and time of index finger to reach the target point revealed that the differences exist in the accuracy grade between both diseases.

Methods and Subjects

EMG activity of the handed deltoid muscle and kinesiological changes of the index finger tip from the horizontal plate to the upward plate in front of the subject were simultaneously recorded in 16 normal control subjects, 10 patients with SCD and 18 patients with PD. Their arms were volutarily elevated from the horizontal point to the decided upward point as soon and correct as possible by signal of electric stimulation to the contralateral median nerve at the wrist joint. With the initial elevation from the horizontal point, the initial EMG was generally characterized by a burst discharge which was composed of two peaks in the deltoid muscle.And then, there was a silent phase of muscle discharge when the finger tip touched the upward point. Latency of initial discharge(L_1) in the deltoid muscle, reaction time(RT) time of finger tip to reach the upward point from the horizontal point(FM) were quantitatively analysed(Fig. 1). Angle degrees to the upward point from the horizontal point were 15° and 30°.

Results

The results as follows;
(1) Each mean value of L_1, RT and FM in patients with respective SCD and PD were significanly prolonged, compared with those values in normal control groups which were composed of control I(11 subjects) and control II(6 subjects with more than 40 years old).
(2) But there was no any significant difference on L_1 and RT between 15° and 30° upward points during eye opened and closed, respectively in normal controls and patients with SCD and also there was no significant difference on L_1 between SCD and PD patients.
(3) FM of patients with SCD was more prolonged during eyes closed than opened.
(4) FM of patients with either SCD or PD was significantly prolonged, compared with that of normal control group and FM of patients wuth SCD was more significantly prolonged than that of patients with PD(Fig. 2).
(5) Variance ratio of FM in SCD group to that of normal control group was significantly higher than that of PD group (Fig. 3).

Discussion and Conclusion

Ataxia is composed of delayed initiation of stereotyped voluntary movement and disturbance of performance process as dysmetry. The former is probably due to disturbance of centrally programmed preparation. The latter can be strongly pointed out to be significantly different between SCD and PD, because of difference of FM and variance ratio of FM from the results of this test. Therefore, contribution of cerebrocerebellar interaction to the performance process of movement must be more exactly examined.

Acknowledgement

This study was supported in part by the Japanese Ministry of Health and Welfare. The author is deeply indebted to Dr. Nobuyuki Murakami, Division of Neurology, National HigashiNagoya Hospital, Nagoya, for his constant supportings.

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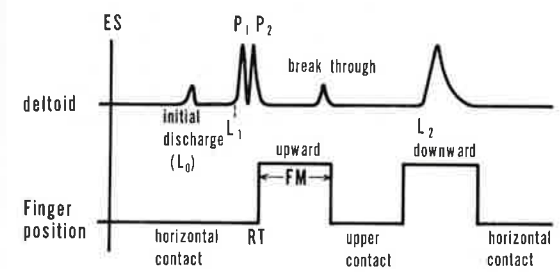

1. Latency of initial discharge (L_0)
2. Latency (L_1)–P_1–primary muscle discharge P_2–secondary muscle discharge
3. Reaction time to release from the horizontal plate (RT)
4. Time of finger movement carried out from the horizontal plate to the upper plate (F.M.)
5. Latency of muscle discharge to come back to the horizontal plate (L_2)

Fig. 1. Relation between muscle dischsrge and motor pattern of voluntary movement

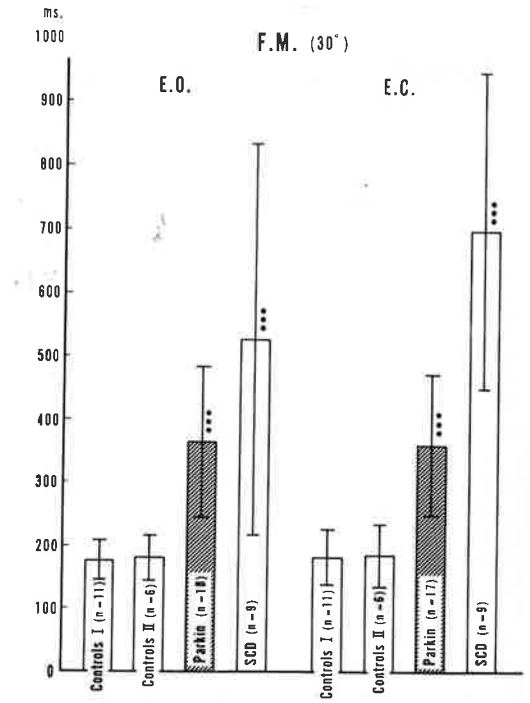

Fig. 2. Comparison of FM between SCD, PD and normal controls.

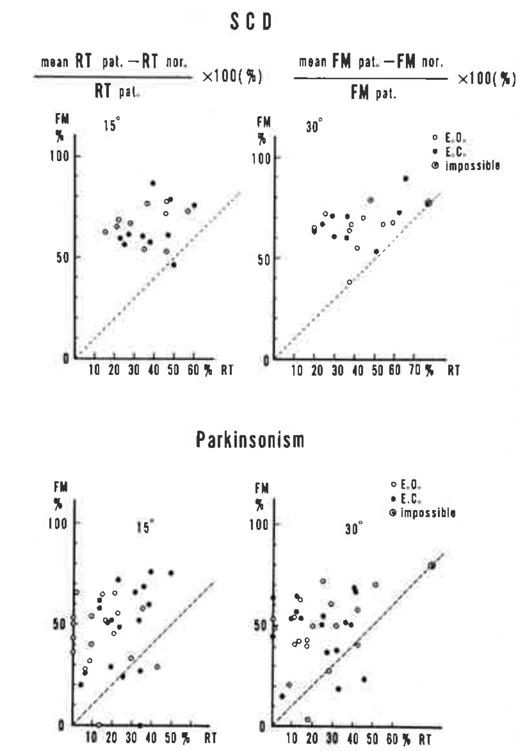

Fig. 3. Variance ratio of FM and RT in SCD and PD to normal controls

<S-9-3>

HOW TO EVALUATE PLEXUS LESIONS WITH SURFACE EMG

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INTRODUCTION

In our rehabilitation centre a special unit for surface EMG analysis has been developed:

- to investigate motoric disorders such as hemiplegia, plexus lesions.
- to evaluate individual treatment programs.
- to evaluate specific treatments e.g. phenolisation.

In a rehabilitation centre such an unit is essential as the state of muscles is one of the main parameters. In a rehabilitation centre the use of surface EMG is preferable to needle EMG, particularly if one considers quantification of the signal and discomfort of the patients. In this paper we will discuss the use of EMG power spectra at patients with a brachial plexus lesion.

METHODS

EMG registrations of two seconds are made of the Biceps brachii during isometric contraction. The EMG signals is sampled at 1024 Hz and saved on floppy disc of a DEC-minicomputer.
An analysis program determines a number of parameters from the amplitude density function and the power spectrum density function (spectrum), calculated from each EMG registration. From the spectrum the following important parameters are calculated:

- Fmed: the frequency at which the total power above and below are equal. In healthy subjects: mean=52 Hz, sd.=5 Hz.
- F10dB: the frequency at which the power density is 1/10 of the maximum power density. In healthy subjects: mean=100 Hz, sd=9 Hz.

An extensive description of all the parameters used can be found in the article of Hermens et al (1984).
A follow up investigation was performed in fifteen patients with a plexus lesion. In all these patients the Biceps was affected due to the lesion.

RESULTS

The time registrations of most patients with a plexus brachialis lesion show marked differences from registrations in unimpaired subjects, apparently due to loss of motor units and changes in motor unit action potentials.
Differences in shape of the action potentials are even more apparent in the power density spectrum. Even, if the EMG shows interference patterns, which is quite common with surface EMG registrations, the spectrum can show marked differences.
Examples of EMG registrations and spectra in one healthy subject and in two patients with a plexus lesion are shown in figure 1. This figure shows that with plexus lesion both a shift to lower and higher frequencies of the spectrum may occur. A shift to lower frequencies may be related to muscle atrophy ($35<Fmed<45$ Hz) or to giant potentials dominating the EMG registration ($30<Fmed<40$ Hz). A strong shift to higher frequencies ($70<Fmed<110$ Hz) is found in all patients with a perinatal plexus lesion. We also observed spectra with a main power shifted to lower frequencies and a relatively long tail (normal value of Fmed and F10dB>120 Hz).

During rehabilitation significant changes in the EMG may be observed. Figure 2 shows a typical example. In the first column a sample of an EMG registration and its spectrum are shown at the start of re-innervation. At this time the patient could hardly exert any force and the EMG showed significant deviations from normal. The second and third columns show the situation three months later. The second column shows a registration at

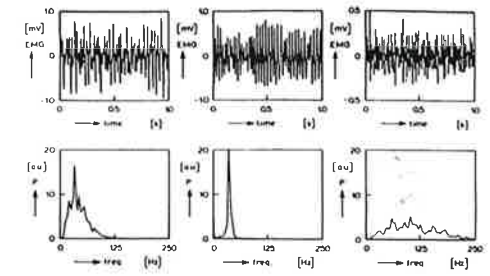

Fig.1

a low force. It is remarkable that at this force the spectrum has become almost normal. However, at maximum force (third column) the spectrum shows again deviations. A large peak becomes apparent at almost the same frequency as the peak in the first column, indicating that at stronger force levels typical 'pathological' motor units dominate the EMG.

STIMULATION MODEL

To investigate pathological patterns a special simulation model has been developed. With this model stochastic series of spikes are generated and added to contribute to the EMG. The shape of each spike can either be obtained from analytical functions or from motor unit action potentials of real EMG registrations. In this way the contributions to the spectrum of different kind of motor units can be studied.

CONCLUSIONS

It may be concluded that remarkable changes in the surface EMG can be found in patients with a brachial plexus lesion. These changes probably reflect the changes of the motor unit action potentials, apparently due to the process of re-innervation (axonal regeneration and collateral sprouting). Surface EMG provides quantification of these changes and by means of simulation models we can study the origin of these phenomena.

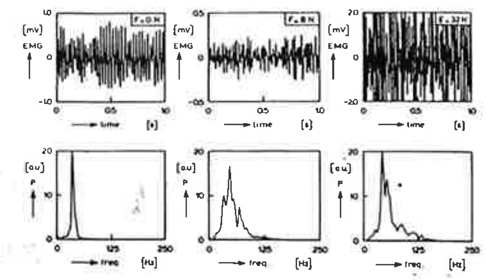

Fig.2

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<S-9-4>

INVESTIGATION OF MOTOR NERVE CONDUCTIVITY IN AMYOTROPHIC LATERAL SCLEROSIS AND POLYNEUROPATHY ; USING DURATION OF COMPOUND ACTION POTENTIAL

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INTRODUCTION

Investigation of motor nerve conductivity in amyotrophic lateral sclerosis(ALS) has been performed using measurment of motor nerve conduction velocity(MCV), and it's considered that they have normal MCV. We analyze duration of compound action potential in ALS, in order to throw light on conductivity of them and to compare with that of polyneuropathy(PN).

In patient with ALS and PN, MCV and duration of compound action potential are studied. The difference of motor nerve conductivity between ALS and PN is analyzed using MCV and duration of compound action potential.

SUBJECTS AND METHOD

Subjects are 22 cases of ALS and 14 cases of PN. Patients with ALS consist of 17 cases of common form, 2 cases of pseudopolyneuritic form and 3 cases of bulbar form. Normal controls are age-matched with ALS group. MCV of median nerve, ulnar nerve and tibial nerve between elbow and wrist or knee and ankle are measured using a former technic.

