The 13th Congress of International Society of Electrophysiology and Kinesiology

ISEK 2000

Millennial Challenges : Electrophysiology and Kinesiology

Date: June 25-28,2000
Place: Keio Plaza Hotel Sapporo
Address: N5, W7,Sapporo 060-0005,Japan
Tel: +81-11-271-0111
Fax:+81-11-221-5450
URL:http://www.keioplaza-sapporo.co.jp/

Congress President: Yukio Mano
Congress Vice-President: Yasunobu Handa
Honorary President: Jun Kimura
Secretary: Ichiro Watanabe

DEAR COLLEAGUE

It is my great pleasure to welcome you, on behalf of the Organizing Committee, of the 13th Congress of the International Society of Electrophysiology and Kinesiology, which is held June 25-28, 2000 in Sapporo, Hokkaido, Japan.

In the warm-hospitality of Sapporo, this congress will give us a chance to exchange the latest information of advances in electrophysiology and kinesiology.

The wide range of topics covered by the congress will give you an opportunity to share ideas and experiences with colleagues from other countries, discuss common problems and determine present needs and the course of future work. You will renew old friendships and make new acquaintances.

The congress will take place during Sapporo's most beautiful season with multiple opportunities for enjoying the abundant flowers of the early summer in most northern island Hokkaido in Japan.

It is the ambition of the Organizing Committee to make this congress an event that is both scientifically significant and cultural memorable and also to make your stay in Sapporo thorughly enjoyable for you and your accompanying persons.

I would like to extend my hearty welcome to the participants from many countries for the 13th congress of the International Society of Electrophysiology and Kinesiology.I hope you will enjoy your stay in Sapporo, Japan.

Yukio Mano

Yukio MANO M. D., Ph. D.

ISEK 2000 Congress President

Rehabilitation Medicine,
Postgraduate School of Medicine
Hokkaido Univ. Sapporo, Japan

WELCOME

ALL MY CHILDREN AND GRANDCHILDREN OF ISEK

BY JOHN V. BASMAJIAN

... because I think of you in that way.

Fully two generations ago, ISEK was founded with small funds and great hopes by a tiny group which I had assembled and most of whom are now gone. Little did we foresee the vigorous international scientific powerhouse that ISEK has become. All of you and your teachers have made enormous important contributions to the basic science of biological function and to the clinical applications that have resulted.

Today I stand before you as a proud parent whose progeny have far exceeded my fondest hopes, not only as a vibrant International Society, but as individual scientists and clincians. At the end of the Montreal Congress Number 12 in 1998, I did not expect I would still be well enough to participate at this Sapporo gathering because again is a stubborn influence on all of us.

Fortunately, I have been spared and here I am to enjoy meeting you all and perhaps absorbing some of the marvelous presentations that younger participants will consume with great gusto. Most of all, I ask you to have fun as well as all the learning you expect on such occasions. I promise that I will !

And so, I declare ISEK 2000 is now formally opened.

ISEK 2000

CONTENTS

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13th Congress of International Society of Electrophysiology and Kinesiology

Cosponsor

Japan Foundation for Neuroscience and Mental Health

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Science and Technology Agency
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Sapporo Medical Association
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Japan Society of Clinical Neurophysiology
Japanese Society of Biomechanics
Japan Society of Medical Electronics and Biological Engineering
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The Japanese Society of Physical Fitness and Sports Medicine
Japanese Physical Therapy Association
Japanese Association of Occupational Therapists

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The organizing committee is pleased to welcome the following exhibiting companies.

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Special Lectures and Sympoium

*35mm slide film will be accepted at slide preview room(Room E)
45 minutes before your presentation.
*Single slide projector only is available for each speaker.
*VHS video projector is available on advanced request.
*Slide will be returned at slide preview room(Room E)

Oral Presentation and their Chairperson

35mm slide film will be accepted at slide preview room(Room E)
45 minutes before your presentation, also over head projector is available.
Site : Main Hall or Room A.

Time of Oral Presentation:	June 26 (Mon)	10:40~12:10	O-11~27
		14:30~16:00	O-31~47
	June 27 (Tue)	10:40~12:10	O-51~67
	June 28 (Wed)	10:40~12:10	O-71~87

*Speaker will have 8 minutes for presentation and 4 minutes for discussion.
*Single slide projector only is available for each speaker.
*Slide will be returned at slide preview room(Room E)

Poster Presentation

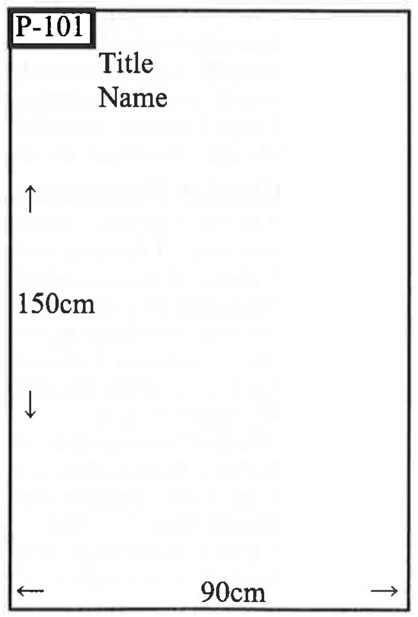
For Presenter

*Your poster will be set up on your presentation day from 7:30 and removed by yourself after 17:30 on Monday,16:30 on Tuesday & Wednesday.
*Your presentation number is mentioned on the left upper corner of poster board.
*Poster should be no longer 90cm wide×150cm high and velcro or pin will be provided.
*You have to stand in front of your poster during the presentation.
Site : Room C or Room D

Time of Presentation:	June 26 (Mon)	16:00~16:30	P-101~120	16:30~17:00	P-121~154
	June 27 (Tue)	14:30~15:00	P-201~222	15:00~15:30	P-223~245
	June 28 (Wed)	14:30~15:00	P-301~329	15:00~15:30	P-330~356

The number of your poster is prepared by ISEK office.
You must make your TITLE, NAME on the headline of the poster.

Number →
(Prepared by ISEK office)



For Chairperson

We have an hour for poster presentation, every presenter have to stand in front of their poster at least 30 minutes.
We would like to possiblly have free discussion in this session.

INFORMATION FOR PARTICIPANTS

To All Participants

Advanced Registrants:	Please pick up the congress bag at the registration desk.
New Registrants:	Please pay 45,000 yen (student fee 30,000 yen,Accompanying person 20,000 yen) as registration fee on the registration desk.
Registration Desk	June 25(Sun) from 12:00 June 26,27 and 28 during the congress

Registration fee for scientific participants covers :

1)Congress kit
2)Book of abstracts
3)Admission to all scientific sessions
4)Precongress lectures
5)Opening ceremony
6)Closing ceremony
7)Exhibition area
8)Seminars
9)Breakfast
10)Lunch
11)Coffee & drink
12)Name card (wear the name card during the congress).

Message Center

A message board is located near the registration desk and will be available during the congress.
During the congress Telephone and Fax-Receiving Service is avilable,too.

Tel:+81-11-271-9268
Fax:+81-11-271-0132

Official Language

The official language of the congress is English.

SOCIAL PROGRAM

Opening Ceremony

Sunday, June 25 18:00～19:30
Main Hall of Keio Plaza Hotel Sapporo

Fee: free

* Introduce ISEK History and Hokkaido by Slide and VTR
* Ensemble

Congress Dinner

Monday, June 26 19:00～21:30
Main Hall & Room A of Keio Plaza Hotel Sapporo

Fee: 5,000Yen

* Shanson Singer, Quartet

Beer Party & City Tour By Bus

Tuesday, June 27 16:00～21:30
Place of meeting : Bus Stop of Keio Plaza Hotel Sapporo

Fee: 1,000Yen

City Tour : Okurayama Olympic Jump Hill and Museum, Hokkaido Shrine

Beer Party : Sapporo Beer Garden
* Musician and Song

Closing Ceremony

Wednesday, June 28 16:00～16:30
Main Hall of Keio Plaza Hotel Sapporo

Fee: free

Award

ACCOMPANYING PERSON PROGRAM

CAMPUS TOUR OF HOKKAIDO UNIVERSITY

June 26 (Mon) 9:30-12:00 Campus Tour, Tea at Enreiso, Hokkaido University, William S. Clark

¥1,000

Hokkaido University has the largest campus in Japan, and it was one of old Imperial Universities in the past.
The large farm land, belonging to the School of Agriculture, in the middle of big city Sapporo, is very popular and famous in Japan.

HISTORY & CULTURE TOUR

June 26 (Mon) 14:00-17:00 Botanical Gardens, Hokkaido Shrine

¥2,500

University Botanical Garden has been collecting a variety of plants of northern Japan.
Hokkaido Shrine shows the Japanese traditional Shinto architecture in the large percincts.

SAPPORO VIEW POINT TOUR

June 27 (Tues) 9:30-12:00 Miyanomori Schanze, Mt.Moiwa Ropeway

¥2,500

Miyanomori Schanze is very well condition Ski Jump Hill, where the Sapporo Olympic Games were held in 1972, and international ski jump games are also held in every winter and even in summer.
Please stand up on the honor platform on the background of Ski Jump Hill.
The summit of Mt.Moiwa gives the great view of city of Sapporo.

SAPPORO ART PARK TOUR

June 28 (Wed) 9:30-12:00 Sapporo Art Park

¥2,500

In Sapporo Art Park, hundreds of sculptures are scattered in the vast garden on the background of mountain.

Please register at tour desk at Keio Plaza Hotel, Kinki Nipon Tourist by 13:30 Monday 26, June, 2000.

HOTEL ACCOMMODATION

Accommodations

We have booked rooms at special room rates at following hotels, including Keio Plaza Hotel Sapporo, where the congress is held.
Keio Plaza Hotel Sapporo is a first rate hotel within 3 minute walk distance from JR Sapporo railway station.

Hotel and room rates

Hotel	Rates & Room type	Address & Phone
Keio Plaza Hotel Sapporo	¥12,000 (single w/bath) ¥11,000 (Twin w/bath)	N5, W7, Sapporo 81-11-271-0111
Crest Hotel Sapporo	¥11,000 (single w/bath) ¥10,000 (Twin w/bath)	N6, W4, Sapporo 81-11-261-3311
Sapporo Aspen Hotel	¥11,000 (single w/bath) ¥10,000 (Twin w/bath)	N8, W4, Sapporo 81-11-261-0111
Sapporo Station Hotel	¥9,000 (single w/bath) ¥8,500 (Twin w/bath)	N7, W4, Sapporo 81-11-727-2111
Toyoko Inn Hokudaimae	¥6,500 (single w/bath) ¥5,500 (Twin w/bath)	N8, W4, Sapporo 81-11-717-1045