Duration of compound action potential which is evoked by electric stimulation on proximal part and distal part are measured. M1 is defined as duration of compound action potential by stimulation on proximal part, and M2 is duration of that by stimulation on distal part. We define M-wave duration ratio(MDR) as follows :

MDR(msec/m) = [M1-M2(msec)] / [distance between proximal part and distal part(m)]. MCV and MDR are measured in ALS group, PN group and normal control group.

RESULTS

ALS and normal controls

MCV(m/sec) of median nerve are 50.4±6.7 in ALS group and 58.4±3.3 in normal control group. MCV of ulnar nerve are 53.2±8.6 in ALS group and 61.7±4.7 in normal control group, that of tibial nerve are 41.3±8.1 in ALS and 45.3±3.1 in normal control group. MCV in ALS are decreased, especially at upper limbs. In cases of pseudo-polyneuritic form, mean of MCV of tibial nerve is 31.2m/sec. Mean of MDR(msec/m) are 2.6 in median nerve, 3.5 in ulnar nerve and 2.1 in tibial nerve in normal control group, while on the other hand 4.3 in median nerve, 6.2 in ulnar nerve and 3.2 in tibial nerve in ALS group. In ALS group MDR tends to be prolonged, and in nearly 30 percentage of them, standard deviation of MDR is large.

PN group

Average of MCV are 36.9 in median nerve, 35.4 in ulnar nerve and 32.0 in tibial nerve. Average of MDR are 13.5 in median nerve, 16.6 in ulnar nerve and 12.2 in tibial nerve. In cases with most prolonged MDR, they are more than 50.0msec/m.

DISCUSSION

Until up to now, there are many reports that motor nerve conductivity of ALS is within normal range using MCV. Althogh there are several papers in which the MCV could be decreased in ALS compared with controls. The pathological condition in motor nerve of ALS is believed to be axonal degeneration. In our study MCV in ALS tends to be lower normal or below normal and MDR in ALS becomes longer than it in controls. From these data

we suspect that MCV in ALS might be decreased due to involvement of largest fiber, which conducts the fastest action potential, and prolonged MDR might represent the involvement of smaller nerve fiber or, in other words, slower conductive fiber.

Although we could say the impaired conductivity in peripheral nerves in ALS, the degree of involvement in peripheral nerves in ALS is slight compared with it in PN. This difference of involvement might be the difference of the site of lesion and even small number of anterior horn cells in ALS could maintain the maximum conduction velocity fairly well.

When we use the combination of MCV and MDR as methods of measurment of peripheral nerve conductivity, we can detect the more details on information of conductivity, because they represent of different views of peripheral nerves.

CONCLUSSION

We analyze the MCV and MDR of 22 cases with ALS with compared of PN and normal controls. The MCV in ALS tends to be slower than normal controls and the MDR in ALS is also to be prolonged with wide standard deviation in statistics. About one third of ALS with normal MCV have pro-longed MDR. In PN group decreased MCV and/or prolonged MDR are observed.

<S-9-5>

INTRAOPERATIVE SENSORY NERVE ACTION POTENTIAL RECORDING AT THE SURGERY OF CARPAL TUNNEL SYNDROME

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Faculty of Medicine, The University of Tokyo

Orthodromic sensory nerve action potentials of median nerve were recorded during operation of 13 consecutive cases of idiopathic carpal tunnel syndrome.

Sensory conduction time(maximum sensory nerve conduction velocity) unchanged in 9 cases and improved in only one case after the release of volar carpal ligament. In 3 cases, it was not determined because of very low amplitude.

Cumulative amplitude of sensory nerve action potentials increased in 7 cases, unchanged in 3 cases and decreased in 5 cases.

These data suggest that a rapidly reversible conduction block due to mechanical, ionic, ischemic factors have little influence upon the maximum sensory nerve conduction velocity in the cases of entrapment neuropathy.

Finding of intraoperative changes in nerve conduction velocity at the surgery of carpal tunnel syndrome is controversial. Hongell (1971), Eversmann (1978) claimed that release of the volar carpal ligament and internal neurolysis is accompanied by immediate improvement in motor or sensory nerve conduction velocity. But, Yates (1981) stated that motor nerve conduction velocity did not improve following section of volar carpal ligament and internal neurolysis. To confirm the finding we observed orthodromic sensory nerve action potentials during carpal tunnel release.

Thirteen cases with idiopathic carpal tunnel syndrome were operated and analysed. Eleven of them were female and 2 cases were male. The age at the time of surgery ranged from 39 years to 63 years.

The operation was done under axillar block anesthesia. The skin was incised and the median nerve was exposed proximal to the volar carpal ligament in the bloodless field using a pneumatic tourniquet. Then the tourniquet was released, and subcutaneous bleeding points were cauterized. A pair of ring electrodes was applied on the middle finger as stimulus electrodes. The needle electrode of 0.2mm diameter was inserted under the epineurium in the volar side of the median nerve 2cm proximal to distal wrist crease as the recording electrode. The other needle electrode was fixed in the subcutaneous tissue 3cm apart and parallel to the recording electrode as indifferent electrode.

Fifteen minutes after the release of tourniquet, sensory nerve action potential was recorded before release of volar carpal ligament. Then the volar carpal ligament was cut carefully with electrodes to be left untouched. After the section of volar carpal ligament, sensory nerve action potential were recorded several times up to 20 minutes. DISA 1500 apparatus was used for the analysis.

Fig.I shows a typical case. The latency of first positive peak (=maximum sensory nerve conduction velocity) was not altered 30 minutes after the release of volar carpal ligament. The peak to peak amplitude increased from 2.5uV to 3.8uV, and the cumulative amplitude increased from 5.5uV to 7.3uV. This increase of the cumulative amplitude was accompanied with the increase of the number of discernible components.

Fig.II shows the intraoperative change of the maximum sensory conductor velocity of 10 cases. In 9 cases, that was unchanged, and one case showed improvement.

Fig.III shows the intraoperative change of cumulative amplitude in 13 cases. That increased in 7 cases, decreased in 5 cases and unchanged in one case.

It will be discussed over the analysis of these data and the pathophysiology of carpal tunnel syndrome.

Fig.I

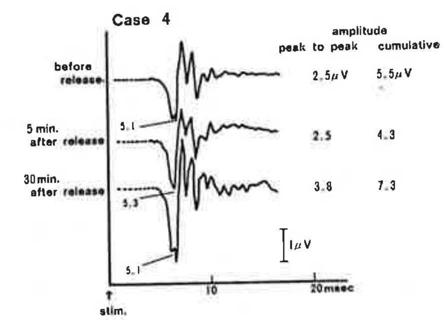


Fig.II

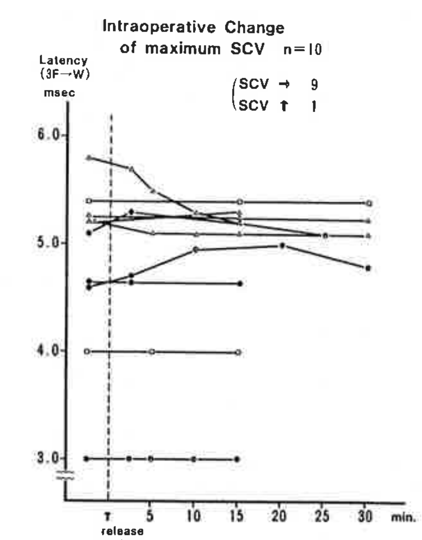
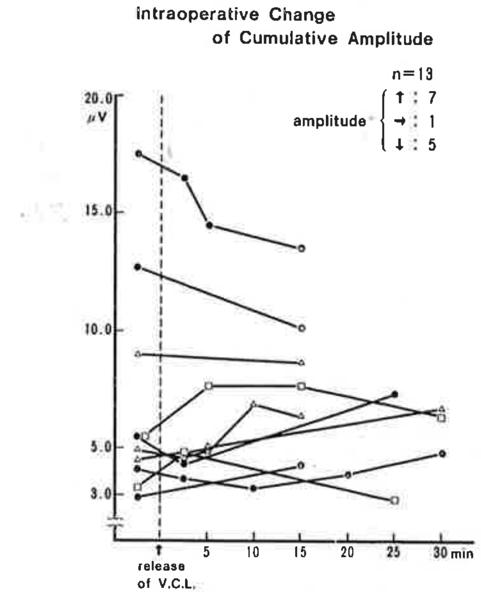


Fig.III



<S-10-1>

AN INVESTIGATION OF THE EXTENSOR CARPI RADIALIS LONGUS AS AN ELBOW FLEXOR.

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INTRODUCTION

Normal movement requires smooth coordination of many joints and muscles in the body. The upper extremity in man has been adapted for fine motor skills such as reaching, grasping, and manipulating objects. The elbow functions as an important link in this kinetic chain, allowing the hand to be moved towards or away from the body. To accomplish these often complex movements, the muscles around the elbow must work alternatively as agonisits, antagonists, synergists, or stabilizers. When muscle activity is impaired or lost, appropriate rehabilitation is indicated to correct or compensate for the decrement in function. To design an effective program it is first necessary to understand the normal functions of the musculature about the elbow joint.

The literature is in agreement with regards to the identification of the brachialis (B), biceps brachii (BB), and brachioradialis (BR) as the primary elbow flexors against resistance. Fewer studies have looked at the pronator teres (PT) but it has also been identified as an elbow flexor. Hollinshead (1982) described the extensor carpi radialis longus (ECRL) as a possible weak elbow flexor, with the forearm pronated. An, et al, (1981) suggested that the ECRL functioned as a major elbow flexor in all forearm positions, based on such biomechanical variables as moment arm and cross sectional area. Hobart (1984) also presented it as an elbow flexor. The purpose of the four studies reported here was to investigate the possibility that the ECRL functions as an elbow flexor.

METHODS

Sixty-three right-hand dominant females between the ages of 18 and 35 were subjects. All trials were performed seated in a specially designed chair with stabilization of the trunk and shoulder. In three studies the elbow was positioned at an angle of 115°, and the position of the forearm was varied. In the fourth study, the elbow was fully extended, the forearm pronated, and wrist position was varied. Each subject performed a series of three isometric elbow flexion contractions at various resistance levels, as measured by a strain gauge attached perpendicular to the forearm just proximal to the wrist. Three maximal voluntary contractions (MVC) were performed and the mean calculated. All other resistance levels were calculated as a percentage of this maximum.

Beckman miniature Ag-AgCl surface electrodes were placed 1 cm apart over the motor points of the five muscles (B, BB, Br, PT, ECRL) as determined by electrical stimulation. Standard preparation procedures reduced skin impedence below 5K ohms. The EMG signal was passed through a Hewlett-Packard 8-channel 8811A multipurpose bioamplifier with upper and lower cut-off frequencies at 3 Hz and 5KHz respectively. The CMRR was 126 db at 60 Hz. Gain was adjusted for each resistance level to maintain an adequate signal without distortion. The reduced data was corrected for differences in amplification. The raw EMG signal was recorded on FM tape, rectified and integrated by a Coulbourn Bioamplification system with a time constant of 0.2 seconds. The entire system was calibrated daily, plus reliability and validity resting was appropriately performed. The integrated curves were displayed on paper, and digitized using a Radio Shack TRS-80 color computer. All trials involved three 3-second isometric contractions, with only the middle second utilized for data analysis. Data for each muscle was normalized to the highest level of activity for that muscle. Therefore all data was expressed as a percentage of maximum of each muscle for each subject. The data were submitted to Analysis of Variance for repeated measures, with significant means further analyzed by a Student Newman-Kuels test at the $p \leq 0.05$ level.

RESULTS

The first study compared the activity of the ECRL with the other elbow flexors with the forearm in midposition and resistance levels of 100, 80, 60, and 20 percent MVC. When muscle activity was compared across all resistance levels, no one muscle was more active than any other. At each individual resistance level, there was no significant difference between any of the muscles' normalized activity levels. All muscles essentially exhibited the same pattern of activity.