Note: Room rates include tax

Official Travel Agent

Yugo Ikemori
Kinki Nippon Tourist Co.,Ltd. Sapporo Ekimae Branch
Shin Hokkaido Bldg. 11F, N7 W4,Sapporo 060-0807 Japan
Tel +81-11-716-5522 Fax +81-11-716-5503
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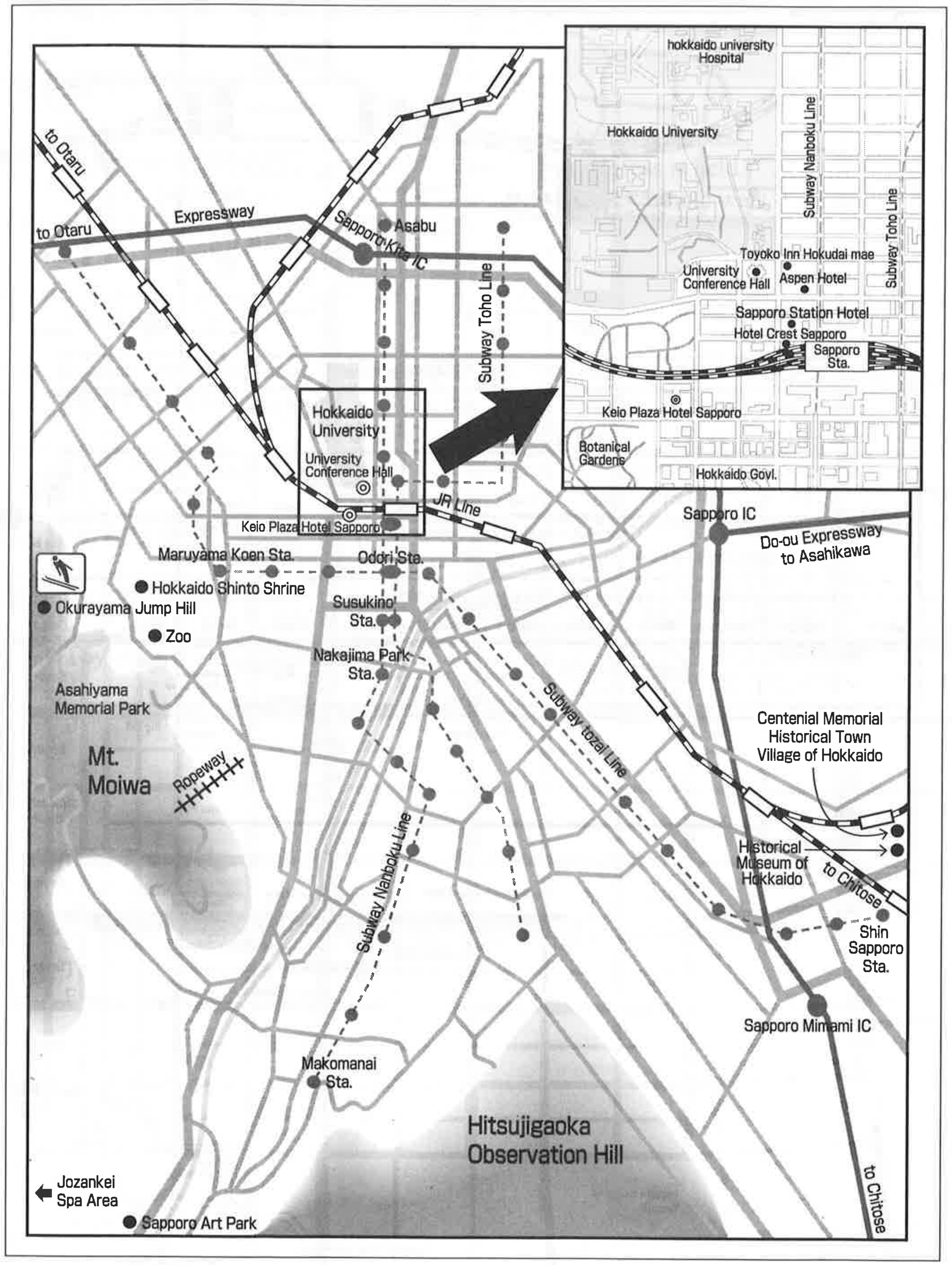
MAP OF SAPPORO CITY

MAP OF SAPPORO AREA



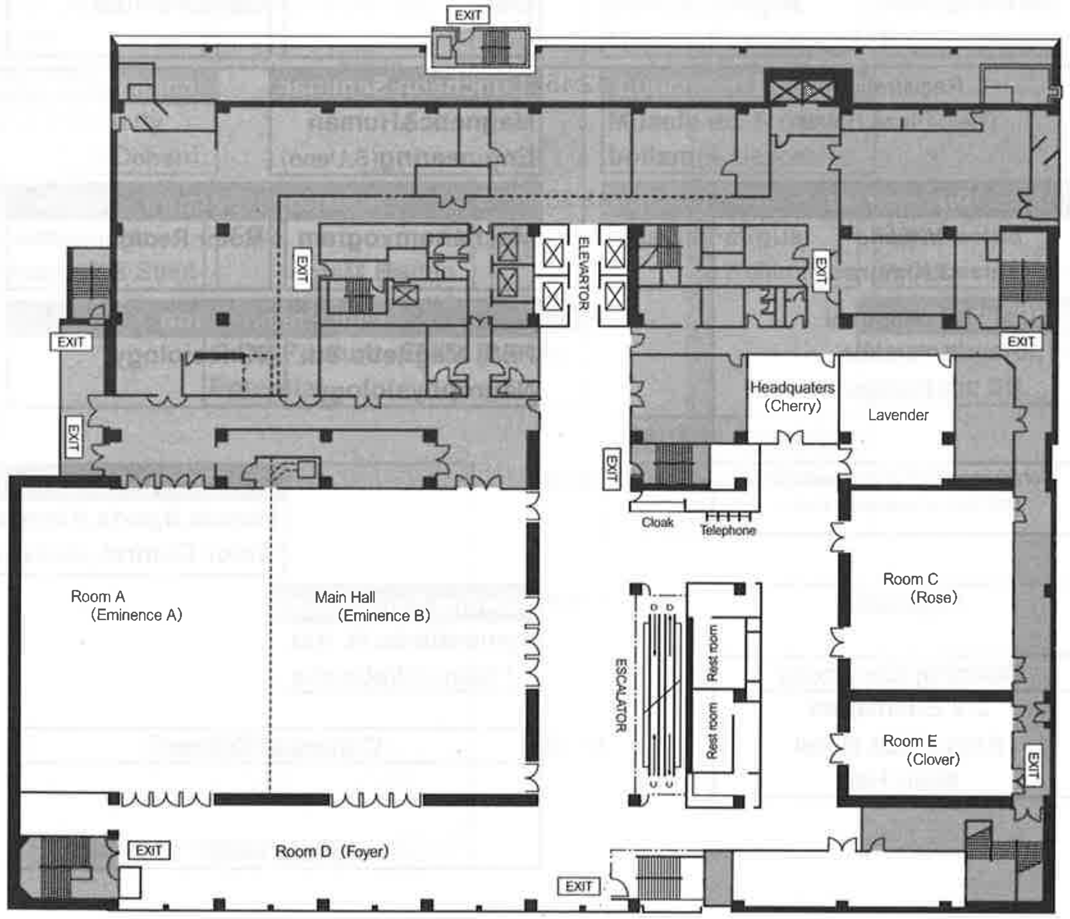
2nd FLOOR OF KEIO PLAZA HOTEL SAPPORO

Main Floor of ISEK2000

Registration Desk - Hall of 2nd floor

Hall of 2nd Floor		: Registration Desk Information Desk,Tour Desk(Kinki Nippon Tourist)
Main Hall	(Eminence B)	: Platform
Room A	(Eminence A)	: Platform
Room C	(Rose)	: Poster & Exhibition,Coffee Service
Room D	(Foyer)	: Poster
Room E	(Clover)	: Slide Registration & Preview
Headquarters	(Cherry)	

Opening Ceremony	: Main Hall (Eminence B)
Dinner	: Main Hall & RoomA (Eminence A.B)
Breakfast	: Room D (Foyer)
Luncheon Seminar	: Main Hall (Eminence B)
General Assembly	: Main Hall (Eminence B)
Closing ceremony	: Main Hall (Eminence B)



Board of Council	: Orion (22nd Floor)
Editorial Meeting of JEK	: Lavender (2nd Floor)

TIME TABLE OF ISEK2000 IN SAPPORO

25 SUN

Time	
12:00	Registration (Keio-Plaza Hotel)
13:30	**Precongress** Y.Mano, J.Kimura, K.Yokogushi, T.Yamada, R.F.Mayer Conference Hall of Hokkaido Univ. (N8,W5 in Hokkaido Univ.)
17:00	Registration
18:00	**Opening Ceremony** J.V.Basmajian Keio-Plaza Hotel Main Hall

26 MON

Time	Main Hall	Room A	Room C,D
7:30	BREAKFAST (Room D, Foyer)		Poster Setting
8:00	**Basmajian Lecture** Motor Unit Analysis C. DeLuca		POSTERS & EXHIBITIONS
9:00–10:20	**Symposium** Muscle Fatigue T.Kiryu, M.Knaflitz, A.B.Arsenault, E.Date	**Symposium** Evoked Potential T.Yamada, L.Sawaki, R.Kayamori, J.Kitamura	POSTERS & EXHIBITIONS
	COFFEE BREAK		
10:40	**Oral Presentation** EMG	**Oral Presentation** Gait&Posture	POSTERS & EXHIBITIONS
12:15	**Luncheon Seminar** Magnetic&Human Engineering(S.Ueno)		POSTERS & EXHIBITIONS
13:30	**Educational Lecture** Mechanomyogram B.Maton	**Educational Lecture** Motor Reorganization Y.Mano	POSTERS & EXHIBITIONS
14:30	**Oral Presentation** FES, Magnetic Sti. Neurophysiology	**Oral Presentation** Kinesiology	POSTERS & EXHIBITIONS
16:00		**Poster Presentation** Muscle,Sports,Kinesiol, Motor Control, Assistive Tech.	
17:00	**Satellite Symposium** Sympathetic N. Act. T.Mano,I.Watanabe		
19:00	**Congress Dinner** (Main Hall)		

27 TUE

Time	Main Hall	Room A	Room C,D
7:30	BREAKFAST (Room D, Foyer)		Poster Setting
8:00	**Keynote Lecture** Wave Form Analysis J.Kimura		POSTERS & EXHIBITIONS
9:00–10:20	**Symposium** Motor Control S.Hiki, Y.Masakado, S.H.Roy, M.Okada	**Symposium** Magnetic Stimulation L.G.Cohen, M.A.Lissens, S.Tsuji, Y.Ugawa	POSTERS & EXHIBITIONS
	COFFEE BREAK		
10:40	**ISB & ISEK** Special Joint Session	**Oral Presentation** Evoked Potential	POSTERS & EXHIBITIONS
12:15	**Luncheon Seminar** Neural Plasticity (L.G.Cohen)		POSTERS & EXHIBITIONS
13:30	**Educational Lecuture** Neuromuscular Control R.B.Stein	**Educational Lecuture** FES Y.Handa	POSTERS & EXHIBITIONS
14:30		**Poster Presentation** Gait&Posture, EMG, Evoked Potential	
16:00	**City Tour(by Bus)** Beer Party (Sapporo Beer Garden)		

28 WED

Time	Main Hall	Room A	Room C,D
7:30	BREAKFAST (Room D, Foyer)		Poster Setting
8:00	**Keynote Lecture** Motor Control J.C.Rothwell		POSTERS & EXHIBITIONS
9:00–10:20	**Symposium** Sound Myogram C.Orizio, B.Maton, K.Akataki, T.Moritani	**Symposium** Gait&Posture M.Bernardi, A.Nene, K.Akazawa, K.Fukusima	POSTERS & EXHIBITIONS
	COFFEE BREAK		
10:40	**Oral Presentation** Muscle Fatigue Muscle Physiology	**Oral Presentation** Rehabilitation Ergonomics	POSTERS & EXHIBITIONS
12:15	**Luncheon Seminar** Muscle ex. & metabolism(A.Ueyoshi)		POSTERS & EXHIBITIONS
13:30	**Educational Lecuture** Muscle Fatigue J.Kollimitzer	**Educational Lecuture** Myoelectric Prosthesis K.Horch	POSTERS & EXHIBITIONS
14:30		**Poster Presentation** Neurophysiol, Rehab.,FES, Magnetic Sti.	
15:30	General Assembly		
16:00	Closing Ceremony		

Program Overview Sunday June 25, 2000

Pre-Congress Symposium

A Challenge in the New Millennium: Mechanisms of Motor Control

Hokkaido University Conference Hall in Hokkaido University(N8, W5, Sapporo)

13:00～13:35

Welcome Remarks
Y.Mano, Hokkaido University, Japan

13:35～14:00

S-39 **Central and Peripheral Origin of Involuntary Movement**
J.Kimura, Iowa University, U.S.A.

14:00～15:00

Chairperson:T.Tada

S-40 **Analysis of Posture and Gait**
K.Yokogushi, Sapporo Medical University, Japan

15:00～16:00

Chairperson:I.Sobue

S-41 **Movement Induced Interference upon Somatosensory Evoked Potentials**
T.Yamada, Iowa University, U.S.A.

16:00～17:00

Chairperson:K.Tashiro

S-42 **Pathophysiology of the Motor Unit**
R.F. Mayer, University of Maryland, U.S.A.

Opening Ceremony

18:00～19:30

Main Hall in Keio Plaza Hotel Sapporo (N5, W7, Sapporo)

Program Overview Monday June 26, 2000

7:30～8:00

Continental Breakfast
Foyer

8:00～9:00

Basmajian Lecture
Main Hall J.V.Basmajian, McMaster University, Canada

Chairperson:J.V.Basmajian

S-1 **Control Properties of Motor Units**
C.J.De Luca, Boston University, U.S.A.

9:00～10:20

Symposium 1.2

<Muscle Fatigue>

Main Hall

Chairperson:S.Roy
Chairperson:M.Okada

S-10 **Snapshot Assessment of Fatigue during Long-Term Repetitive Exercise**
*T.Kiryu, K.Tanaka, M.Okada, Niigata Univesity & Tsukuba University, Japan

S-11 **Muscle Fatigue Evaluation : From Basic Research to Clinical Applications**
*M.Knaflitz, Politecnico di Torino, Italy

S-12 **The Reliability of Different EMG Indices Used in the Evaluation of Back Muscle Fatigue**
*A.B.Arsenault, C.Lariviere, University of Montreal, Canada

S-13 **Electrodiagnosis and Muscle Fatigue**
*E.S.Date, Stanford University Medical Center, U.S.A.