The second study extended the range of resistance levels to 100, 80, 60, 40, 20, 10, 5, 2.5 and 1% of MVC with the forearm supinated. Again the results showed no differences between the muscles, including the ECRL, across all or at any individual resistance level.

Study #3 utilized the same range of resistances, with the forearm in pronation. As before, with resistance levels combined, no differences were noted among the muscles. There were significant interactions between muscles and resistance levels, but present comments will be restricted to the ECRL. At 100% MVC, ECRL normalized activity equaled that of the BR, B and PT; at 80%, equal to BR, B; 60% to BR and PT; 40% equal to BR, B and PT; 20-1% all muscles were the same.

It appeared that the ECRL was functioning as an elbow flexor. To address the multijoint nature of the muscle and the possibility its activity was predominantly associated with the wrist, Study #4 was undertaken. It compared ECRL activity with the other elbow flexors in two wrist positions, with the elbow in full extension, at resistance levels of 100, 60, and 20% MVC. There was significantly more activity of all muscles across all resistance levels in wrist extension compared to wrist flexion. Was this due to generalized increased activity in all muscles, or to the influence of increased ECRL activity on the other muscles? Combined wrist flexion and extension data were compared with combined resistances, yielding no significant differences between muscles. This may have been due to very high ECRL activity in extension and low activity in flexion, resulting in an overall mean equal to muscles unaffected by wrist position. Muscle activity at individual resistance levels ruled out this possibility. At 100% MVC the ECRL and BB were equal in normalized activity; at 60% the ECRL, PT and BR were of equal activity and at 20% the ECRL equaled the BR in % activity. With resistance levels combined, the brachioradialis, not the ECRL, was the most active muscle. Even with the influence of changes in wrist position the ECRL still followed the pattern and was similar in activity to the established elbow flexors. These data are also further supported by the recent isotonic data of Ober (1985).

To further examine the ECRL the physiological moment arm and cross section data of An, et al (1981) was combined with the EMG data of Study #4. The resulting data indicated that above 20% MVC the B and BB could generate the greatest torque, the BR, PT and ECRL were essentially equal in their possible contribution to elbow flexion. Below 20% MVC all muscles were similar and no major contributor could be isolated.

It can be concluded that since the ECRL essentially mimics the primary elbow flexors under all conditions, it should be considerd as an elbow flexor in normal movement. Rehabilitation programs must consider that elbow flexion is controlled by three major nerves and the loss of one should minimize debilitation of a patient if a proper exercise regime is employed.

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<S-10-2>

KINESIOLOGICAL STUDY OF POST-TRAUMATIC INSTABILITY OF THE ANKLE TREATED BY SKIN ALLOGRAFT

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SPECIFIC PURPOSE OF THE STUDY :

Chronic instability of the rear foot may require surgical reconstruction of the damaged ligament using the tendon of the peroneus brevis, the plantaris or preserved skin allografts. Our aims were to evaluate the influence of the replacement of damaged ligaments with preserved skin implants on the motor reaction times of the muscles preventing mechanical stresses on the graft and the possible changes in gait.

The following hypothesis were made and studied :

1. Muscle activity in the lower leg cannot be produced quick enough to prevent ankle sprains in an unexpected twist of the rear foot in normal subjects as well as in the unstable ankle group.
2. After the surgical treatment, the increased stability of the ankle is due to the implanted skin replacement of the ligaments and not the muscular activity itself.
3. The phasic muscular activity and articular mobility of the ankle should be normal after the operation.
4. The placement and the rolling off of the foot with respect to the duration, latency and sequence of the foot-switches used should be normal after operation.

MATERIAL AND METHOD :

3 groups of adults were studied.

1. Seven able-bodied subjects, without history of ankle or neurological disorders, were used as the control group. Both legs were tested.
   - Ten after reconstruction of the lateral ligament of the ankle. Ages ranged from 21 to 50 with a mean of 30.8.
2. Healthy side : 7 (2 patients presented a controlateral unstable rear foot).
3. Post-op side : 11 with a follow-up of 6 months to 12.5 years, mean 5.2 years (1 patient was operated on both ankles).

For the clinical analysis, each post-op patient participated in an interview, a range of motion measurement and stressed x-rays of the rear foot conducted by an orthopaedic surgeon.
The kinesiological evaluation was done with the use of a 6 channel telemetry system.

- Surface electromyography (EMG) of tibialis anterior, peroneus longus, peroneus brevis and soleus muscles (bipolar Beckman miniature electrodes placed over the area of minimal cross-talk between adjacent muscles),
- electrogoniometers measuring ankle flexion-extension and varus-valgus of the rear foot,
- accelerometers mounted on the tilt board,
- foot-switches placed under the heel, head of the 5th metatarsal head of the 1st metatarsal, the great toe.

The band widths of the 4 EMG channels were 1 = 365 Hz, 2 = 350 Hz, 3 = 1500 Hz, 4 = 1500 Hz.
The raw EMG was filtered (second order active filters 34 Hz $\pm$ 3 dB) then RMS'ed and sampled at 100 Hz.

The sample rates were 15 ms for the multiplexed goniometers, 2 ms for the accelerometers (Z, X, Y axis) and every 1 ms for the foot-switches. All the data were stored on disk.

A special tilt board was designed to measure motor reaction times during combined ankle plantar flexion of 10° and subtalar varus of 4°. During the gait analysis, the subjects walked in a hall, at their comfortable speed, bare feet on an even floor.

DATA ANALYSIS :

1. For each test on the tilt board, the tilt duration, the latency of muscle onset and the latency to peak EMG were measured and the descriptive statistics computed.
2. For the gait data, after normalisation of the stride duration, the RMS'ed EMG and joint rotations were averaged.
3. The results of the three groups were compared.

RESULTS :

All the treated patients suffered from frequent ankle sprains before the operation. During the follow-up period none of them had a recurrence and all were able to continue in prefered sport activities.

Reactions to unexpected twists of the rear foot :

In the majority of the subjects and tests, the tibialis anterior, peroneus longus and brevis muscles showed a pattern of activity starting with a large burst, followed by a brief period of non-activity, then an inconstant, second, smaller but sharp burst, ending with constant activity (Fig. 1)(Fig. 2)
The mean reaction time in table 1 represents the time from when the tilt board began to rock until the muscles started to contract. The tibialis anterior was the first to reach in all cases, followed by the peroneus longus and finally the peroneus brevis. The soleus muscle was not reported because of its lack of reaction.

The shortest latency from the unbalancing of the board to peak RMS EMG was found in the tibialis anterior muscle (table 2).
The tested muscles are either inactive or too slow to prevent or control the ankle and subtalar joint rotations.

Gait analysis :

The phasic pattern of muscular activity, the integrated EMG and the range of movement, showed no significant differences between muscles of the groups.

The placement and rolling off of the foot in the three groups were normal according to all measured parameters. The differences were within the accepted between-subject variations. (Fig. 3)

CONCLUSION :

Considering the latency times of the muscles onset and peak EMG activity, it is obvious that the muscles tested cannot prevent an unexpected twist and sharp movement of the ankle and subtalar joints. It, therefore, suggests that the entire stability of the rear foot is ligament dependent and, after the surgical treatment, the increased stability of the ankle is due to the implanted skin replacement.

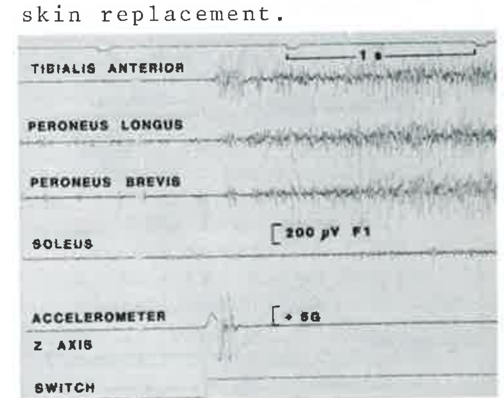


Fig. 1

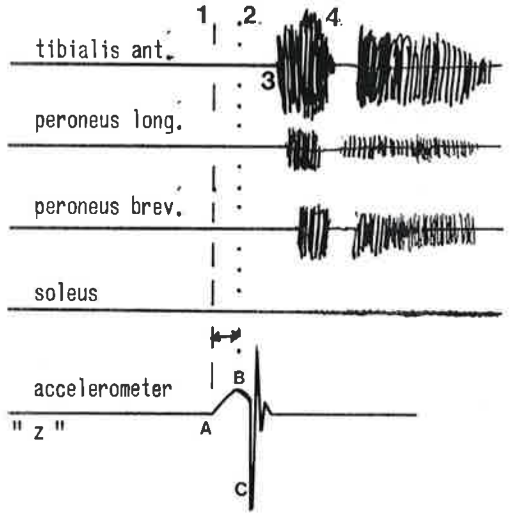


Fig. 2 : METHOD OF MEASURING FOR MOTOR REACTION TIME AND THE LATENCY PEAK EMG

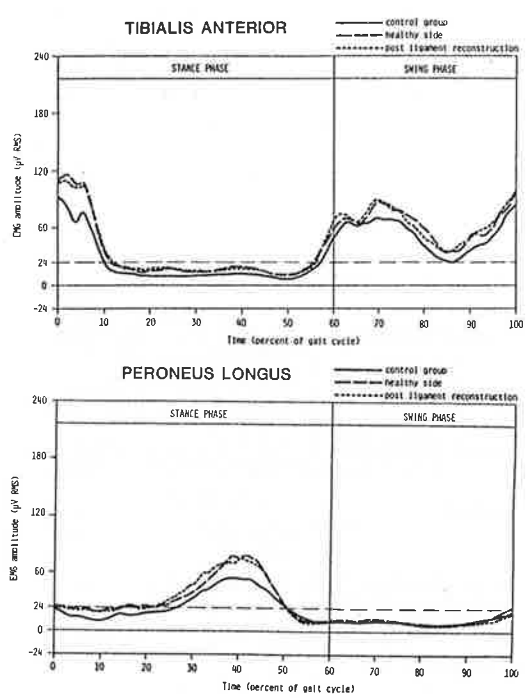
A-B or 1-2 = duration of the unexpected twist of the rear foot

B-C = main shock absorption of the board

1-3 = motor reaction time

1-4 = for each muscle, group and all their performances, the RMS'd EMG is averaged and the delay between the tilt of the board and the maximum value of the mean (peak EMG value) is measured in ms.

2. GAIT ANALYSIS



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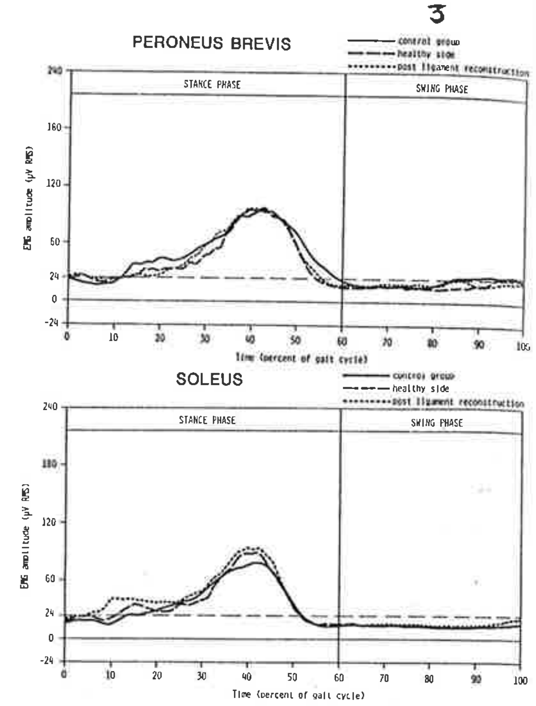

Fig. 3 : Averaged RMS'd EMG for each group during the gait tests.

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<S-10-3>

ELECTROMYOGRAPHIC STUDIES OF THE THIGH MUSCLES IN KNEE OSTEOARTHROSIS

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The etiology of the primary knee osteoarthritis (knee O.A.) is considered to be some chronic mechanical stresses loaded on the articular cartilage in addition to the underlying aging process.

Such chronic mechanical stresses may be body weight loading due to obesity, hard labor, sports, etc., and the influence of some of these stresses should be taken into consideration together with the protecting function of the thigh muscles. But the significance of the thigh muscles are not clarified yet.

Thus, in the present investigation, muscle activity of the thigh muscles was examined while using the treadmill for the purpose of clarifying the significance of these muscles in the disease state. Examinations were performed (1) in connection with the integrated electromyographic potentials (i.EMG) during treadmill walking of normal young subjects, and comparison of the active electromyographic potentials of the patients with the knee O.A. and of the normal young subjects during the treadmill walking, and (2) for examining the change in the muscle activity accompanied by the anteflexion position of the spine.

Materials and Methods

The muscles examined were vastus medialis, vastus lateralis, rectus femoris, tensor fasciae latae, biceps femoris, medial hamstring, and gluteus medius. At the belly of each muscle, superficial electrodes were fixed at 4 cm interval.

In the examination (1) 18 normal men and 3 normal women, (18 to 34 years of age) were studied. The walking speed on the treadmill was changed from 1.6 km/hr to 8 km/hr, and the corresponding change in the electromyographic potential was measured. The walking speed in 30 female subjects (48 to 76 years old) with the knee O.A. was 1.6 km/hr, and the electromyographic potential was compared with that of the normal subjects. In the examination (2), 11 normal men and 10 normal women (15 - 57 years old) were studied. The walking speed on the treadmill was 3.2 km/hr with anteflexion and upright spine position, and change in the active electromyographic potential was examined.

The electromyographic potential was lead through a telemeter and recorded. The mean i.EMG per a walking cycle and the phase of the muscle activity were examined.

The i.EMG was obtained as the product of the wave numbers and the mean amplitude by a signal processor.

Results

Examination (1)

1. Change in the i.EMG at each speed of walking was obtained as the ratio to the i.EMG at walking speed, 3.2 km/hr. It was found that the i.EMG changed with the walking speed, from 1.6 km/hr to 8 km/hr; as the mean values from 0.8 to 4.9 in the vastus medialis, from 1.1 to 3.3 in the vastus lateralis, 1.0 to 5.2 in the rectus femoris. On the other hand, during the same treadmill walking, the i.EMG decreased from 1.5 to 0.6 in the tensor fasciae latae and from 1.3 to 0.7 in the gluteus medius. The active potential change in the biceps femoris was from 1.2 to 2.8, and in the medial hamstring was from 1.0 to 1.2.

2. Ratios of the i.EMG in the vastus medialis, tensor fasciae latae and medial hamstring to the i.EMG in the vastus lateralis were obtained, and the ratios in the knee O.A. and in the normal subjects were compared. There was no difference in the ratio of the active potential in the vastus medialis

to vastus lateralis, but the ratio of the tensor fasciae latae to the vastus lateralis was 8.8 in the normal subjects, while it was 2.7 in the subjects with the knee O.A. The ratio of the medial hamstring to the vastus lateralis was 3.7 in the normal subjects, while it was 1.3 in the subjects with the knee O.A. with significant difference ($p < 0.001$).

Examination (2)

Change in the electromyographic potential in the anteflexion position of the spine was obtained as the ratio of the i.EMG in the anteflexion position to the i.EMG in the upright position. The mean value was 0.8 in the vastus medialis, 0.6 in the vastus lateralis, 0.3 in the rectus femoris and 0.6 in the tensor fasciae latae, showing decreasing tendency of the active potential as the position changed to the anteflexion from the upright position. On the other hand, the mean ratio of the active potential was 1.5 in the gluteus medius, 4.5 in the biceps femoris and 5.9 in the medial hamstring, showing increasing tendency.

Conclusion

1. The quadriceps femoris plays an important role in the stabilization of the sagittal plane, and the activity of the quadriceps femoris increases as the walking speed increases. The tensor fasciae latae and gluteus medius contribute to the stability of the frontal plane, and they function more at slow walking speed. Hamstrings control the knee joint precisely according to the various situation.

2. Reservor capacity of the thigh muscles is poor in the knee O.A. The possible effort is concentrated on the stability in the upright position in the subjects with the knee O.A compared with the most efficient activity in the young subjects.

3. Changes in action potential following anteflexion posturing are thought to play an important role in building up pathological conditions of the knee O.A. as medial tibio-femoral joint degeneration, flexion contracture of the knee, abducent and external rotational inclination of the hip joint and internal rotation of the leg, etc.

<S-10-4>

THE ROLE OF THE QUADRICEPS IN NORMAL AND THE MALALIGNMENT SYNDROME OF THE PATELL-FEMORLA JOINT.

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The quadriceps, which is a extensor is one of the most important musclein human locomotion. For long time its function has been studied and discussed anatomically and physiologically. However, the correlation of each muscle of which the quadriceps is conposed has not been reported so much. We think the correlation between the vastus medialis and the vastus lateralis in the quadriceps is very significant, especially in considering the cause and treatment of the malalignment syndrome of patello-femoral joint because two muscles work each other antagonistically in the movements of the patella during the extension of knee. The aims of our research are as follow.

1) The kinesiological analysis of the vastus medialis and the vastus lateralis during the knee extension.

2) The detection of the difference between normal group and the malalignment group of pattello-femoral joint in the correlation between these two muscles.

3) The discussion of the diganostic reliability of our method.

The L/M ratio between the vastus medialis and the vastus lateralis in control gorup (10 cases), the unstable patella group (34 cases) and the recurrent subluxation of patella group (9 cases) was evaluated by EMG and Cybex II machine (Lumex Co. Ltd).

The correlation between L/M ratio and Q angle was statistically disclosed. And also, the correlation in the recurrent subluxation of patella group and one in the control group and unstable patella group was reverse. However the L/M ratio among these three group was not statistical significant.

Besides, we divided the knee joint into M-dominant group and L-dominant group by frequency analysis of EMG and found there was a tendency for the L-dominant group to suffer from the malalignment syndrom of the patello-femoral joint.

ALTERATIONS IN THE DYNAMIC INTRA-ARTICULAR PRESSURE OF THE KNEE JOINT IN DISEASE AND INJURY.

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Japan.

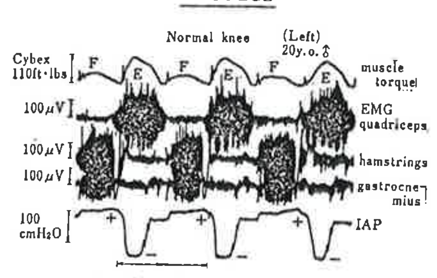
Purpose

The purpose of this report is to measure the dynamic intra-articular pressure of the knee joint and investigate the correlation between the intra-articular pressure and the muscular contraction of the knee joint using the cases of affected knee joint. The normal knee of each volunteer was studied as control.

Material and methods

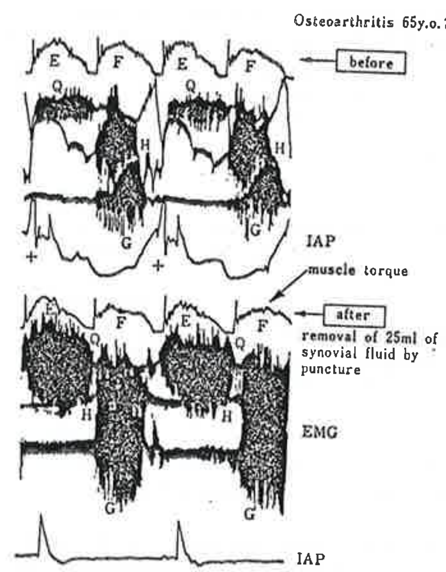
70 cases of affected knee joints were used for this study. Original conditions were 50 cases of degenerative osteoarthritis, 20 cases of rheumatoid arthritis and 30 cases of meniscus injury. At first, torques of the extensor and flexor muscles of the knee were evaluated in isokinetic contraction by use of Cybex II (Lumex, Inc., New York, U.S.A.). Thereafter, a dynamic intra-articular pressure during motion was measured by a water manometer connected to a No.8 teflon needle which was inserted into the knee joint. At the same time, bipolar electromyographies were taken by electrodes which were attached to the extensor and flexor muscles of the knee joint. The normal knees of 50 volunteers were also examined in the same way.

Results



(Fig. 1)

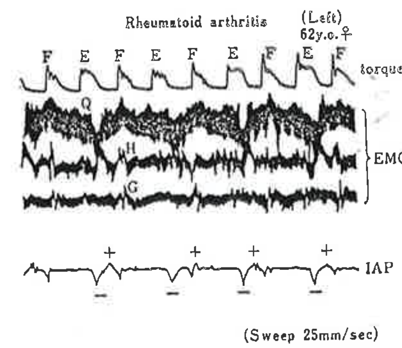
Figure 1 containes the typical results of a dynamic intra-articular pressure, muscle torque curve and electromyographies of each detective muscles in the normal knee joint. This illustration prove that the intra-articular pressure show large negative values in the extension position and 0 or slightly positive in the flexion.



(Fig. 2)

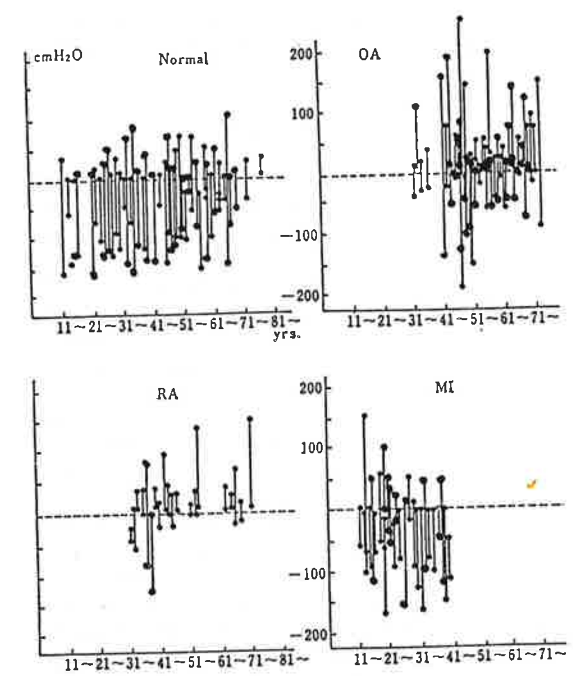
Figure 2 demonstrates the typical patterns of the degenerative osteoarthritis associated with joint effusion. The results were divided into two categories before and after removal of the joint fluid. After the joint fluid is removed out, the rage of motion is widenned and action potentials of muscles become higher voltage of amplitude. And also the abnormal positive intra-articular pressure in the flexion position restore towards normal

level approaching to 0 value.



(Fig. 3)

Figure 3 illustrates the case of rheumatoid arthritis. All of results show within small alterations. On the other hand, all of results indicate simular patterns of the normal knee joint in the cases of meniscus injury.



(Fig. 4)

Figure 4 is pointed out briefly the change width of the intra-articular pressure during movement in normal and each affected knee. In this sample, the values of intra-articular pressure make usually in high positive if there are association with joint effusion.

Discussion and summary

This analysis made it clear that the changes of the intra-articular pressure of knee were commonly synchronized with joint movement in any cases. The major factor correlating with the intra-articular pressure is considered to be the muscular contraction of the knee joint, although there include other factors of position, joint effusion and elasticity of the joint capsule.