<Evoked Potential>

Room A

Chairperson:N.Ando
Chairperson:A.M.Sherwood

S-14 **Neuroanatomical Substrates of Lower Extremity SSEP**
T.Yamada, Iowa University,U.S.A.

S-15 **Specific and Non-specific Effects of Transcranial Magnetic Stimulation on Reaction Time Paradigms**
*L.Sawaki, T.Okita, M.Fujiwara, K.Mizuno, L.G.Cohen, NIH,U.S.A. & Hyogo College of Medicine, Japan

S-16 **Facial Synkinesis:Evaluation and Rehabilitation**
R.Kayamori, Teikyo University,Japan

S-17 **Movement Related Cortical Potentials in Recovered Hemiparesis**
J.Kitamura, Nippon Medical School Chiba-Hokusoh Hospital , Japan

10:40~12:10

Oral Presentation

<Gait & Posture>

Room A

Chairperson:M.Bernardi
Chairperson:T.Masuda

O-11 **Cervical Impulsation and Posture-clinical and Experimental Studies**
*P.Osinski, K.Pawlak-Osinska, H.Kazmierczak, J.Talar

O-12 **Gait Analysis in Ankle Arthrodesis**
*F.C.Su, W.L.Wu, Y.M.Cheng, P.J.Huang, Y.L.Chou

O-13 **Measurement of the Trajectory of the Whole Body's Center of Mass to Evaluate the Surgical Outcome for Children with Spastic Celebral Palsy**
*R.J.Cherng, L.S.Chou, W.J.Shaughnessy, F.C.Su, K.R.Kaufman

O-14 **New Corrective Shoes to Improve Ataxic Gait of Patients with Spinocerebellar Degeneration**
*N.Ando, M.Ando, T.Takayanagi, Y.Mano, A.Suzumura

O-15 **Quantitative Measurement of Spasticity of Triceps Surae**
*N.Suzuki, K.Mita, T.Okagawa, M.Kimizuka

O-16 **Upper Motor Neuron Gait Recovery a Clinical and Research Collaboration**
*D.DeForge, J.Nymark

O-17 **Use of a Piezo-dynamometric Platform to Analyse the Foot Loading Pattern in Diabetic Patients with Peripheral Neuropathy**
*C.Giacomozzi, V.Macellari, R.Bernarducci, A.Caselli, L.Uccioli

<EMG>

Main Hall

Chairperson:S.Hiki
Chairperson:R.Merletti

O-21 **Development of Recommendations for Recording and Processing SEMG:The SENIAM Project**
*HJ Hermens, B.Freriks, R.Merletti, C.Disselhorst-Klug, G.Hagg, D.Stegeman, G.Rau

O-22 **Fine-wire EMG Measurment of Cervical Muscles in Patients with Late Whiplash Syndrome Performing Isometric and Dynamic Exercise**
*T.Wissmeyer, M.Kramer, V.Ebert, E.Hartwig

O-23 **Fuzzy-Logic to Support the Assessment of the Muscular Co-ordination Pattern Detected by Surface-EMG**
*C.Disselhorst-Klug, S.Ziegler, F.U.Niethard, G.Rau

O-24 **High Spatial Resolution EMG in Children with a Rupture of the N.Plexus Brachialis**
*A.Trachterna, J.Bahm, C.Disselhorst-Klug, G.Rau

O-25 **Myoelectric Recordings of Multiple Motor Units of the Human Larynx**
*R.Roark, S.Schaefer, C.De Luca, J.Li,A.Adams

O-26 **Studies on Characteristic of Constant Exercise around VT Using Spectral Analysis of EMG and ECG-RR Interval Variability**
*M.Takahashi, T.Hosokawa, T.Saito

O-27 **Sural Nerve Reflex in the Back Muscles during Human Walking**
*N.Kojima, T.Furuna, M.Sugiura, Y.Aoyagi, K.Kanda

12:15~12:55

Luncheon Seminar

Main Hall

Chairperson:K.Yunokuchi

S-34 **Recent Advances in Biomagnetics**
S.Ueno, University of Tokyo, Japan

13:30~14:20

Educational Lecture

<Mechanomyogram>

Main Hall

Chairperson:C.Orizio

S-4 **Muscle Sounds:From Birth to Now**
B.Maton, Universite d'Orsay, France

<Motor reorganization>

Room A

Chairperson:S.Tsuji

S-5 **Motor Control and Sensory System**
Y.Mano, Hokkaido University, Japan

14:30~16:00

Oral Presentation

<Kinesiology>

Room A

Chairperson:R.B.Stein
Chairperson:K.Yasuda

O-31 **Angular Displacement in One Joint Affects the Coordination around Other More Distal Joints in Cycling**
*H.H.C.M.Savelberg, P.J.B.Willems

O-32 **Assessment of Functional Activities during Skiing Exercise**
*T.Kiryu, N.Motomiya, Y.Ushiyama, M.Okada

O-33 **Control Strategy of Isometric Contraction in Different Muscle Lengths**
*I.S.Hwang, C.Y.Cho, J.J.Chen

O-34 **Firing Frequencies of Single Motor Units in the M.Biceps Brachii during Elbow Flextion at Constant Angular Velocities**
*H.Nakamura, M.Yoshida, R.Okuno, K.Akazawa

O-35 **Influence of Motor Unit Synchronisation on Force and EMG in Skeletal Muscles :A Simulation Study**
*Seghers J, Spaepen AJ, Hofkens N, Van Audekercke R

O-36 **Relative Contribution of Recruitment and Rate Coding in Force Increment**
*M.Yoshida, K.Akazawa

O-37 **The Relationship between Muscle Activity and R-R Interval Variations in ECG during Bridge Exercise**
*H.Iwatuki, J.Iwatuki, A Furukawa

<FES/Magnetic Stimulation/Neurophysiology>
Main Hall
Chairperson:A.B.Arsenault
Chairperson:S.Izumi

O-41 **Adaptive FES Switching Control for Hemiplegics Using EMG Signal**
*H.Yamaguchi, W.Yu, M.Maruishi, H.Yokoi, Y.Mano, Y.Kakazu

O-42 **Clinical Rehabilitation Using Electrical Stimulation via Telematics(CREST) An EU Programme for Restoration of Improvement of Gait of Incomplete Paraplegics**
*Hermens HJ, Baardman G, Granat MH, Heller BW ,Biering-Sorensen F, Montoto A

O-43 **Differences in Cervical Muscle Dysfunction in Subgroups of Neck Pain Patients**
*M.J.Nederhand, M.J.IJzerman, H.J Hermens, G.Zilvold

O-44 **Functional Recovery of a Hemiplegic Hand by Intensive Training and Motor Cortical Mapping by Transcranial Magnetic Stimulation**
*S.Etoh, K.Kawahira, K.Kamata, K.Takehara, N.Tanaka

O-45 **I-wave Networks in Human Motor Cortex**
*T.Kujirai, K.Kujirai, T.Yamaguchi, S.Ueno

O-46 **Localization Error Pattern of Stroke Patients to Binaural Sound**
*S.Sonoda, M.Mori, A.Goishi, Y.Kobayashi, N.Tanaka, Y.Okajima, N.Chino

O-47 **Suppression of the Hand Motor Area by Painful Stimuli on Chin**
*T.Furubayashi, Y.Ugawa, Y.Terano, R.Hanajima, Y.Shiio, I.Kanazawa

16:00～16:30
Posterpresentation

<Muscle Fatigue>
Room C
Chairperson:Y.Okajima
Chairperson:H.Toyoshima

P-101 **Power Spectrum Changes in Surface EMG during Sustained Isometric Contractions**
*T.Aoki, Y.Shirai, Y.Kim, Y.Suzuki, Y.Banzai, A.Nanbu

P-102 **Evaluation of Muscle Fatigue for Field Assessment**
*N.Ichinoseki, T.Kiryu

P-103 **Changes in Surface EMG during Static Fatiguing Contractions in the Upper Trapezius Muscle**
*T.Sadoyama, K.Sakai, S.Hosoya, M.Kamijyo, T.Masuda

P-104 **Effects of Fatigue on the Biomechanics of a Repetitive Knee Exercise in Patients with ACL Injury**
*P.Bonato, A.Kline, S.H.Roy, A.Leardini, J.O'Connor

P-105 **Effects of Muscle Fatigue on Alternate Muscular Activity in Synergistic Muscles during Low-Level Sustained Contraction**
*M.Kouzaki, M.Shinohara, H.Kanehisa, T.Fukunaga

P-106 **Voluntary Muscle Activation Estimated with Twitch Interpolation and Endurance Capacity in Fatiguing Isometric Contractions**
*H.Yamada, T.Kizuka, T.Masuda, T.Kiryu, T.Shiozaki, M.Okada

P-107 **Effect of Joint Angle on Recruitment Property of Single Motor Unit in Human Gastrocnemius Muscle**
*Y.Nishimura, D.Abla, Y.Nakajima, S.Toma, K.Nakazawa, I.Shimoyama

<Motor Unit Analysis>
Room C

P-108 **Rate Cording and Recruitment of Motor Units for Maintaining Sustained Contraction**
*M.Kamo, S.Morimoto

P-109 **Unusual Gait Disorders Caused by Tethered Spinal Cord Syndrome**
*G.Nikolic, M.Markovic, A.Marsavelski, I.Petronic, D.Nikolic, D.Cirovic

P-110 **Effect of Plasmapheresis to Changes in Single Fiber EMG in Patients with Chronic Inflammatory Polyradiculoneuropathy**
*A.Matsumoto, T.Miyagishi, K.Tusaka, K.Tashiro

<Muscle Physiology>
Room C
Chairperson:A.Matumoto
Chairperson:T.Asami

P-111 **Effects of Electric Stimulation on Intramuscular Energy Metabolism of Disuse Atrophied Muscle. A ^{31}P-MRS Study**
*N.Yoshida, T.Ikata, K.Sairyo, M.Fukunaga, K.Koga

P-112 **The Effect of Forearm Endurance Training on Muscle Activity during Submaximal Handgrip Exercise**
*M.Kuno-Mizumura, S.Homma, K.Kagaya

P-113 **Differences in Sensitivity of Short- and Long-Latency Stretch Reflexes in Human Elbow Flexor and Extensor Muscles**
*S.Yamamoto, K.Nakazawa, T.Ohtsuki, H.Yano

P-114 **Effect of Long-term Bed Rest on Activation of the Human Soleus Muscles during Walking**
*T.Miyoshi, T.Sato, K.Yamanaka, H.Sekiguchi, M Miyazaki, S.Igawa, T.Kemuriyama, T.Komeda, K.Nakazawa, H.Yano

P-115 **Assessment of Muscle Sound Properties from Intramuscular Microstimulations**
*Y.Yoshitake, H.Ue, M.Miyazaki, T.Moritani

<Sports Application>
Room C

P-116 **The Quantitative Control of the Athletic Training Intensity**
Y.Tianbai

P-117 **Strength Training-induced Changes in Muscle Fiber Size and Isometric Specific Strength**
*T.Ryushi, K.Kumagai

P-118 **The Effect of Initial Graft Tension on Mechanical Behaviors of the Femur-Graft-Tibia Complex during Submaximal Cyclic Loading is Different between Bone-Tendon-Bone and Flexor Tendon Grafts.**
*M.Yamanaka, K.Yasuda, H.Nakano, T.Wada, H.Tohyama

P-119 **Electromyographic Analysis of Trunk Muscle in College Golfers with or without Low Back Pain**
*T.Kobayashi, H.Horiuchi, T.Ito, K.Hori, M.Yamanaka

P-120 **In Vivo Dynamics of Muscle-tendon Complex during Stretch-shortening Cycle Exercise**
*T.Fukunaga, K.Kubo, Y.Kawakami, H.Kanehisa

16:30～17:00

Posterpresentation

<Kinesiology>

Room C

Chairperson:M.Toyokura
Chairperson:H.Horikawa

P-121 **Activation Patterns of Mono-and Bi-articular Muscles in the Lower Extremity during Open and Closed Kinetic Chain Conditions**
K.Kawamura

P-122 **Pelvic Movement Pattern during Squatting**
*T.Fukui, SH.Kim, M.Takahashi

P-123 **The Length of Hamstring Muscles of Workers with Different Profesional Loading**
*K.Boskovic, A.Zamurovic, N.Naumovic, D.Filipovic

P-124 **Stretch Reflex Sensitivity in Human Elbow and Ankle Muscles - Implication for Role of Stretch Reflex during Quiet Standing-**
*K.Nakazawa, S.Yamamoto, H.Yano

P-125 **Isometric Knee Flexion is Reinforced in the Dorsiflexed Ankle Position through the Function of Biarticular Gastrocnemius**
*K.Ohyama Byun, Y.Manabe, K.Adachi, M.Okada

P-126 **EMG Activities of the Wrist Extensors under Maximum Isometric Dorsiflexion**
*M.Oyama, K.Momose, H.Onishi, T.Soma, D.C.Kim, M.Ichie, Y.Handa

P-127 **Relationship between the M-wave Amplitude and the Joint Movement during Repetitive Stimulation - Study in the Tibialis Anterior Muscle-**
*Y.Tanino, S.Daikuya, H.Hirose, S.Nishiguchi, H.Lee, T.Suzuki

P-128 **Comparison of Surface Electromyographic Parameters of Quadriceps Femoral Muscles during Sustained Isometric Knee Extensor Contractions and Static Contractions in One-Legged Standing**
*M.Yuri, T.Kobayashi, M.Sakagami, T.Kikumoto, K.Hori, Y.Mano

P-129 **Comparison of Oxygen Uptake and Muscle Activity in Lower Extremity during Walking Exercises on Land and in Water**
*M.Sakagami, T.Kobayashi, T.Kikumoto, M.Yuri, K.Hori, Y.Mano

P-130 **Relation of Pinch Strength to Finger Distance**
*K.Hoshina, Y.Mano, M.Ishizawa

<Motor Control>

Room D

Chairperson:H.Kamoshita
Chairperson:M.Kasai

P-131 **Fundamental Research on the Autonomous Adaptive Human Interface Used EEG amd EMG**
*Y.Ishiwaka, H.Yokoi, Y.Kakazu

P-132 **Variation in First Agonist Burst during Ballistic Contraction**
*S.Mizumura, T.Ohtsuki, T.Yoneda, M.Kimura

P-133 **The Effect of Motor Control on Oro-facial Dysfunctions in Stroke Patients under Indian Conditions**
A K.Varma

P-134 **Effect of Phenol Block of Femoral Nerve for Leg Extensor Spasms**
*K.Nori, Y.Mano, I.Watanabe, T.Chuma, M.Kanno, I.Miyahata, M.Igawa

P-135 **Modulation of Use-dependent Plasticity in Adult Human Motor Cortex**
*L.Sawaki, C.Butefisch, J.Classen, B.Boroojerdi, A.Kaelin-Lang, A.Burstein, B.Davis, L.G.Cohen

P-136 **Phenol Block Treatment for Varus Deformity of Ankle due to Spasticity**
*F.Sato, Y.Mano, I.Miyahata, M.Kanno, T.Chuma, I.Watanabe, T.Sugata

P-137 **A Study of the Fall from a Rocking Platform and a Thin Beam**
*G.Izuta, T.Yamaguchi, Y.Kato, Y.Wang

P-138 **Effect of Sound Stimulation for Ataxia,Part 1:Effect in Patients with Deep Sensory Disturbance**
*M.Maruishi, N.Uemi, Y.Mano, Y.Ifukube, T.Ikeda, M.Sato, T.Koyama, H.Kishimoto, S Sasaki

P-139 **Effect of Sound Stimulation for Ataxia,Part 2:Effect in Healthy Volunteers with Their Limbs Vibrated**
*M.Maruishi, N.Uemi, Y.Mano, Y.Ifukube, T.Ikeda, M.Sato, T.Koyama, H.Kishimoto, S Sasaki

P-140 **Functional MRI in Patient with Post-Stroke Mirror Movement**
*M.Maruishi, Y.Mano, C.Takahashi, K.Kaneko

<Myoelectric Prosthesis>

Room D

Chairperson:T.Konndo
Chairperson:S.Maeda

P-141 **Functional MRI of Amputees during Use of Myoelectrical Prosthetic Hand**
*M.Maruishi, D.Nishikawa, Y.Mano, W.Yu, H.Yokoi, Y.Kakazu, T.Nakagawa

P-142 **The Study of Sensor Pegboard Test Method for Estimating 'Dexterity' of Myoelectric Hand**
Y.Okada

P-143 **On-line Learning Based EMG Prosthetic Hand**
*D.Nishikawa, Y.Ishikawa, W.Yu, M.Maruishi, I Watanabe, H.Yokoi, Y.Mano, Y.Kakazu

<Assistive Technology>

Room D

P-144 **Permeability of Non-Polarized Near-Infrared Light**
*T.Asou, D.Ma, K.Toda, H.Muneshige

P-145 **Foot Pressure Distribution of Artificial Limbs in Patients with Below Knee Amputee by Photoelastic Methods**
*J-I.Kitamura, H.Nakagawa, T.Jivacathe, Kitisomprayoonkul.W

P-146 **Quantitative Evaluatioin of Writing Using the Hiroshima University Writing Evaluation System**
*H.Muneshige, T.Iitsuka, T.Murakami, Y.Ikuta, M.Nakamasu, A.Mitsunari

P-147 **Phantom Pain of Missing Hand by Stimulation to Lip**
*A.Yamakoshi, M.Maruishi, Y.Mano, T. Nakagawa

<*Miscellany*>
Room D

P-148 **Dominance of Electrical Brain Activity According to Zones at Reading Aloud Rhythmed and Unrhythmed Text**
V.Radicevic

P-149 **Physiological Analysis of Effect of Negative Air Ion on Human**
*I.Watanabe, K. Hori, Y. Mano

P-150 **Clinical Analysis of Acupuncture in Patients of Osteoarthrosis**
*G.Jiang, I.Watanabe, Y.Hashimoto, Y.Mano

P-151 **Senile Chronic Lumbago Treat with Kinesitherapy**
S.Li-Zhong

P-152 **Effect of Antioxidants on Ethanol-induced Peptic Toxicity-An In Vivo Study**
*L.Chifeng, H.Tian-Chyuan, Y.Jen-Yuann, H.Sheng-Shuenn, Y.Pao-Pao, W.I-Lin

P-153 **Evaluation of Hemodynamic Change on Forefeet in Dialysis Patients with Complicating Arteriosclerosis Obliterans(ASO)**
*H.Hayashi, M.Nagaishi, H.Seno, M.Yokoya, T.Toriyama, H.Iwatsuki

P-154 **Electromyographic Analysis of Abdominal Muscles during the Performance of Various Forms of Situp Exercises**
*J.Klaphajone, P.Tanmukayakul

P-155 **Electrodiagnostic Changes in True Neurologic Tos**
*B.Zamani, G.Shahidi, S.Rajaii, F.Benissa

17:00~18:00
Satellite Symposium
Main Hall — Chairperson:O.Kenmotsu

S-37 **Muscle Sympathetic Nerve Activity in Humans**
T.Mano, Nagoya University, Japan

S-38 **Super Lizer Irradiation Therapy**
I.Watanabe, Hokkaido University, Japan

19:00~21:30
Congress Dinner
Main Hall & Room A

Program Overview Tuesday June 27, 2000

7:30~8:00
Continental Breakfast
Foyer

8:00~9:00
Keynote Lecture 1
Main Hall — Chairperson:M.Shimamura

S-2 **Waveform Analysis in Electrophysiology**
J.Kimura, Iowa University, U.S.A.

9:00~10:20
Symposium3.4
<*Motor Control*>
Main Hall — Chairperson:K.Akazawa
Chairperson:C.Disselhorst-Klug

S-18 **Predicting the Optimal Threshold of Pulse Detection for Pulse Density Demodulation Processing of Electromyograms(PDD-EMG)**
*S.Hiki, K.Choi, H. Kawai, T.Shimono, Waseda University, Japan

S-19 **Motor Unit Firing Behavior in Health and Disease**
*Y.Masakado, A.Kimura, N. Chino, Keio University, Japan

S-20 **Fatigue-related Changes of Trunk Motor Control during Repetitive Lifting**
*S.H.Roy, P.Bonato, P. Boissy, P. Loisel, U. Della Croce,D.K.Parikh, *A. Patel,
Boston University, U.S.A., Clinical Research Center in Work Rehabilitation PREVICAP, Canada,
Universita di Sassari, Italy

S-21 **Surface EMG Variables as Influenced by Force and Speed in Isokinetic Contractions**
*M.Okada,T.Kizuka, E.Kin, H.Yamada, T.Masuda, University of Tsukuba, Japan

<*Magnetic Stimulation*>
Room A — Chairperson:Y.Nakamura
Chairperson:J.C.Rothwell

S-22 **Mechanisms of Plasticity in Human Motor Cortex Studied with Transcranial Magnetic Stimulation**
*L.G.Cohen, C Butefisch,L.Sawaki, J.Classen, A. Burstein, NIH, U.S.A

S-23 **The Use of Motor Evoked Potentials in Rehabilitation of Locomotor Disorders**
*M.A.Lissens, University Hospital Gent, Belgium

S-24 **New Clinical Applications of Transcranial Magnetic Stimulation**
*S.Tsuji, T.Uozumi, K.Matsunaga, T.Hashimoto, H.Ishiguchi, J.Nakamura
University of Occupational and Environmental Health, Japan

S-25 **Air-puff-induced Motor Cortical Facilitation in Humans**
*Y.Ugawa, Y.Terao, University of Tokyo, Japan

10:40～12:10
Oral Presentation
<ISB & ISEK>
Main Hall

Chairperson:R.B.Stein
Chairperson:T.Moritani

O-51 **A Comparison of Surface EMG and Clinical Measures of Altered Motor Control and Spasticity after Spinal Cord Injury**
*A.M.Sherwood, D.C.Lee, D.E.Graves, M.M.Priebe, J.K.Dunn

O-52 **Assessment of Paraspinal Muscle Fatigue during Repetitive Lifting in Patients with Chronic Low Back Pain**
*P.Boissy, P.Bonato, S.H.Roy, P.Loisel

O-53 **Changes in Muscle Force and Volume Following Surface Therapeutic Electrical Stimulation in Patients with Hemiplegia**
*T.Fujii, H.Ohsawa, M.Ichie, Y.Handa

O-54 **Effects of Fatigue on the Activity of the Ankle Flexor Muscles in Running**
*J.Mizrahi, E.Isakov, O.Verbitsky

O-55 **Relationship between Joint Force / Muscle EMG and fMRI-Measured Brain Activation**
*G.H.Yue, A.Shah, T.H.Dai, J.Z.Liu, V.Sahgal

<Evoked Potential>
Room A

Chairperson:S.Tochigi
Chairperson:R.F.Mayer

O-61 **A Study of Motor-Evoked Potentials by Transcranial Magnetic Stimulation in Children with Cerebral Palsy(Spastic Diplegia)**
*A.Yasuhara, T.Niki, T.Suzuki

O-62 **Abnormal Electrodiagnostic Studies in Litigated Vs.Non-Litigated Cases:Is There a Difference?**
*O.Hunter, D.C.Sims

O-63 **Effects of Antagonistic Voluntary Contraction on Motor Evoked Potentials in the Forearm Differ between Dominant and Nondominant Sides**
*S-I.Izumi, M.Arita, A.Kimura, N.Chino

0-64 **Facilitation and Inhibition Effects on Event-Related Potentials and Reaction Times in Patients with Parkinson's Disease**
J.Ito

O-65 **In Vivo Study of the Carrying Angle of the Elbow by Means of a Electromagnetic Tracking System**
*P.V.Roy, J.P.Baeyens, D.Fauvard, R.Lanssiers, J.P.Clarijs

O-66 **Motor Imagery Tuned to Auditory Rhythm Increases Motor Cortical Excicitability:Effect of the Contents of Imaged Task**
*K.Kujirai, T.Kujirai, T.Watanabe, M.Saito, N.Saito, T.Kato, M.Tominaga, S.Ueno

O-67 **The Correlation between the Blink Reflexes(BRs)and Exogenous Auditory Evoked Potentials (AEPs)in Patients with Parkinson's Disease(PD)**
*S.Tochigi, K.Yonemoto, S.Sonoda, M.Kono, E.Saito, M.Kawakami, T.Sato, Y.Takahashi, Y.Nishimura, H.Watanabe

12:15～12:55
Luncheon Seminar
Main Hall

Chairperson:Y.Ugawa

S-35 **Task-related Activation Changes after Constraint-induced Rehabilitation Therapy**
*GF.Wittenberg,R.Chen,K.Ishii,E.Croarkin,S.Eckloff,LH.Gerber,M.Hallett,L.G.Cohen, NIH, U.S.A

13:30～14:20
Educational Lecture
<FES(TES)>
Room A

Chairperson:T.Moritani

S-6 **Effect of Electrical Stimulation on Impaired Human Function**
Y.Handa, Tohoku University, Japan

<Neuromuscular Control>
Main Hall

Chairperson:M.Ichie

S-7 **Neural Control of Walking**
*R.B.Stein, University of Alberta, Canada

14:30～15:00
Poster Presentation
<Gait & Posture>
Room C

Chairperson:S.Morishita
Chairperson:Y.Nakazumi

P-201 **Effects of Silent Period in Gastrocnemius during Standing on the Forward Tilting Plate**
*H.Iwatsuki, J.Iwatsuki, H.Hayashi