<S-11-1>

ELECTROPHYSIOLOGICAL STUDY OF RESPIRATORY FUNCTION IN AMYOTROPHIC LATERAL SCLEROSIS (ALS)

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Introduction

A patient of ALS commonly falls in respiratory failure in the terminal stage on account of neurogenic degeneration of the respiratory muscles. It is important to evaluate the respiratory function in ALS. Previous workers used blood gas analysis or spirogram for this purpose, but had not studied the function of the respiratory muscles i.e. diaphragm and intercostal muscle. We recorded diaphragmatic evoked potential(DEP) by phrenic nerve stimulation, and found the amplitude and the latency of DEP useful in evaluating the respiratory function of ALS.

Materials and methods

10 patients (4 males and 6 females, the age 44-65 years, average 59 years) with ALS, who had no respiratory disease, were studied. 8 normal persons were used as controls. The diaphragmatic evoked potential was recorded from surface electrodes placed over the seventh intercostal space by stimulating a phrenic nerve at the posterior border of the sternocleidomastoid muscle. Stimulation was carried out by suprathreshold square wave pulses of 0.2 msec duration. At the same time, the disability of limbs, blood gas and spirogram were recorded.

Results

The disability of limbs was light or moderate. In blood gas analysis, Pco_2 was normal in 8 patients of 10, but Po_2 was lower than 80 mmHg in 4 patients. Spirogram showed that %VC was less than 80% in 9 cases of 10, but all cases revealed normal values of FEV1% (72.4-100.0%).

The mean amplitude±SD of DEP in ALS was 410±240μV in the right diaphragm, 441±331μV in the left. 4 patients of 10 showed the values less than one third of mean values(right 780μV, left 810μV) of normal controls.

The mean latency±SD of DEP was 10.1 ±3.3 msec in the right diaphragm, 9.5 ±3.3 msec in the left. 5 patients of 10 showed longer latency than mean+2SD (right 7.1+1.2 msec, left 6.8+1.0 msec) of normal controls.

The correlation coefficient between the amplitude of DEP and Po_2 was 0.81; $p<0.01$(Fig.1), but the amplitude had no relation to the degree of the disability of limbs, Pco_2, %VC and FEV1%. The correlation coefficient between the latency of DEP and Po_2 was -0.68; $p<0.05$ (Fig.2). %VC showed low values (range 34-60%) in the cases who had longer latency than 8 msec. FEV1% tended to decrease as the latency was prolonged. But they had no significant correlation to the latency.

Discussion

Previous workers reported the latency of DEP was prolonged in neuropathy, invasion of tumor to phrenic nerve, injury etc., but normal in ALS. On the contrary, we found that the latency of DEP in ALS was prolonged in 3 cases of 10 compared with normal controls. The latency is a summation of the phrenic nerve conduction time, the neuromuscular junction transmission time and the muscle excitation time. It was reported that the histogram of myelinated fiber diameters of the anterior root in ALS showed decrease of large fibers, which decided the maximal velocity of nerve conduction. It was considered that the velocity would decrease in the case with the destruction of the largest nerve fiber. This seemed to be support ed by some reports that MCV of the other motor nerve significantly decreased in ALS. Transmission disturbance in regenerated neuromuscular junction and delayed activation of

destroyed muscle fibers were also considered to account for the prolongation of the latency.

The amplitude of DEP decreased in 4 patients of 10 as previous workers reported. These findings were similar to those about other motor nerves. In general, the amplitude of evoked potential recorded by surface electrodes is said to be unreliable parameter of muscle function because of variable distance between recording point and motor point, variable resistance between skin and electrode and so on. In this study, the recording point of DEP was far from motor point of diaphragm, so the error induced by difference of recording point seemed to be smaller than the record on the motor point. For an electric potential of muscle exponentially decreases away from the motor point.

The amplitude and the latency of DEP were significantly correlated to Po_2 which seemed to be an index of chronic respiratory failure in ALS according to some workers' report that Po_2 in ALS gradually decreased as the disease progressed, but Pco_2 kept well even in the terminal stage.

A phrenic nerve could be easily stimulated by surface electrodes at the neck. Phrenic nerve stimulation would be least invasive to a patient, and a patient's cooperation could be negligible unlike spirometry. Phrenic nerve studies seemed to be useful in evaluating respiratory function of ALS patients. The amplitude and the latency of DEP would be considered to denote the diaphragmatic function and could be utilized as the valuable indexes for the evaluation of chronic ventilatory impairement in ALS.

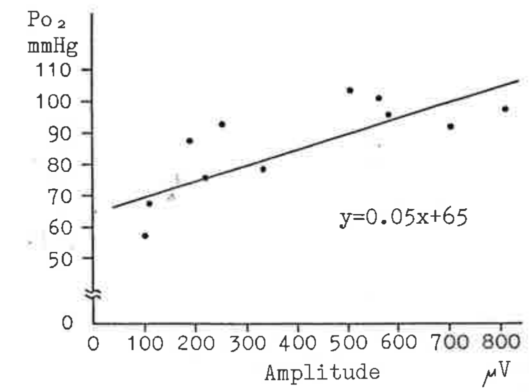

Fig.1.Correlation between the amplitude of DEP and Po_2 was 0.81; $p<0.01$.

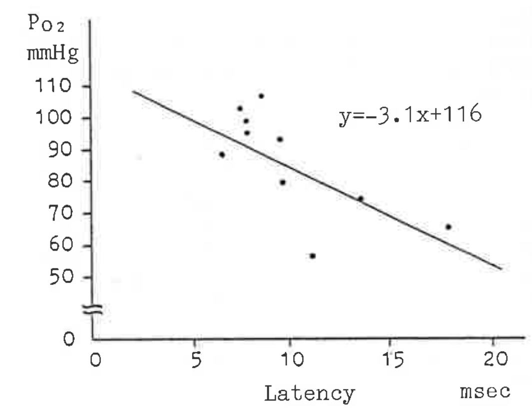

Fig.2. Correlation between the latency of DEP and Po_2 was -0.68; $p<0.05$.

<S-11-2>

ELEVATION IN UPPER PART OF TRAPEZIUS MUSCLE IN FSH MUSCULAR DYSTROPHY

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INTRODUCTION

In facioscapulohumeral muscular dystrophy (FSH), the main distributions of atrophy are the parts of body around the face, scapula and humerus, although these areas are not uniform in atrophy and muscular weakness. We noticed that the elevation in upper part of trapezius muscle during shoulder abduction was the characteristic phenomenon in FSH and we investigated and analysed of this phenomenon fromthe clinical, roentogenological and electrophysiological points

MATERIALS AND METHODS

We studied 3 cases with FSH (2 males and 1 female), aged 61, 18 and 33 years. The durations of illness from onset were 35, 4 and 3 years each. 2 normal persons were used as controls.

The neurological examination, roentogenelogical study of upper trunk and arm, and the surface EMG of upper trapezius, supraspinatus, infraspinatus, deltoid and serratus anterior muscles were investigated in neutral and full abduction position of shoulders.

RESULTS

In 3 cases with FSH, the active maximum abductions of shoulder were about 90 , although they had the full range of motion in shoulder in passive movement. Marked weakness were observed in serratus anterior, lower part of trapezius and rhomboideus muscles, moderate weakness were observed in upper part of trapezius, supraspinatus, deltoid, latismus dorsi, pectralis major, biceps brachii, triceps brachii and brachialis muscles. The elevation from neck to shoulder were observed in all cases during the active maximum shoulder abduction. The hypertrophy of muscles was not noticed at rest. In normal controls, the elevations from neck to shoulder were not seen even in active full abduction of shoulder.

From roentogenological study, it was shown that in shoulder abduction the superior angle of shoulder was elevated markedly without upward rotation of shoulder in FSH, and superior angle of shoulder were lowered in 1 or 2 level of thoracic body with upward rotation of shoulder in controls. Although the ratio of rotatory movement between scapula and humerus in controls was 2 to 1, the upward rotatory movement of shoulder in FSH was not observed.

From the surface EMG study, although the deltoid, supraspinatus and serratus anterior muscles showed marked muscle discharges without discharges of upper part of trapezius muscle in controls, the remarkable discharges of upper trapezius, deltoid and supraspinatus muscles were observed in FSH without marked discharges of serratus anterior muscle. When the inferior angle of scapula in FSH was pushed to outer direction, as the compensation of function of serratus anterior muscle, the shoulder abduction was increased up to 150 and the muscle discharges of upper part of trapezius muscle were disappeared. And the application of the elastic band or scapular pad oven the inferior angle of scapula also made the increase of shoulder abduction and the disappearance of muscle discharges of upper part of trapezius muscle.

DISCUSSION

The detail analysis of elevation on the neck to shoulder during shoulder abduction in FSH was not done in the past. Due to the marked weakness of serratus anterior muscle. the upward rotation of scapula during shoulder abduction became weak and the muscle activities of upper part of trapezius muscle, which was the assistant muscle of upward rotation of scapula, were increased. It was considered that, as the functions of upper part of trapezius muscle were not only upward rotation of scapula but also the elevation of scapula, the elevation from neck to shoulder was observed during shoulder abduction in FSH, although other muscles like the levator scapula muscle might work as the assistant muscle in these special situations and might increase the elevation of scapula.

The muscle hypertrophy in FSH were reported in deltoid and triceps muscles of upper limb, but the paper about trapezius muscle was not present, and in our cases there was no muscle hypertrophy at rest.

<S—11—3>

AN ISOKINETIC ASSESSMENT OF THE LOWER LIMB MOVEMENTS IN ATAXIC HEAD INJURED PATIENTS

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INTRODUCTION

Evaluation of functional lower limb movement of head injured patients is an area almost untouched in the literature. It is, however, of critical importance in the rehabilitation of patients who have received major head trauma. Isometric assessment of muscle function (1) has not contributed much in the way of clinical prognosis nor has it provided a criteria for functional ability. Patterns of EMG activity (3) during movement have provided more information but have not provided a detailed baseline from which individualized therapy strategies could be developed and applied. Isokinetic evaluation of the knee musculature (2) has been shown to be an effective measurement of muscle strength relationships. This investigation was undertaken to assess the functional relationships of ataxic leg musculature of head injured patients.

MATERIALS AND METHODS

This investigation utilized two young adult males who had suffered diffuse head injury as a result of automobile accidents. Each had undergone an extensive treatment regimen including occupational, physical and speech therapy supported by appropriate psychological, occupational and educational counseling. Pateint B had completed inpatient treatment, had been discharged, and is living independently. Patient A, still an inpatient, is making steady progress. No admission baseline data is available, so only between subject data is presented.

Each patient underwent an isokinetic evaluation using the CYBEX II (Lumex, Inc., Bayshore, NY) unit. Isokinetic tests were carried out on knee extension and flexion utilizing three speeds of 90°/sec, 180°/sec and 240°/sec. A measure of work (the integral of the mechanical power over a specified period of time) was taken on the basis of 10 repetitions at 240°/sec. Two additional torque measurements were taken at 30° and 90°. Normals are based on a within-subject comparison.

RESULTS

In addition to the position (electrogoniometer) and torque curves presented in Figure 1A and 1B, a table of critical values is presented below for an isokinetic speed of 90°/sec for the involved side.

Table 1: Selected Values for Torque in an Isokinetic Contraction of 90°/sec, involved side.