P-202 **Posture Control and Activity of Erector Supinae Muscles during Lateral Shift of Center of Gravity in Sitting**
*H.Fujisawa, F.Hoshi, R.Takeda

P-203 **Somatosensory Inputs Modulate Soleus H-reflex during Static Posture under Water Immersion in Human**
*K.Egawa, Y.Oida, Y.Kitabatake, H.Maie, T.Mano, S.Iwase

P-204 **Control in Motor Units of Lower Extremity Muscles in Stance Phase and Swing Phase during Fast, Free and Slow Walking Speeds**
*M.Yamaguchi, A.Kobe, N.Ikeda, M.Hamada

P-205 **Validity and Reliability of the Body Trunk Muscle Rigidity Measurement in Dynamometer**
*H.Hino, S.Nishio, K.Choi, A.Yamaguchi

<EMG>
Room C

P-206 **Distribution of Muscle Fiber Conduction Velocity on M.Biceps Brachii Using Surface Array Electrodes and the Model of Generation**
*K.Mito, K.Sakamoto

P-207 **Neurophysiological Effect of the Devised Therapeutic Foot Sole on Equinovarus Foot of Hemiparetic Patient**
*S.Matsumoto, N.Tanaka, T.Shido, K.Asayama

P-208 **Analyses of Surface Electromyographic Findings of Isometric Contraction of the Vastus Lateralis, the Vastus Medialis and the Rectus Femoris**
*O.Nitta, K.Yanagisawa

P-209 **Essential Factor to Produce Faster Step Initiation**
*N.Yamashita, T.Ito, T.Azuma

P-210 **Muscle Fiber Conduction Velocity Estimated through an Inverse Problem Analysis of Surface EMG**
T.Masuda

P-211 **Habituation Process and Rail Effect in Treadmill Walking: An EMG Study of the Ankle Antagonist Pairs in Normal and Hemiparetic Subjects**
*H.M.Lee, I.S.Hwang, J.J.Chen

<Gait & Posture>
Room C
Chairperson:T.Ohnishi
Chairperson:T.Sadoyama

P-212 **Control in Motor Units of Lower Extremity Muscles in Swing Phase during Fast, Free and Slow Walking Speeds**
*A.Kobe, M.Yamaguchi, N.Ikeda, M.Hamada

P-213 **The Mechanical Efficiency of Walking and its Clinical Applicability**
*H.Kanzaki, H.Iida, T.Nakamura

P-214 **Effect of Load and Carrying Position on the Electromyographic Activity of Gluteus Medius in Unilateral Standing**
*N.N.Ansari, G.Olyaei, S.Talebian

P-215 **Upgrade of Low-cost Technology for Accurate Analysis of Foot-ankle Dynamics**
*R.Bernarducci, V.Macellari, C.Giacomozzi, G.Maccioni

P-216 **Effects of Bilateral Upper-limb Exercise on Trunk Muscles Activity**
*Y.Shiba, C.Saitou, S.Obuchi, Y.Habata, M.Maeda

Room C

P-217 **Time-Frequency Analysis of the EMG Signals:Investigations on Heel Strike Transient**
*F.Verdini, T.Leo, M.G.Benedetti, F.Catani, S.Giannini

P-218 **Effect of Current Source Distribution on the Inverse Analysis Solution of Surface EMG**
*K.Saitou, T.Masuda, M.Okada

P-219 **Age-related Changes in the Conduction Velocity and Spectral Variables of Myoelectric Signals Detected from the Tibialis Anterior with Surface Electrode Array**
*T.Oda, M.Okada, H.Yamada, T.Kizuka, T.Shiozaki, S.Kuno, T.Masuda

P-220 **Fine Wire EMG of the Cervical Muscles in the Diagnostic of Whiplash Injuries**
*M.Kramer, T.Wissmeyer, V.Ebert, E.Hartwig

P-221 **The Contribution of Grouping Discharges in Surface EMG to its Spectrum Change**
J.Ohashi

P-222 **Surface EMG Decomposition: Preliminary Results**
*M.Gazzoni, D.Farina, A.Rainoldi, R.Merletti

15:00～15:30

<Gait & Posture>
Room D
Chairperson:T.Nakamuro
Chairperson:M.Sumita

P-223 **Synergistic Strategy among Ankle Extensors during Human Quiet Standing**
*K.Masani, K.Nakazawa, D.Nozaki

P-224 **EMG Activity of the popliteus Muscle during Standing and Descending a Step**
*H.Onishi, R.Yagi, M.Oyama, K.Akasaka, K.Ihashi, Y.Handa

P-225 **Measurement of Center of Pressure after Forward Translation in Healthy Subjects**
*H.Nakamura, T.Tsuchida, Y.Mano

P-226 **The Effect of Pelvic Inclination on Trunk Muscle Activities and Lumber Spine Movement during a Repeated Lifting Task**
*T.Kikumoto, M.Sakagami, O.Shirado, T.Wada, Y.Mano

P-227 **Postural Muscle Control Prior to and during Arm Raising in Young and Older Adults**
*S.I.Lin, R.M.Lin

<Evoked Potential>
Room D

P-228 **Dissociation of the Objective Sensory Exmaminations and the Electrophysiological Findings in Peripheral Nerve Damage**
*Y.Nakazumi, A.Hiratsuka, K.Takahashi, T.Asakura, H.Komazawa

P-229 **Quantitative Evaluation of Facial Hypesthesia by Electrical Blink Reflex**
*R.Kayamori, M.Mikami

P-230 **The Relation between the High Intensity Area on MRI and the Motor Conduction**
R.Shibuya

P-231 **P300 and Mismatch Negativity in Parkinson's Disease**
*Y.Mochizuki, M.Oishi, T.Mizutani

P-232 **Event-related Potentials(P300,Mismatch Negativity)in Diabetes Mellitus**
*M.Oishi, Y.Mochizuki, T.Mizutani

P-233 **Soleus H-reflex Response to Vestibular Stimulation by Horizontal Linear Acceleration**
*Y.Oida, K.Egawa, Y.Kitabatake, H.Maie, S.Mori, N.Katayama

<Gait & Posture>
Room D
Chairperson:M.Takahashi
Chairperson:Y.Oida

P-234 **The Gate Analysis of Rheumatic Patients by Force Plate and F-scan**
*K.Hori, T.Chuma, I.Watanabe, Y.Mano

P-235 **Gait Disturbance after Corpus Callosum Injury**
*N.Shimmyo, M.Maruishi, F.Sato, T.Ito, Y.Igawa, Y.Mano

P-236 **The Effects of Rhythmic Sound Stimulation for Gait of Parkinson Disease**
*T.Chuma, T.Ito, Y.Urakami, Y.Mano

P-237 **Effects of Repetitive Passive Range-of-Motion Exercise on the Gait of Spastic Patients**
*N.Tanaka, M.Taki, S.Uchida, Y.Okajima, Y.Tomita, S.Okada, T.Sasaki, T.Horiuchi

P-238 **The Effect of Jogging on P300 Event Related Potentials**
*Y.Nakamura, I.Yamada, K.Miura, K.Nishimoto

<Evoked Potential>
Room D

P-239 **Motor Fiber Evoked Potentials in Somatosensory Evoked Potentials(SSEP)**
*K.Inoue, Y.Kaseda, R.Kumagai, Y.Mimori, K.Mistuoka, Y.Nakano, S.Nakamura

P-240 **Spinal Cord Evoked Potential Changes due to Conduction Block:a Simplified Model Using Solid Angle Approximation**
*T.Tani, T.Ushida

P-241 **Cerebellum May Contribute to Generate Scalp-recorded Cortical Potentials Evoked by Electrical Stimulation of the Median Nerve**
*J-I.Kitamura, A.Sugimoto, H.Fukuchi

P-242 **Effects of Bed Rest on Postural Modulation of Soleus H-Reflex**
*Y.Kitabatake, Y.Oida, K.Egawa, H.Maie, T.Fukunaga, H.Fukuoka

P-243 **Soleus and Gastrocnemius Silent Period with or without Visual Information in Natural Standing and Hemi-Standing by Dominant Leg**
*S.Daikuya, T.Suzuki, H.Hirose, S.Nishiguchi, Y.Tanino, H.Lee

P-244 **Spinal Neural Function in Different Stretched Positions of Shoulder and Elbow Muscles in Patients with Cerebrovascular Diseases - F - Wave Study -**
*T.Suziki, S.Daikuya, H.Hirose, R.Nabeta, M.Tani, I.Wakayama, S.Nishiguchi, Y.Tanino, H.Lee, T.Fujiwara, E.Saitoh

P-245 **Age Related Changes on Human Postural Stability**
*H.El-Karabaty, I.K.Ibrahim, H.E.Sultan, M.A.El-Abd

16:00~21:30
Beer Party & City Tour
Place of Meeting : Bus stop of Keio Plaza Hotel Sapporo
By Bus

Program Overview Wednesday June 28, 2000

7:30~8:00
Continental Breakfast
Foyer

8:00~9:00
Keynote Lecture3
Main Hall
Chairperson:J.Kimura

S-3 **The Startle Reflex, Voluntary Movement and the Reticulospinal Tract**
J.C.Rothwell, Institute of Neurology, U.K.

9:00~10:20
Symposium5.6
<Sound Myogram>
Main Hall
Chairperson:K.Mita
Chairperson:B.Maton

S-26 **The Physiological Meaning of the Surface Mechanomyogram during Voluntary and Stimulated Muscle Contraction**
C.Orizio, Universita degli Studi di Brescia, Italy

S-27 **Muscle Sounds Recording during Fatigue and Muscle Equivalent Concept**
*B.Maton, M.Petitjean, University Orsay, France

S-28 **Mechanomyographic Behavior of Biceps Brachii Muscles during Linearly Increased Voluntary Contractions**
*K.Akataki, K.Mita, K.Itoh, M.Watakabe, Aichi Human Service Center, Japan

S-29 **Analysis of Muscle Sound Properties during Voluntary and Electrically Induced Contractions and its Application to Low Back Muscle Fatigue**
*T.Moritani, Y.Yoshitake, Kyoto University & Waseda University, Japan

<Gait & Posture>
Room A
Chairperson:M.Lissen
Chairperson:Y.Handa

S-30 **Energy Cost of Walking and Locomotor Impairment**
M.Bernardi, "La Sapienza" University, Italy

S-31 **Gait Studies and Dynamic Electromyography-Past, Present and Future**
*A.Nene, H.Hermens, G.Zilvold, Roessingh Research & Development, The Netherlands

S-32 **Negative and Positive Stiffness of Human Elbow Flexors with Constant Muscle Activation in Isovelocity Movements**
*K.Akazawa, R.Okuno, Kobe University, Japan

S-33 **Ocular Tracking of a Slowly Moving Object: Role of the Frontal Eye Fields (FEF) in Pursuit-Vestibular Interactions**
*K.Fukushima, T.sato, J.Fukushima, Y.Shinmei, T.Yanamobe, Hokkaido University, Japan

10:40〜12:10

Oral Presentation

<Mascle Fatigue/Mascle Phsiology>

Main Hall

Chairperson:M.Knaflitz
Chairperson:K.Kawahara

O-71 **An in vivo Model of Electromyographic Signal Propagation and Muscle Function**
*J.E.Meyer, T.F.Salvini, S.H.Roy

O-72 **Assessment of Muscle Fatigue during Biking**
*M.Knaflitz, F.Molinari, C.Pelosi

O-73 **Comparison of the Effects of Active and Passive Recovery on the Intracellular Events Detected by ^{31}P-Magnetic Resonance Spectroscopy**
*K.Sairyo, T.Ikata, N.Yoshida

O-74 **Effect of Muscle Fiber Length on the Conduction Velocity Distribution Estimation**
*J.A.Glez-Cueto, P.A.Parker

O-75 **In Vivo Force-Length Relationship of Human Tibialis Anterior Muscle**
*M.Ito, Y.Iwamoto, J.Kubo, T.Fukunaga, T.Asami

O-76 **Muscle Fatigue during Concentric and Eccentric Isokinetic Knee Flexo-Extensions**
*F.Molinari, M.V.Actis, P.Bonato, D.Loria, M.Knaflitz

O-77 **Muscle Fatigue Evaluation for Longitudinal Assessment of Dystrofic Patients**
*G.Balestra, M.Knaflitz, M.F.Norese

<Rehabilitation/Ergonomics & Occupational Medicine>

Room A

Chairperson:E.Zinzen
Chairperson:H.Muneshige

O-81 **A Morpho-kinematic Writing Analysis in Dominant-handhemiparetics:Size-related Characteristics of Writing and Motor Learning with the Non-dominant Hand**
*Y.Okajima, N.Tanaka, S.Sonoda, N.Chino

O-82 **An Ergonomical Study of Adjustable Beds in Hospitals**
D.Caboor, *E.Zinzen, M.Verlinden, J.P.Clarijs

O-83 **Effect of Body Weight Supported Treadmill Training on Severe Gait and Disorders in Neurological Diseases**
*I. Miyai, Y.Fujimoto, Y.Ueda, H.Yamamoto, M.Eto, T.Saito, A.Kunitomi, S.Nozaki, J.Kang

O-84 **Electromyography Patterns of Cerebral Palsy Children in Gait**
*L.Y.Guo, F.C.Su, Y.L.Chou, C.J.Lin, R.J.Cherng

O-85 **Some Characteristics of the Knee Muscles Activity during Ambulation of Trans-tibial Amputees**
*E.Isakov, H.Burger, J.Krajnik, M.Gregoric, C.Marineck

O-86 **Supported Treadmill Ambulation Training for Patients after an Acute Stroke**
*Protas E.J, Chunha I, Henson H, Quresy H, Monga T, Lim PAC

O-87 **The Importance of Early Rehabilitation in Treatment of Labor Paralysis of Plexus Brachialis and its Role in Prevention of the Undesired Consequences**
*M.Markovic, K.Cvetkovic, I.Petronic

12:15〜12:55

Luncheon Seminar

Main Hall

Chairperson:K.Yonemoto

S-36 **The Clinical Effect of Rucksack Therapy on Osteoporosis**
A.Ueyoshi, Wakayama Medical College, Japan

13:30〜14:20

Educational Lecture

<Muscle Fatigue>

Main Hall

Chairperson:S.Roy

S-8 **Postural Responses during Manual Material Handling(MMH)**
*J.Kollmitzer, L.Oddsson, *University Vienna, Austria, Boston University, U.S.A.