INVOLVED SIDE	Peak Torque in FT-LBS	Percent Body Weight	TAE 240°/sec % Deficit
Pat. A			
Ext	120 * 49°	65%	-44%
Flex	25 * 75°	14%	0%
Pat. B			
Ext	129 * 53°	62%	-4%
Flex	78 * 27°	37%	-20%

DISCUSSION

The cerebellar ataxia determined by clinical assessment is evident in both patients' isokinectic torque charts. Effective power for locomotion is dependent on relative equal torque generation in the quadriceps and hamstrings. Patient B is ambulatory and shows a proper geometrical relationship between these two muscle groups. However, we suggest that the unevenness in the hamstring torque curves on the initiation slope is the reflection of the cerebellar involvement. Patient A is not ambulatory and the unequal torque generation is evident. In addition, we would point out the delay in the reciprocal innervation time (RIT) between the quadriceps and hamstring curves. This we suggest shows the increased tone and an interference with motor planning. It should be noted from Table 1 that the major deficits appear in the flexion movements. This suggests that the control of the reciprocal movement might be a result of weakness of that muscle group at selected areas in the range of motion of the limb.

It should be pointed out that clinical assessment attributes a predominant involvement to one side or the other for each patient. Close observation of the torque curves reveal a similarity for both sides. We attribute the similarity in pattern to the diffuseness of the lesion and to the final distribution of the descending motor pathways.

CONCLUSION

Briefly, we conclude that the isokinetic evaluation is an effective means to provide an accurate representation of the cerebellar ataxia evident in head injured patients. In addition, the capability of this method to provide quantitative data on torque at various ranges of motion provides a baseline on which therapies can be designed. Subsequent testing coupled with clinical assessment can provide the means for determining successful therapies.

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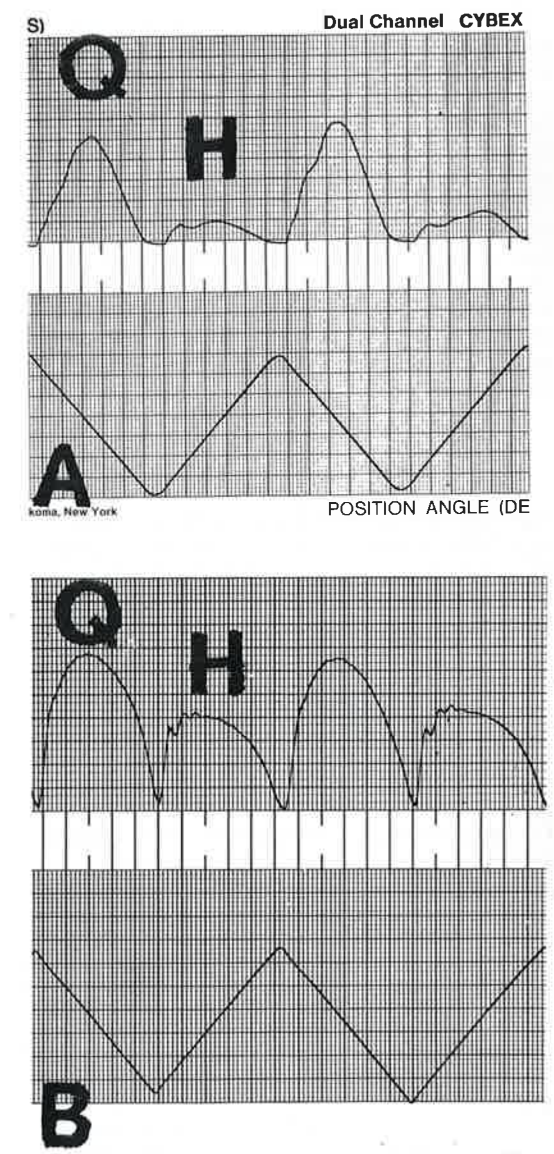

Fig. 1. Pat. A upper, Pat. B lower. Movement of involved knee joint at 90°/sec. Top channel is torque; lower channel is position. Q=quadriceps. H=hamstrings.

<S-11-4>

Three cases of lingual ballistic movement followed by rigid-dystonic state of the tongue

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(Introduction)

Although there have been many reports concerning orolingual dyskinesia, the ballistic protrusive movement and rigid-dystonic protrusive state of the tongue have not been taken into any consideration. In this report, three cases of atypical dyskinesia were described. The characteristic of these dyskinesias was ballistic protrusive movement which was altered to dystonic protrusion of the tongue by the administration of anti-dopaminergic agents. Then, the clinico-pharmacological analyses were carried out on these lingual protrusive movement and dystonia.

(Case reports)

Case 1 was 74 year-aged woman. She had not yet been treated with any anti-psychotic agents. At the age of 71 year, she showed vigorous involuntary lingual movement. A general physical examination was normal. Her tongue stirred involuntarily forward and backward without rotation. CT scan of brain showed mild atrophy of cerebrum and minimum low density areas scattered in subcortex. The administration of haloperidol caused remarkable dystonic protrusion of the tongue without hyperkinetic movement. Trihexyphenidyl altered the involuntary movement to a typical orolingual dyskinesia.

Case 2 was 74 year-old woman. She caught parkinsonism with tremor, rigidity and bradykinesia by the administration of metoclopramide for chronic gastritis. The treatment with trihexyphenidyl improved parkinsonism, but hyperkinetic protrusive movement of tongue occurred. A general physical examination was normal. On the neurological examinations, there were neither tremor, rigidity nor bradykinesia. She also showed lingual protrusive movement stirring vigorously forward and backward without rotation. By the administration of sulpiride, the involuntary lingual movement changed into remarkable lingual protrusive dystonia.

Case 3 was 78 year-aged man whose protrusive movement of the tongue was caused by metoclopramide administration. The general physical examination demonstrated slight anemia and liver enlargement. On the neurological examination, there were neither rigidity, tremor nor bradykinesia. The laboratory tests showed slight pancytopenia, macroglobulinemia and chronic liver dysfunction. The protrusive movement of the tongue was not also accompanied with rotatory movement. Either sulpiride or haloperidol administration led the movement to a static protrusion.

(Discussion)

On the basis of electrophysiological study, orolingual dyskinesia has been generally assumed to be a localized chorea on facio-masticatory muscles and tongue. But the involuntary lingual movement observed with these cases had vigorous, stereotypical, stirring forward and backward, rather rhythmic character, which could be expressed as ballism. Ballism has the kinesiological characteristic of nearly ceaseless activity and movements tend to be persistent, while chorea has the kinesiological characteristic of intermittent activity with long pauses and movements show little tendency to be persistent. And ballism of extremities is the involuntary hyperkinetic movement which shows the same pharmacological reactions as chorea. There have been some studies for kinesiological classification of orolingual dyskinesia, but very few reports have been described on ballism and dystonia of the tongue. Then, we carried out the kinesiological and clinico-pharmacological analyses of lingual ballism and dystonia.

The causes of lingual protrusive movements of these patients were considered as follows: Case 1 was so-called idiopathic, due to lacunar stroke, case 2 was caused by trihexyphenidyl and case 3 by metoclopramide. Inspite of different causes, the lingual involuntary movements had almost the same characteristics.

Generally, extrapyramidal disorders are classified according to the hypothesis of imbalance between dopamine(DA) and acethylcholine(Ach) in basal ganglia. The state of DA excess and/or Ach deficiency is assumed to cause hyperkinetic movement disorders including chorea, ballism, tardive dyskinesia and so on. The mirror image of this paradigm, namely the state of DA deficiency and/or Ach excess, is thought to manifest rigid-dystonic movement disorders including Parkinson disease, dystonia musculorum deformans and so on.

In the present cases, the administration of dopaminergic or anti-cholinergic agents enhanced the protrusive ballistic movement of the tongue, and the medication of antagonist of dopaminergic receptor caused remarkable static protrusion of the tongue with rigidity of extremities. Thus, it is said there are also two phases of lingual extrapyramidal symptom in these cases, i.e., hyperkinetic ballistic movement in predominancy of dopaminergic system and rigid-dystonic state in the counter state. Then, it seems to be noteworthy of investigations of lingual hypokinesia in addition to well-described hyperkinesia.

(Conclusion)

Three cases of atypical lingual dyskinesia were reported. The involuntary movement had the characteristic of lingual ballism and dystonia, which scarcely described in the past. And the clinico-pharmacological analyses of them were reported.

<S-11-5>

REMARKABLE PSEUDOATHETOSIS OF UPPER LIMBS DUE TO ABNORMALITY IN ATLAS AND AXIS

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INTRODUCTION

A case with abnormality in atlas and axis who presents remarkable pseudoathetosis of upper limbs is reported as such a case is rare and is very important to analyze the pathogenesis of pseudoathetosis. We study this case, clinically and physiologically.

CASE REPORT

A 46-year-old male felt difficulty in movement of right hand and foot and had radiating pain on right upper limb on January 1 1984. His symptom progressed for 3 days from the day of onset, when he couldn't handle chopstics. And his symptom subsided after bed rest for a month. In February 20 1984 he started to feel difficulty in movement of right limbs again. Since then there was no improvement in his symptom. He was referred to our department of neurology on March 27 1984. There is no past history of trauma in cervical spine and head.

General physical examination are unremarkable. In mental state, consciousness is alert and well orientated. Cranial nerves system are normal.

In motor system, pseudoathetosis is observed on bilaterel upper limbs and muscle tonus is slightly hypotonic. In finger-nose test & heel-knee test, decomposition and dysmetria are seen. Romberg's sign is positive. His walking is wide-based and unstable.

Character of his involuntary movement is 0.1-2.0Hz frequency, irregular and intermittent. This abnormal movement is observed mostly in fingers and the width of finger movement is about 1 to 5cm. This involuntary movement is observed slightly even during sleep.

Muscle stretch reflexes(MSR) is slightly hypoactive on upper limbs and slightly hyperactive on lower limbs.

In sensory system, vibratory, joint sense, stereognosis, two-point discrimination are severely disturbed and superficial sensation is moderately and temperature sense is mildly disturbed in four limbs. The upper segmental level of hypesthesia is C-3 segment.

In myelogram, defect of metrizamide filling is found at flava ligament on part of axis.

DISCUSSION

By the leasion of cervical spine, the posterior funiculus might be involved and they might show disturbance of fine movement, abnormal posture and involuntary movement like dystonia. In this case, the abnormality of atlas and axis could compress the posterior funiculus and it is suspected that pseudoathetosis and disturbance of position and vibratory sense are induced by it.

It is considered that the cause of athetosis is abnormal function of basal ganglia and the cause of pseudoathetosis is due to severe disturbance of deep sensation. But the pseudoathetoid movement observed during sleep can not be well explained on the basis of lack of deep sensation, and we also cann't explain the big movement in pseudoathetosis. On these observation we suspect that pseudoathetosis in this case may be induced not only by severe deep sensory disturbance due to compression of posterior funiculus but also by increased and decreased activity of interneurons and long tract due to mild compression of lateral and posterior funiculus.

CONCLUSION

A rare case of severe pseudoathetosis in a 46-year old male with abnormality in atlas and axis is presented. He suffered from severe disturbance of deep sensation and fine movement. On his myelogram compression of spinal cord in upper cervix is showed. We suspect that this pseudoathetosis might be caused by disturbance of deep sensation and by disorder of interneurons and lateral funiculus in the spinal cord.

<S-12-1>

DYNAMIC ANALYSIS OF HUMAN ERECT POSTURAL SWAYS

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Introduction

Human erect posture is very unstable. The constant pull of the earth's gravity, etc. upon the human erect body serves to disturb and cause the sway of the standing posture at every moments. The sway in any direction, however, will always be corrected to hold a dynamic equilibrium ("homeostasis") of the posture, so that only invisible minute sway is exhibited from time to time.

As the amount of this sway at an arbitrary time will depends in stochastic fashion on previous amount of this sway, it can be described as an high-order autoregressive (AR) process.

In this study, the most appropriate sampling interval of the discrete time series of this sway for applying the AR-process was determined for the first step. In the next, the high-order postural control activity analysed by the AR-process was decomposed of one or two first and some second order activitivites by the AR-component analysis. The former displayed a damped exponential average time pattern with its power higher than 90 % of the total one. Each power of the lateral and antero-posterior sways was displayed on the XY-plane and the vector was obtained.

Fig.1 BLOCK DIAGRAM OF EXPERIMENTAL APPARATUS

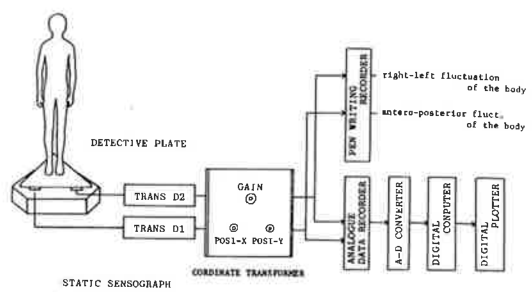
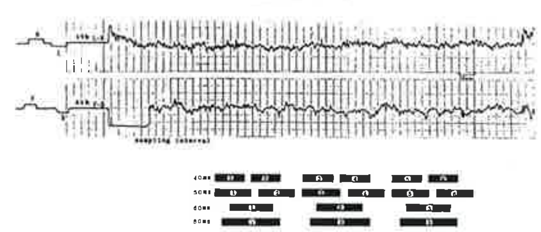


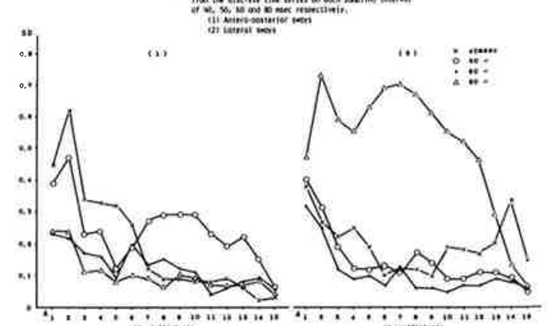
Fig.2 Lateral and antero-posterior sways during standing with eyes open and the feet together, case 1: Female 40yrs 55kg 150cm



Method

The postural sways of thirty one healthy adults were studied. Each subject stands on the detective plate of the sensograph with eyes open and feet closed, whereas sixteen ones with eyes open and feet opened for 30 cm width. The lateral and antero-posterior sways of the gravity were recorded magnetically (MT) by an analogue data recorder (FC-14, SONY) and ink-written by a pen recorder (RECTIGRAPH-8K, Nihon Denki Sanei) (Fig. 1). The MT recording was reproduced for AR-analysis with each sampling interval of 40, 50, 60 and 80 ms, respectively (Fig. 2). AR coefficients (A_1-A_{15}) and Akaike's Information Crieterion (AIC) (Fig. 4) were computed in each discrete time series with these sampling intervals (Fig. 3).

Fig.3 Standard deviation (SD) of the AR coefficients obtained from the discrete time series on each sampling interval of 40, 50, 60 and 80 msec respectively.
(1) Antero-posterior sways
(2) Lateral sways



The vector of the first order lateral and antero-posterior component activities was recorded on the XY-plane (Fig. 5) and the histograms of the vector to the X-axis were obtained (Fig. 6).

Results

It was verified that the least standard deviation of the AR-coefficients (A_1-A_{15}) and AIC will indicate the most appropriate AR-process. From this point of view, the most appropiate sampling interval seemed to be 50 ms (Fig. 3 and 4). The angle of the vectors of the first order human postural sway in its power was amounted to 47.5 ± 13.4 degrees in the case of eyes open and feet closed, whereas 75.7 ± 11.3 degrees in the case of eyes open and feet opened for 30 cm width (Fig. 6).

Fig.4 Average and SD of the minimum AIC estimates.
(1) Antero-posterior sways
(2) Lateral sways

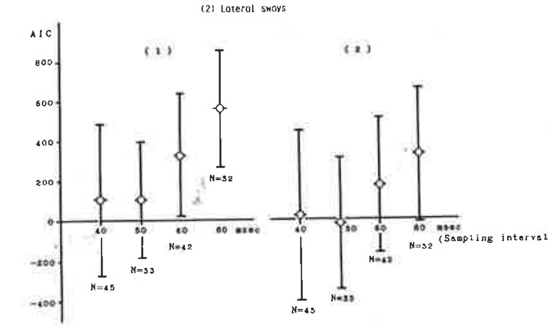


Fig.5 Voctor of the first component power of the human standing postural sways. (case I.Y.)
X: The power of the lateral sway
Y: The power of the antero-posterior sway

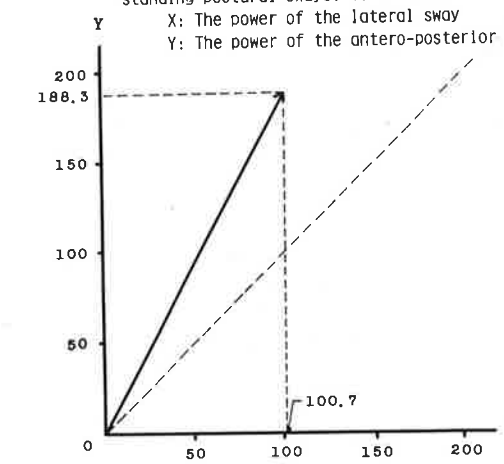
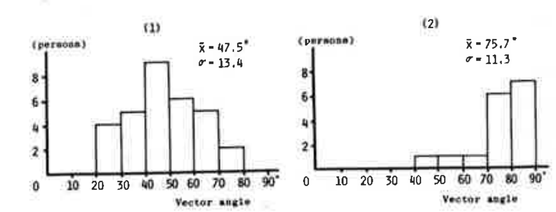


Fig.6 The histograms of the vector angle of the human standing postural sways
(1) With the feet together
(2) With the feet open



<S-12-2>

MUSCULAR FACTORS INFLUENCING ON THE INTRAABDOMINAL PRESSURE

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INTRODUCTION

During the study on the disc pressure of the lumbar spine, one of the authors noticed that this pressure might be affected by the intraabdominal pressure (IAP). These two kinds of pressure are thought to be influenced by more physiological function such as muscular activity*. Our interest is now focused how the muscle activity influences on IAP. Inthis study, we (1) observed the muscular activity patterns of the trunk during various motions, and (2) investigated how IAP corresponds to the muscular activity patterns.

METHODS

Ten healthy male adults whose mean age was 27.6 years participated in this study. Using MICROTIP transducer of Miller Comp. IAP was measured per rectally. Using the surface electrodes, EMG was picked up from the erector spinae muscle (erect. sp.) at the third lumbar vertebra, and from the rectus abdominis muscle (rect. abd.) and the obliquus abdominis muscle (obl. abd.) at the navel level.

Once measurements were recorded on TEAC R210-B data recorder, later, using Signal Processor 7T08 of Sanei-Sokki, an integrated EMG (IEMG) and IAP in a unit time (100 msec) were derived. That is, a sammation of 200 absolute amplitude values sampled at 500 μsec intervals, based on the integrated values in a unit time, correlation coefficients between IEMG and IAP were calculated using Signal Processor. To evaluate the grade of the muscular activity, and also of IAP, in various static motions for 2sec, indices were calculated as follows : the activity index of each muscle in a given motion was from

$$\frac{\text{IEMG of a given motion}}{\text{maximum IEMG of all motions}} \times 100$$

and the ratio of IAP change was from

$$\frac{\text{IAP in a given motion}}{\text{maximum IAP of all motions}} \times 100$$

RESULTS

1) Isometric trunk flexion and extension

In the neutral position where the subjects were fixed with their pelvis and thighs in the apparatus, flexion and extension of the trunk were isometrically done in five steps of effort from maximum to 1/5 of maximum.

In flexion, little activity was observed in erect. sp, in any grade of effort, while activities to be appropriate to efforts were observed in rect. abd. and obl. abd.. IAP, also, showed correspondence to the grade of effort. The latter three parameters showed the same grade of the response, for yielding flexion torque of the trunk, which was revealed in almost the same indices in each five steps of effort. Correlation coefficients between IEMGs of rect. abd. and obl. abd., and IAP were o.89 and 0.92.

In maximum extension, the activity index of erect. sp.was the highest (93) of all procedures and that of obl. abd. was 42, and the ratio of IAP change was 48. these four indices showed decrese in correspondence to decrease of effort. The ratio of IAPchange was rather equivalent to the activity index of obl. abd. than that of erect. sp..

2) Holding arm elevated

The subjects were situated as above and asked to hold both arms for 5 sec in the front of the body with loads of 12, 8 and 4kg, and without load.

From obl. abd., slight activity and from rect. abd..very slight activity were observed in comparison with much more activity from erect. sp. which showed decrease in correspondence to decrease of load. The ratio of IAP change was rather equivalent to the activity index of obl. abd..

3) Traction by the arm in standing

The subjects were asked to pull and return repeatedly the weight of 8, 12, 16, 20, 24 and 30kg by both arms in the position same as above. Phasic muscular activity associated with excursion of the weight was observed in erect. sp.. The activity level of active portion was moderate to high corresponing to weight level. None to slight in rect. abd. and none to moderate activity in obl. abd., and none to moderate increase in IAP were observed, and relatively low correlations were seen between muscular activities and IAP.

4) Extension by the arm in standing

The subjects were asked to push and return as above. Phasic activities ranging fair to high were observed from rect. abd. and obl. abd., while the activity of erct. sp. was negligible. Phasic IAP change was seen in synchronization with the activities of the abdominal muscles, showing relatively high correlation to them (0.69 & 0.62).

5) Isokinetic flexion-extension of the trunk

The subjects were asked to flex and extend the trunk isokinetically in 5 RPM. During extension, erect. sp. was very active and abdominal muscles also were moderately active(obl. abd. was more distinbctive). During flexion abdominal muscles were very active. IAP showed phasic change corresponding to the activity of obl. abd. as obviously seen from correlation coefficient.

DISCUSSION AND CONCLUSIONS

1) Muscular activity pattern of isometric trunk flexion and extension is classified as abdominal muscle type because much to trace activities corresponding to various loads are seen in abdominal muscles but negligible in back muscle. That of isometric trunk extension, holding arm elevated and arm traction is classified back muscle type, of which co-contraction(back muscle initiative) type is subdivided when moderate activities of the abdominal muscles are accompanied during high mechanical demand.

2) In abdominal muscle type, rect. abd. and obl. abd. as a prime mover are concerned in increasing IAP. In co-contraction type, it is thought that obl. abd. is concerned in IAP change, because the ratio of IAP change is equivalent to the activity index of obl. abd., and coefficient shows high correlation between them. While erect. sp. is activated in correspondence to the load, it does not yield IAP in back muscle type and it does not correlate to IAP during phasic activity.

*1) Andersson G B J et al: Clin Orthop, 129:156-164, 1977.
2) Grew N D et al: Spine, 5: 149-154, 1980.
3) Ortengren R et al: Spine, 6: 98-103, 1981.