<Myoelectric Prosthesis>

Room A

Chairperson:K.Akashi

S-9 **Beyond Myoelectric Control : The Neuroprosthetic Arm**
*G.S.Dhillon, S.Lawrence, K.Horch, University of Utah,U.S.A.

14:30〜15:00

Poster Presentation

<Neurophysiology>

Room C

Chairperson:A.Yamaguchi
Chairperson:T.Yamamoto

P-301 **The Study of Distribution and Types of the Muscle Spindles of the Mouse EDL Muscles**
*A.Takagi, S.Matsutani, H.Furusawa, S.Komoto, T.Tosaka, E.Suzaki, K.Kataoka, H.Kajihara

P-302 **Electroencephalographic Characteristics of Imipenem/Cilastatin Induced Seizures**
*D.Zivanovic, V.Susic, O.Stanojlovic, J.Stojanovic

P-303 **N-methyl-D-aspartic Acid and Metaphit-induced Audiogenic Seizures in Rat**
*O.Stanojlovic, D.Zivanovic, V.Susic

P-304 **Neurophysiological Estimate of Sensomotor System of Parkinsonism**
*Staroseltseva N.G., Ivanichev. G.

P-305 **Quantitative Sensory Evaluation by Neurometer in Early Cubital Tunnel Syndrome Patients**
*T.Sawada, T.Murakami, H.Kurumadani

P-306 **An Experimental Study of the Double Crush Syndrome Using Sciatic Nerves in Rabbits**
*Y.Suzuki, Y.Shirai, T.Takeuchi, T.Aoki

P-307 **Current Perception Thresholds in Cerebrovascular Disease**
*Y.Suzuki, M.Oishi, H.Shiota, H.Tsuda, T.Mizutani

P-308 **The Relation between Muscle Fiber Conduction Velocity and Muscle Strength in Patients with Lower Limb Disorders**
*K.Mase, H.Kamimura, I.Siga, K.Fujimoto, S.Imura, H.Kuroda, M.Fujiwara

P-309 **Automatic Evaluation of EEG Coherence after Traumatic Brain Injury**
*O.Vysata, V.Kellerova

P-310 **Sympathetic Responses to Letter Matching as a New Communication Channel for Persons with Severe Motor Disability**
*R.Tsukahara, Y.Kuno, H.Aoki

<Neurophysiology>
Room C
Chairperson:F.Hoshi
Chairperson:K.Ikoma

P-311 **Grading Stretch Reflex Responses According to Target Positions during Quick Adjustment Movements of Human Wrist**
*T.Kizuka, T.Masuda, M.Okada, T.Asami

P-312 **Fractal Dimension of Alpha-rhythm Fluctuations and Paroxysmal Activity Formation in Case of Epilepsy**
*E.A.Korsakova, V.B.Slezin, S.K.Khorshev, V.M.Uritsky

P-313 **The Characteristics of the Women's EEG Alpha Rhythm in Their State of Pregnancy**
A.G.Smirnov

P-314 **Pathological Temporal Alpha-Activity of Human Brain**
G.Boldyreva

P-315 **Interhemispheric Coherence Asymmetry of EEG as a Reflection of Specific Functional States of the Human Consciousness**
*I.Dobronravova, N.Lebedeva

P-316 **Significance of the Frontal Lobes in the Process of Mental Recovery After Long-Term Posttraumatic Coma**
E.V.Sharova

P-317 **The Effects of Gravity on H-reflex in the Human Soleus Muscle during Parabolic Flight**
*T.Sato, T.Miyoshi, K.Yamanaka, H.Sekiguchi, K.Kimura, T.Kemuriyama, D.Nozaki, S.Yamamoto, K.Nakazawa, H.Yano, K.Masani

P-318 **Treatment of Complex Regional Pain Syndrome(CRPS) Type I (a Case Report); Combination Therapy of Ketamine Continuous Infusion and Transcutaneous Electrical Nerve Stimulation(TENS)**
*T.Ogawa, N.Shimmyo, I.Watanabe, Y.Mano

P-319 **Quantification of the Spasticity by Reflex Torque and Reciprocal Inhibition**
*Y.Z.Huang, H.M.Lee, J.J.Chen

P-320 **Influence of Bimanual Coordination on Activation in the Sensorimotor Cortex and Supplementary Motor Area:Analysis Using Functional Magnetic Resonance Imaging**
*M.Toyokura, I.Muro, T.Komiya, M.Obara

<Rehabilitation>
Room C
Chairperson:S.Ito
Chairperson:T.Tsuchida

P-321 **Muscle Weakness in Parkinson's Disease:A Follow-up Study**
*H.Nogaki, S.Kakinuma, M.Morimatsu

P-322 **Development of an Exercise-Therapy Evaluation System for the Elderly**
*H.Kuno, T.Yoshimura, J.Goto, T.Tamura

P-323 **Reflex and Non-Reflex Components of Muscle Tonus in Hemiplegic Patients**
*H.Kawajiri, T.Murakami, T.Hattori, T.Yamamoto, H.Iida, H.Yazawa, H.Katsuta, S.Kimura, K.Sato

P-324 **Influence of Body Weight Unloading(BWU) and Treadmill Gait Training on Hemiplegic Gait**
*J.Seo, K.Chun, K.Cho, S.Bok, J.J.Lee, Song, Y.Yoon, B.Kim

P-325 **A Study on the Quantitative Biomechanical Measurement for the Spasticity with Newly Developed Protocol for Pendulum Test**
*K.Cho, H.Lim, B.Kim, T.Kim, B.An, B.Seo, H.Lee, J.Gu, Y.Lee

P-326 **A Study on Nonlinear Analysis of Plastic Ankle Foot Orthosis(AFO) Based on 3-Dimensional Gate Analysis**
*Y.Lee, K.Cho, H.Lim, K.Choi, M.Sohn, J.Chae, S.Kang, B.Kim

P-327 **Importance of Physical Therapy in the Treatment Children with Arthrogryposis Multiplex Congenita**
*K.Cvetkovic, M.Markovic, D.Cirovic

P-328 **EEG Estimation of the Rehabilitation Effects in Head Injury Patients**
*L.Zhavoronkova, O.Maksakova, N.Smirnova, O.Krotkova, V.Naydin

P-329 **Clinical Effect of Therapeutic Exercise on Dialysis Patients with Complicating Arteriosclerosis Obliterans(ASO)**
*M.Nagaishi, H.Hayashi, H.Seno, M.Yokoya, T.Toriyama, H.Iwatuki

15:00～15:30

<Rehabilitation>
Room D
Chairperson:S.Morimoto
Chairperson:T.Ryushi

P-330 **Preservation of Motor Neuron Excitability during the Cutaneous Silent Period in Amyotrophic Lateral Sclerosis**
*W-K.Kim, S-G.Kim, Y-C.Choi

P-331 **High Frequency Oscillations Evoked by Posterior Tibial Nerve Stimulation in Multiple System Atrophy**
*K.Inoue, Y.Kaseda, R.Kumagai, Y.Mimori, K.Mitsuoka, Y.Nakano, S.Nakamura

P-332 **Respiratory Dysfunction in Patients with Parkinson's Disease**
*T.Jimi, M.Murahashi, H.Yamada, Y.Wakayama

P-333 **Functional Restoration in Patients with Peripheral Nerves Injuries Followed-up by EMNG Controls**
*S.Soldo-Butkovic, B.Barac, R.Kukic, B.Kovac

P-334 **Effect of Spasticity in Cerebral Palsy and Spinal Cord Injury**
*M.Maruishi, Y.Mano, T Sasaki, N.Shimmyo, F. Sato, T Aso, T.Ogawa

P-335 **The Comparison with Exercise Load and Thermal Load at Respiratory-Circulatory Responses**
*K.Hori, I.Watanabe, Y.Mano

P-336 **Needle EMG Findings in Post-polio Syndrome(PPS)**
*N.Shimmyo, Y.Mano, T.Chuma, M.Maruishi, T.Sugata, I.Watanabe, T.Nagashima

P-337 **Delayed Radiation-Induced Brachial Plexopathy: A Case Peport**
*T.Ito, M.Maruishi, F.Sato, Y.Mano

P-338 **Spinal Cord Injury Associated with Brachial Plexus Injury in Neck Trauma**
*A.Toki, M.Sumida, M.Sasaki, M.Fujimoto, S.Saito

P-339 **Cardiovascular Responses to Isometric Exercise during Head-out Water Immersion**
*Y.Ohtsuka, I.Watanabe, Y.Mano

P-343 **Serial Central Motor Conduction Studies in the Miller Fisher Syndrome**
*Y.L.Lo, P.Ratnagopal

<FES>
Room D

Chairperson:A.Takagi
Chairperson:S.Sonoda

P-340 **The Effects of Electrical Nerve Stimulation of the Lower Extremity on H-Reflex and F-Wave Parameters**
*H.Bagheri, Gh.ROlyaei, M.R.Joodaki

P-341 **Endurance Test of New Material FES Electrode**
*H.Ohsawa, T.Fujii, D.C.Kim, S.Ohba, M.Ichie, Y.Handa, N.Hoshimiya

P-342 **The Use of Therapeutic Electrical Stimulation for Gait Disturbance Due to Severe Flexor Reflex:A Case Report**
*Y.Igawa, M.Maruishi, W.Yu, H.Yamaguchi, N.Shimmyo, F.Sato, Y.Urakami, I.Miyahata, T.Ito, Y.Mano

<Magnetic Stimulation>
Room D

P-344 **Task-dependent Excitabilities of Motor Evoked Potential(MEP) were not Modified by Different Muscle Contraction Modes.**
*Y.Hasegawa, T.Kasai, S.Yahagi

P-345 **Affect of Visual Feedback on Motor Cortex Excitability during Voluntary Contraction**
*A.Nuruki, K.Nakamura, K.Yunokuchi, J.C.Rothwell

P-346 **Localization of Electric Field in an Inhomogeneous Medium exposed by Pulsed Magnetic Field**
*K.Yunokuchi, T.Fuchigami, H.Yoshida, Y.Tamari, H.Hosaka, M.Saito

P-347 **Central Motor Inhibitory Mechanism in Patients with Parkinson's Disease A Study with Paired Transcranial Magnetic Stimulation**
*K.Ikoma, A.Suzumura

<Magnetic Stimulation>
Room D

Chairperson:K.Ihashi
Chairperson:T.Chuma

P-348 **Speech Dominancy of Left Handeders Evaluated by Single Magnetic Stimulation**
*H.Tokimura, S.Miyajima, K.Hayashi, J.Kuratsu

P-349 **Transcranial Magnetic Cerebellar Stimulation for the Treatment of Spinocerebellar Degeneration**
*Y.Shiga, H.Shimizu, T.Tsuda, K.Miyazawa, T.Yamazaki, Y.Itoyama

P-350 **Central Motor Conduction Time Study in a Patient with Lightning Strike Injury**
*P.Ratnagopal, Y.L.Lo, F.R.Jaufeerally

P-351 **Changes in the Electroencephalogram Monitored during Repetitive Transcranial Magnetic Stimuli**
*M.Kanno, I.Miyahata, T.Chuma, Y.Mano

P-352 **Motor Evoked Potential Study in Causalgia-dystonia Syndrome**
*N.Shimmyo, M.Maruishi, T.Chuma, F.Sato, T.Ito, Y.Igawa, Y.Mano

P-353 **The Effects of Repetitive Trascranial Magnetic Stimulation in Parkinson Syndrome**
*T.Chuma, Y.Igawa,I .Miyahata, M.Kanno, Y.Mano

P-354 **Silent Period in Spinocerebellar Degeneration and Parkinson Disease**
*T.Chuma, Y.Mano, I.Watanabe

P-355 **Effect of Transcutaneus Therapeutic Electrical Stimulation on Sacral Region**
*Y.Urakami, N.Shimmyo, M.Maruishi, I.Miyahata, Y.Igawa, Y.Mano

15:30～16:00

General Assembly
Main Hall

16:00～16:30

Closing Ceremony
Main Hall

PRE-CONGRESS SYMPOSIUM

A Challenge in the New Millennium: Mechanisms of Motor Control

June 25, Sunday

Hokkaido Conference Hall in Hokkaido Universisty, N8 W5, Sapporo
13:00〜17:00

Moderator: J.Kimura

13:00〜13:35
Welcome Remarks
Y.Mano, Hokkaido University, Japan

13:35〜14:00
Central and Peripheral Origin of Involuntary Movement
J.Kimura, Iowa University, U.S.A.