Table I Activity Index and Ratio of IAP Change

Procedure		Activity index Erect. sp.	Rect. abd.	Obl. abd.	Ratio of IAP
Isometric flexion	max	x	100	89	78
	4/5	x	69	57	49
	3/5	x	36	37	28
	2/5	x	16	20	18
	1/5	x	5	7	7
Isometric extention	max	93	x	41	48
	4/5	72	x	23	24
	3/5	57	x	13	12
	2/5	45	x	7	6
	1/5	35	x	5	2
Holding arm elevated	12kg	62	5	19	15
	8	38	2	9	3
	4	27	2	8	3
	0	8	2	5	1

Table II Correlation Coefficient Between Muscular Activities and IAP

Procedure	Coefficient to IAP of Erect. sp.	Rect. abd.	Obl. abd.
Isometric flexion	x	0.89	0.92
Isometric extension	0.70	x	0.83
Holding arm elevated	0.79	0.65	0.77
Arm traction	0.34	0.26	0.39
Arm extension	0.10	0.69	0.62
Isokinetic 5RPM	0.02	0.36	0.67

x Due to limited function of processor

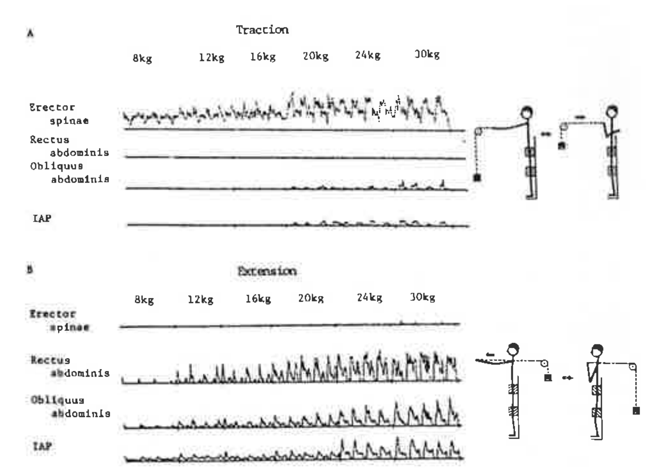

Fig. Traction (A) and extension (B) by the arm was done as shown in the sight. A and B show that IAP change corresponds to the activities of the abdominal muscles.

<S-12-3>

ELECTROMYOGRAPHIC FEAUTURES OF IDIOPATHIC SCOLIOSIS

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Introduction

No definite conclusion has been reached as to the pathogenesis of idiopathic scoliosis despite intensive investigations conducted from various approaches. The analysis by electromyographic investigation, which was initiated by Piper et al. in 1907, has proved effective, but has not been widely accepted.

Since 1978, we have studied, using surface electrodes, the changes in the paravertebral muscle activities brought about by the treatment in scoliotic children.

Materials and Methods

Forty-three patients – 4 boys and 39 girls – with idiopathic scoliosis of the adolescent type were examined. Ages at the first examination ranged from 10 years 2 months to 16 years 4 months, the mean being 13 years 5 months. The curvature at the time was between 10 degrees and 45 degrees by Cobb's scale, with a mean of 26 degrees. Classified by the curve pattern, 23 cases had single curve, 19 double curve, and one triple curve. The most common was single thoracic rightside curve which was found in 20 cases. The period of follow-up study ranged from 1 year 2 months to 5 years 1 month, the mean being 2 years 9 months.

In the course of observation, 8 children used Milwaukee braces and 19 underarm braces. Electromyography was carried out on all the patients on two occasions: at the first examination and 2 years 9 months later on average.

The action potential of the paravertebral muscles was recorded on a four-channeled electromyograph from the surface electrodes attached to the back 2 cm from the apex spine process both on the convex and concave sides of the curve.

The points studied were as follows:

(1) With the subjects assuming still-standing position and then performing flexion, extension, bilateral bending and bilateral rotation, the difference in the level of action potential on both sides of the spine between scoliotic and normal subjects was compared.

(2) The myographic differences between the 8 patients with Milwaukee braces and those without I were compared.

(3) Electromyographic study was carried out on two occasions on all the patients irrespective of the brace used and the results were compared to detect chronological changes.

(4) The 19 patients with underarm braces were divided between those who had menarche before using the brace and those who had it afterward, and the chronological changes in the electromyogram and spinal curvature were studied correlatively with the time of menarche and brace application.

Results and Discussion

The level of action potential was graded as (++) for activity in 80 % or more of total muscles; (+) in 79-60 %; (±) in 59-40 %; and (-) in 39 % or less.

(1) In still-standing position, normal subjects showed no action potential on either side of the spine, whereas about half of the scoliotic children revealed a distinct action potential on the convex side of the spine. In flexion, the action potential was diminished on the concave side of the scoliotic cases, and in extension no activity was detected in either normal or affected children.

(2) When a Milwaukee brace was used, the action potential in still-standing position tended to be slightly higher on the convex side of the spine.

(3) The initial electromyogram revealed a dominant activity on the convex side of the spine. In the second analysis, the high action potential had mostly subsided, with little difference in the level of activity between both sides of the spine. This tendency was noted especially in groups whose conditions had either improved or were unchanged.

(4) Menarche occurred most frequently at the age of 13 with most experiencing it between 10 and 13. In those who used underarm braces before menarche, the high action potential on the convex side of the spine was smaller in a larger proportion of the patients than those who had begun wearing braces after menarche.

IN VIVO MEASUREMENTS OF VIBRATION TRANSMISSION IN THE HUMAN SPINE

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Although conclusive evidence does not exist, there are many epidemiological surveys suggesting an increase risk of low back pain in persons' exposed to vibrations. Theoretical calculations indicate that spinal motion segment components can be stressed by whole body vibration exposure to the degree that fatigue failure can occur. Further, it is also known that vibration can interfere with disc nutrition.

Several studies have been published in which the response of the trunk as a whole to vibration was measured. These measurements were usually made with a single uniaxial accelerometer placed on the head of the subject or at some place on the surface of the trunk. The output accelerations have then been related to the input, i.e., vibration transfer functions have been calculated. In this paper we report on *in vivo* experiments in which vibration was measured in the three principal directions in the sagittal plane with accelerometers attached directly to lumbar vertebrae in human volunteers.

MATERIALS AND METHODS

The study was performed on five healthy vounteers. The vibration exposure was provided using a special vibration exciter that is based on a resonating system. Using this exciter the subjects were vibrated when sitting with sinusoidal vertical accelerations of .1g and .3g (0.98 and 2.94 m/s^2) in a frequency range from 2 to 15 Hz. Vibration along the spine was measured at three different points, two lumbar vetebrae and the sacrum. Measurements were made with a plane motion acceleration transducer (PAT), consisting of three linear accelerometers mounted in a special configuration on an aluminum fixture. The transducer was mounted on a K-wire which was inserted into the spinous processes and the sacrum. The PAT accelerometer measurements were validated using several fresh cadaveric functional spinal units mounted on an electro-mechanical vibrator.

The vibration amplitude, which was measured by an accelerometer placed on the seat, was kept constant while the frequency was varied in several steps from 2-15 Hz. At each step, recordings were made for about 30 s. The output from each PAT was transformed to its corresponding vertebral body. This was done using a mathematical model with the help of measurements taken from lateral photographs of each subjects as well as a lateral x-ray of the spine. Transfer functions were then calculated and defined as the ratio of the vertebral or sacral acceleration in a given direction to the vertical seat acceleration. Rmsvalues were used in all analyses. Temporal relationships between the vertebral acceleration and the seat acceleration were documented by measurements of the phase angle. The subjects were sitting directly on a force plate and thus the vertical force between the seat and the subject was also plotted as a function of the frequency.

RESULTS

The vertical acceleration transfer functions for the five subjects were quite similar. They reached a peak value of about 1.6 at about 4.5 Hz, and decreased to about 0.5 at 7 Hz and then remained constant for the rest of the observed frequency range. The transfer functions for the horizontal accelerations increased from about .2 to a maximum of .8. There was no resonance along the horizontal translation within the frequency range studied. Transfer functions for the rotatory accelerations show significant variation in response between subjects. The curves appear to peak at about 5 Hz, close to the resonance frequency for the vertical acceleration.

The phase angle for the vertical acceleration was throughout negative indicating that the vertebral acceleration lags behind the seat acceleration. The curves start at zero value and decrease to about -60 degrees at about 6 Hz, and then slowly increase. Force measured from the force plate and plotted versus frequency yielded curves that were similar to those for the vertical vertebral transfer functions.

Accelerations measured at the two vertebral levels (L1 and L3) did not differ significantly. There was no significant difference in the system response for .1 and .3 g inputs.

CONCLUSIONS

Pure vertical sinusoidal input to the body produces vibrations of the lumbar vertebrae that are not only vertical but also horizontal and rotatory. The resonance frequency of the lumbar vertebrae in the vertical direction was 4.5 Hz, in the horizontal direction beyond the upper limit of the experiment, and for the rotatory motion it was about 5 Hz.

ACKNOWLEDGEMENTS;

Supported grants from the Swedish Work Environment Fund and Volvo AB.

<S-12-5>

STUDIES OF THE MOVEMENTS IN SITTING DOWN, SQUATTING DOWN AND STANDING UP ---KNEE JOINT MUSCLE ACTIVITIES AND POSTURE CONTROL IN YOUNG AND AGED PERSONS.

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From the clinical studies the movements of squatting down and standing up in Japanese style toilet room were harder for the aged people than those of sitting down on and standing up from a stool.

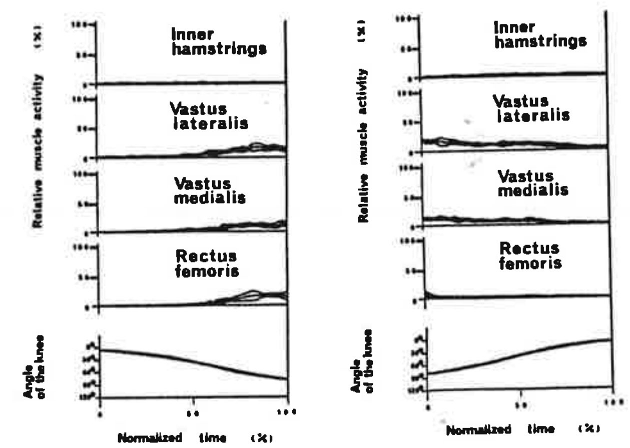
Estimating the influence of age on the postural control and on the magnitude of muscle activity of knee joints during the movements was performed.

Sixteen healthy aged persons ranging in age from 64 to 82 years and twenty young persons from 22 to 35 years were evaluated about their knee joint muscle activities in the movements of sitting down and standing up from a chair (seat is 42cm high) as well as squatting down and standing up. A rectified-and-normalized method was used to process EMG activities in these movements and to find differences between the young and the aged groups.

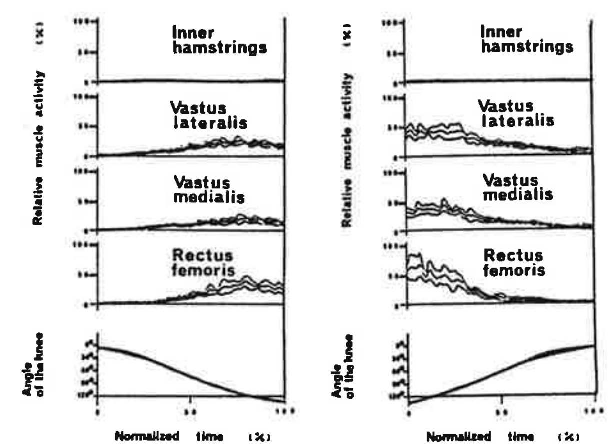
Twenty aged persons who have difficulties of these movements due to the muscle dysfunction were also evaluated in these same methods. The time required for the movements was estimated and the posterial sway was measured by the use of a force platform on which both feet of examinee were placed apart 20cm. The center of force and its fluctuation in the movements were measured in order to evaluate the postural disturbance of the sufferers.

Following findings are obtained from this study.

1. The quadriceps muscles showed higher activity during standing up from a squatting posture than rising from a chair.
2.The peak value of EMG activity of the aged group was higher than that of the young group both in standing up from a chair and from a squatting posture.
3. In many of the aged group the continuous muscle activities were demonstrated still after they stood up from a chair because of the presence of their knee joint extension deficits.
4. The time required for sitting and squatting movements were larger in the elderly group than in the young group.
5. It took the disabled persons more time to carry out these movements than the healthy aged persons.
6. A broad antero posterial or lateral sway of the center of force was demonstrated in the movements of aged persons who have difficulties of squatting movements.



a, Sittig down　　b, Standing up



a, Squatting down　　b, Standing up

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