14:00〜15:00
Analysis of Posture and Gait
K.Yokogushi, Sapporo Medical University, Japan

15:00〜16:00
Movement Induced Interference upon Somatosensory Evoked Potentials
T.Yamada, Iowa University, U.S.A.

16:00〜17:00
Pathophysiology of the Motor Unit
R.F. Mayer, University of Maryland, U.S.A.

Supported by Eisai Co., Ltd.

LUNCHEON SEMINAR

June 26,Monday

Main Hall 12:15〜12:55

Recent Advances in Biomagnetics
S.Ueno, University of Tokyo, Japan

Supported by Tanabe Seiyaku Co.,Ltd.

June 27, Tuesday

Main Hall 12:15〜12:55

Task-related Activation Changes after Constraint-induced Rehabilitation Therapy
*GF.Wittenberg,R.Chen,K.Ishii,E.Croarkin,S.Eckloff,
LH.Gerber,M.Hallett,L.Cohen, NIH, U.S.A

Supported by Mutho Co.

June 28, Wednesday

Main Hall 12:15〜12:55

The Clinical Effect of Rucksack Therapy on Osteoporosis
A.Ueyoshi, Wakayama Medical College, Japan

Supported by Asahi Chemical Industry Co., Ltd.

SATELLITE SYMPOSIUM

June 26,Monday

Main Hall 17:00〜18:00

Muscle Sympathetic Nerve Activity in Humans
T.Mano Nagoya University, Japan
Super Lizer Irradiation Therapy
I.Watanabe, Hokkaido University, Japan

Supported by Tokyo Iken Co., Ltd.

Basmajian Lecture
Keynote Lecture

S-01

Control Properties of Motor Units

Carlo J. De Luca

NeuroMuscular Research Center
and
Departments of Biomedical Engineering and Neurology
Boston University

It is a great honor for me to deliver the Basmajian Lecture at the XIIIth ISEK Congress in Sapporo, Japan. It is a pleasure for me to be here and renew my friendships with many Japanese colleagues whom I have collaborated on numerous research projects over the past 15 years. It is fitting that I should address this Congress on the subject of motor unit control, for it is in this research area that I have shared many rewarding and happy days with over 9 researchers who spent extensive periods of time at the NeuroMuscular Research Center in Boston.

The work that I am about to describe was presented as the Basmajian Lecture at the XIIth ISEK Congress in Montreal in 1998. This paper has been expanded to include the results of work performed in the interim. As always, I wish to acknowledge the contributions of numerous associates and students. They are too numerous to mention, but their contributions are well documented in the literature.

From the beginning, we set out to study the recruitment and firing rate behavior of simultaneously active motor units. A technique, now called "Precision Decomposition" was developed (LeFever *et al.*, 1982; LeFever and De Luca, 1982; Mambrito and De Luca, 1984; Mambrito and De Luca, 1983; De Luca, 1993; De Luca and Adam, 1999). It enabled us to separate the individual action potentials from a needle EMG signal detected during isometric contractions. This technique is capable of decomposing with 100 % accuracy the EMG signal obtained during contractions which reach the maximal voluntary contraction (MVC) level, but only for isometric contractions and not for all contractions. We have decomposed signals containing up to 9 motor units with considerable effort; decomposition of 4 motor units is more typical. We developed a test for verifying the accuracy of the technique. This was a non-trivial problem because it is not obvious that the decomposition of a set of superimposed pseudo random action potential trains will have a unique solution. The technique was originally developed using a special needle electrode which detects three independent channels of EMG signal from three pairs of differential 50 μm diameter electrode surfaces located orthogonally. Recently it has been modified to work with wire electrodes consisting of three 50 μm diameter wires glued together and cut to expose only the cross section of the wires. The signals are conditioned to accentuate the differences in the wave shapes and are sampled at 50 k/s. Rule-based algorithms identify action potentials using template matching and probability of firing, resolve superpositions, and allocate the action potentials to motor units. User interactive editing algorithms are used to check the accuracy and make modifications according to well established rules. Having the precise timing of all the action potentials of several concurrently active motor units allows us to study the recruitment, firing rate, and synchronization interaction.

We have been publishing on this technique for studying the control properties of simultaneously active motor units for almost two decades. For the first 15 years there appeared to be limited interest in this approach, but during the past five years interest appears to have developed. For example during the past six months at least four publications have appeared on this subject (Akaboshi *et al.*, 1999; Kamen and Du, 1999; Marsden *et al.*, 1999; Christensen and Sjogaard, 1999). Our first observation was the Firing Rate Adaptation (De Luca and Forrest, 1973; De Luca, 1985; De Luca *et al.*, 1996). We reported that during isotonic isometric contractions, the firing rate of the motor units decreased as a function of time. As the firing rate decreased, we never saw a new motor unit being recruited during the first 20 s of a contraction. We suggested (De Luca, 1979) and later (De Luca *et al.*, 1996) we interpreted the firing rate decrease during sustained voluntary contractions to be a manifestation of two phenomena: a) The intrinsic property of the motoneuron to exhibit a firing rate decay over time when stimulated with a DC current which was first described in an animal preparation by Kernell (1965). b) A reduced need to fire a motor unit due to the increase in amplitude and duration of its force twitch upon repeated discharge, commonly referred to as twitch potentiation.

The second observation was the phenomenon of Common Drive (De Luca *et al.*, 1982a; 1982b). We found that the firing rates of motor units fluctuated in unison with essentially no time delay between them. This was seen by cross-correlating the firing rates of pairs of concurrently active motor units. We saw this behavior in all muscles tested, ranging from small distal muscles to large proximal muscles. Even motor units belonging to different motoneuron pools exhibited common firing rate fluctuations when controlled as one functional unit; this we observed during antagonist muscle co-activation (De Luca and Mambrito, 1987). The existence of the common drive has been verified by independent investigators (Miles, 1987; Stashuk and de Bruin, 1988; Guiheneuc, 1992; Iyer *et al.*, 1994; Semmler *et al.*, 1997; Marsden *et al.*, 1999). This finding that the motor units are not controlled independently contradicted the previously proposed concept of individual control of motor units. It indicates that the CNS has evolved a relatively simple strategy for controlling motor units. Additionally we found that the irregular nature of the firing rates and the common drive phenomenon imply that muscles cannot produce smooth constant forces. We verified this fact by cross-correlating the firing rates and the force output of the muscle and found a significant correlation with a latency due to the mechanical delay in force build up of the muscle fibers and force transmission through the muscle and tendon tissue.

The existence of a high degree of cross-correlation between the firing rates of motor units does not imply that the individual firings of the motor units are synchronized. By Synchronization it is meant that motor units fire at a fixed time latency with respect to each other. Synchronization occurs in two modalities: short-term and long-term. A study of motor unit pairs detected during isometric isotonic contractions in six muscles revealed that an average of 8 % of the firings were short-term synchronized and only 1 % long-term synchronized (De Luca *et al.*, 1993). Short-term synchronized firings occurred at sporadic intervals and in bursts of typically one or two consecutive firings which had no apparent effect on the force produced by the muscle. More recent work has shown that the amount of synchronization increases as the force output increases, and that it is not affected by the process of aging (Erim and co-workers, unpublished observation). We concluded that synchronization of motor unit firings is an epi-phenomenon with no physiological design of its own.

The third observation was the Onion Skin phenomenon. Along with Person and Kudina (1972) as well as Tanji and Kato (1973), we (De Luca and Forrest, 1973) were among the first to

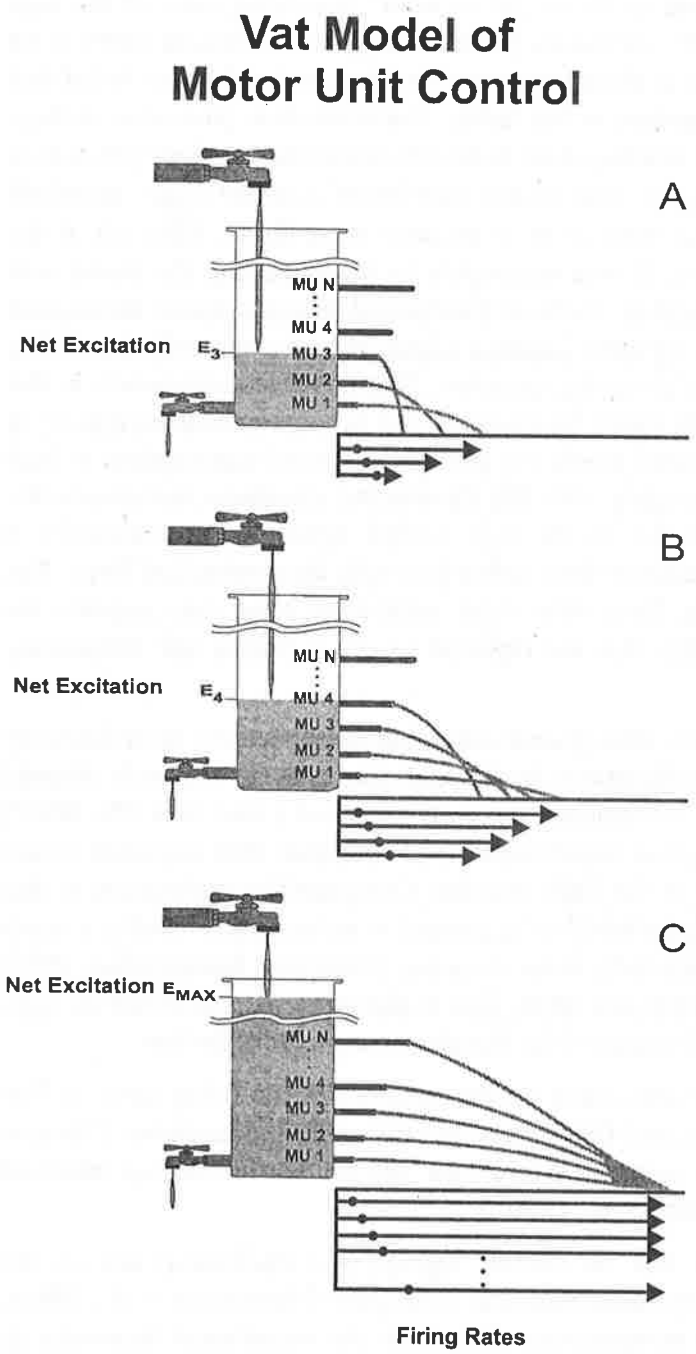
report that during isometric contractions lasting less than 20 s, the earlier recruited motor units always fired at greater average rates than later recruited motor units. (When the firing rates are plotted as a function of time, the hierarchal values of the motor unit firing rates form overlapping layers resembling the structure of the skin of an onion.) Subsequently (De Luca *et al.*, 1982a) we documented this phenomenon in detail. Independent verifications followed by Kanosue *et al.* (1979), Hoffer *et al.* (1987) and Stashuk and de Bruin (1988). Thus, the later recruited, more glycolytic, faster-twitch motor units which require a greater firing rate than the earlier recruited, more oxidative, slower-twitch motor units to fuse would be less likely to tetanize. Even during high level contractions in the neighborhood of 80 to 100 % MVC, the firing rates of the high threshold motor units is in the range of 20 - 30 pulses per second (pps), an amount likely to be insufficient for complete tetanization. This finding ran counter to the previously held belief that higher threshold motor units would be expected to fire faster. The onion skin phenomenon begs the question as to why motor unit control developed so as to not maximize the force generating capacity of a muscle. In fact, there was a previous widely held belief that the higher threshold motor units would fire with greater firing rates so as to produce more force. After all, if the purpose of a muscle was to generate force, it was reasonable to speculate that the motor unit control would be organized to make the most of available mechanical capacity within the muscle. Why should muscles evolve to have an apparent Reserve Capacity not commonly accessible during voluntary contractions? This is an intriguing question. One possible explanation is that the higher threshold motor units, which are faster fatiguing, would become exhausted quickly if they fired fast. A control system so organized would not provide sustained contractions at high force levels which would be necessary to cope with life threatening situations and ensure the survival of the species. It appears that the motor unit control developed to maximize a combination of contraction force and contraction time rather than only the contraction force. The available reserve capacity for generating force over brief periods of time may explain the occurrence of exceptional feats of strength that are reported to occur during life threatening situations.

An apparent exception to the Onion Skin phenomenon has been recently been found by Westgaard and De Luca (submitted for publication). In the trapezius muscle, a muscle adapted for postural control rather than dynamic movements, the early recruited (less than 2% MVC) motor units presented a suppressed firing rate which remained lower than later recruited motor units. This behavior was not seen in any of the limb muscles. One possible explanation is that the Renshaw recurrent inhibition generally believed to be present in axial muscles and to a much lesser extent, if at all, in limb muscles, especially distal muscles, (Rossi and Mazzocchio, 1991) suppresses the firings of the low threshold motor units. This explanation reconciles the concept of the Common Drive with the known influences of the Renshaw recurrent inhibition.

(Two corollary observations were also made for the behavior of the firing rates: a) The latter recruited motor units had greater initial firing rates as previously indicated by Clamann (1970). b) The firing rates of all units converged to a near common value during maximal contractions (De Luca and Erim, 1994; Erim *et al.*, 1996).)

All the above findings indicate that he control signals (net excitation) act on the motoneuron pool as a unit. As proposed by Henneman and colleagues (Henneman *et al.*, 1965a; 1965b) the individual properties of the motoneurons determine the recruitment hierarchy in response to the net excitation. To that enlightening observation we now add that the firing rate of the individual motor units respond to the net excitation communally and simultaneously, and that the average value of the firing rates is also hierarchically organized with an inverse relationship to the recruitment threshold.

The fourth observation was the Diversification of the control properties (De Luca *et al.*, 1982a). The motor units of smaller, distal muscles such as the first dorsal interosseous tend to be recruited in the force range up to 50 % MVC and have mean firing rates which reach relatively high values (approx 40 pps) at 80 % MVC. Whereas, those from larger, proximal muscles such as the deltoid and the trapezius recruit their motor units in a force range up to 80 % MVC and have firing rates which reach relatively lower values (approx 30 pps). A similar observation in the adductor pollicis and biceps brachii muscles was reported independently by Kukulka and Clamann (1981). The reduced dynamic range of the larger more proximal muscles may be due to the increased recurrent inhibition of the Renshaw system which is more prominent in these muscles as shown by Rossi and Mazzocchio (1991). These diverse control properties are useful in at least two ways. First, they allow for a smoother force. Smaller muscles have less motor units, therefore, force gradation due to recruitment would be coarser throughout the full range than in larger muscles which have many more (an order of magnitude or more) motor units. Second, the larger more proximal muscles tend to be more postural and are required to produce sustained contractions more often. The lower firing rates in these muscles delay the progression of fatigue.



Many of the above observations can be conveniently summarized by a simple hydraulic analog which we call the Vat Model (De Luca and Erim, 1994). The water flowing into the tank corresponds to the excitation reaching the motoneuron pool, and the water flowing out of the tank corresponds to

the inhibition. The level of the water in the tank corresponds to the net excitation received by the motoneuron pool. The broken line indicates that the height of the tank is greater than depicted. The spouts correspond to the motor units, with their location on the side of the tank corresponding to their recruitment threshold. The length of the spout corresponds to the initial firing rate and the distance traveled by the water stream corresponds to the firing rate of the individual motor unit. The common drive is represented by the fact that all the motor units respond to a fluctuation in the level of the tank. (A) Demonstrates the case when the net excitation is sufficient to activate only three motor units. (B) As a new motor unit is recruited, the firing rate of previously activated motor units increases. (C) As the excitation reaches the maximal value, (presumably) all the motor units have been recruited and the firing rates tend to converge to the same value.

We found that long-term Exercise appears to induce modifications in the motor unit control properties (Adam *et al.*, 1998). We compared the motor unit control parameters of the first dorsal interosseous muscles of the dominant and non-dominant hands performing isometric, isotonic contractions at the same MVC level. We found that when compared to the non-dominant hand, motor units of the dominant side had lower firing rates for the same level of contraction, and a larger number of motor units were found to be recruited at lower force levels. This finding is consistent with previously known facts that the dominant hand has slower-twitch muscle fibers, probably due to the life-long preferential use. The twitches of slower fibers fuse at lower firing rates allowing for a reduced excitation and decreased firing rates in the dominant hand without a reduction in force output.

My colleague, Dr. Z. Erim, and I have recently found that Aging causes alterations in the motor unit control properties (Erim *et al.*, 1997). In our study in the first dorsal interosseous muscle of elderly subjects above 65 years of age, we found that the firing rate and the recruitment threshold of motor units became modified in the same manner as that induced by exercise. This observation was not surprising because it is well known that aged muscles contain a greater percentage of slow twitch Type I fibers, as is the case in exercised muscles, although the cause for the increased percentage of Type I fibers appears to be different. When we studied the common drive in the elderly, we found that in approximately one-half of them the cross-correlation between pairs of motor units was severely reduced and in some cases apparently non-existent. Also, in the elderly, the onion skin phenomenon was disrupted. When plotted as a function of contraction time, the firing rates of numerous motor units crossed over those of earlier recruited ones and the behavior of the firing rates was not orderly in a hierarchial sense; some decreased while others increased during an isometric, isotonic contraction. We surmise that this dissociation among the firing rates of motor units leads to an inefficient force generation scheme.

All the above observations were made on relatively short-duration (less than 20 s) isometric, isotonic contractions. They may not fully describe the behavior of the control properties during sustained contractions of limb muscles or postural muscles which are commonly required to contract for prolonged periods of time. My colleague Dr. R. Westgaard and I have seen cases where the onion skin property is disturbed during short-term (20 s or less) contractions of normal healthy trapezius muscle and during long-duration (150 s or more) contractions in normal healthy first dorsal interosseous muscles. These are relatively new observations. We suspect that the cross over of the firing rates is due to at least two factors which cause the firing rates of earlier recruited motor units to decrease below the value of the newly recruited motor units: a) The Renshaw recurrent inhibition of earlier recruited motor units which is more dominant in proximal muscles such as the trapezius, hence the disturbed onion skin during short-duration contractions. b) The motoneuron adaptation process reported by Kernell (1965) which decreases the firing rates of motor units during sustained activation causing the discharge rates of earlier recruited motor units to decrease below that of later recruited motor units.

While studying long-duration contractions in the range of 5 min to 60 min, Westgaard and De Luca (1999) also observed definite examples of Motor Unit Substitution. These are cases where a motor unit stopped firing during a sustained contraction when the activity level decreased slightly, and in response to a subsequent slight increase in the force output, a new motor unit was recruited in place of the one which was derecruited. We believe this phenomenon is the result of adaptation of the recruitment threshold of active motoneurons. The recruitment threshold of a motor unit which had been active for some time would have become greater than the recruitment threshold of the next one in the hierarchy. In this fashion the next motor unit becomes recruited in response to an increase in the net excitation to the motoneuron pool.

We continue to pursue this line of investigation and we anticipate additional interesting observations.

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S-02

WAVEFORM ANALYSIS IN ELECTROPHYSIOLOGY

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1. Analysis of Triphasic Waveform

Analyzing waveforms plays an important role in the assessment of nerve or muscle action potentials. A sequence of potential changes arise as two sufficiently close wave fronts travel in the volume conductor from left to right. This results in a positive-negative-positive triphasic wave as the moving fronts of the leading and trailing dipoles, representing depolarization and repolarization, approach, reach, and finally pass beyond the point of the recording electrode. Thus, an orthodromic sensory action potential from a deeply situated nerve gives rise to a triphasic waveform in surface recording. The potentials originating in the region near the electrode, however, lack the initial positivity, in the absence of an approaching volley. A compound muscle action potential, therefore, appears as a negative-positive diphasic waveform when recorded with the active electrode near the end-plate region where the volley initiates. In contrast, a pair of electrodes placed away from the activated muscle registers a positive-negative diphasic potential indicating that the impulse approaches but does not reach the recording site.

The number of triphasic potentials generated by individual muscle fibers summate to give rise to a motor unit potential recorded in electromyography. The waveform of the recorded potential varies with the location of the recording tip relative to the source of the muscle potential (Buchthal, Guld and Rosenfalck, 1957; Dumitru, King, and van der Rijt, 1994; Gootzen, Stegeman and Van Oosterom, 1991; Theeumen, Gootzen and Stegeman, 1993; Van Veen, Wolters, Wallinga, et al 1993). Thus, the same motor unit shows multiple profiles depending on the site of the exploring needle. Moving the recording electrode short distances away from the muscle fibers, results in an obvious reduction in amplitude. Additionally, the duration of the positive - to - negative rising phase, or rise time, becomes greater. The rise time gives an important clue in determining proximity to the generator source. Amplitude may not serve for this purpose, because it may decrease with smaller muscle fibers or lower fiber density.

According to the volume conductor theory, the location of the needle dictates the waveform of recorded potentials. Thus, the same single fiber discharge may be registered as initially positive triphasic fibrillation potential, initially negative biphasic endplate spike or initially positive biphasic positive sharp wave. Despite this prevailing unifying concept (Dumitru, 1996a,b), an accurate description of the observed potential often provides clinically useful information (Kraft, 1996a,b). For example, positive sharp waves recorded in the absence of fibrillation potentials may imply subliminal hyperexcitability of single muscle fibers, that "spontaneously" fire only with mechanical irritation of the needle. If the tip of a needle blocks a propagating impulse, the recorded potential appears as a positive sharp wave signaling only the approach of the positive front of depolarization.

2. Near-Field And Far-Field Potentials

The specific potential recorded under a particular set of conditions depends not only on the location of the recording electrodes relative to the active tissue at any instant in time, but also on the physical characteristics of the volume conductor (Cunningham, Halliday and Jones, 1985; Kimura, Mitsudome, Beck et al, 1983; Kimura, Mitsudome, Yamada et al, 1984; Nakanishi 1983; Stegeman, Van Oosteron and Colon, 1985). The near and far-field potentials distinguish two different manifestations of the volume-conducted field (Jewett, 1970; Jewett and Williston, 1971; Sohmer and Feinmesser, 1970). The near field represents recording of a potential as it propagates under a pair of usually closely spaced electrodes placed directly over the path of the impulse. A bipolar recording registers primarily, though not exclusively, the near field from the axonal volley along the course of the nerve. In contrast, the far field implies detection of a voltage step long before the signal arrives at the recording site, usually by a pair of widely separated electrodes located far from the traveling volleys. A referential montage preferentially records far field potentials unless one of the electrodes lies near the passage of the traveling volley. A far-field derivation has become popular in the study of evoked potentials to detect voltage sources generated at a distance. Original work on short-latency auditory evoked potentials (Jewett, 1970; Jewett and Williston, 1971; Sohmer and Feinmesser, 1970) suggested that synaptically activated neurons in the brainstem gave rise to stationary peaks. Subsequent animal studies (Vaughan, 1982) emphasized the role of a synchronized volley of action potentials within afferent fiber tracts as their source. Further work with the human peripheral nerve has documented that stationary peaks can result solely from the propagating impulse in the absence of synaptic discharge (Eisen, Odusote, Bozek et al, 1986; Kimura, 1984a; Kimura, Mitsudome, Beck et al, 1983; Kimura, Mitsudome, Yamada et al, 1984; Kimura, Yamada, Shivapour et al, 1982; Lin, Phillips and Daube, 1980). Hence stationary activities registered in far-field recording may represent a fixed neural source such as synaptic discharges or alternatively, a nonpropagating peak from an advancing front of axonal depolarization.

As for the second of the two possibilities discussed above, short sequential segments of the brainstem pathways may each summate in far-field recording, resulting in successive peaks of the recorded potentials (Arezzo, Legatt and Vaughan, 1979; Arezzo and Vaughan, 1982; Vaughan, 1982). This mechanism by itself, however, does not account for the standing peaks derived from the propagating volleys at certain points along the greater length of the afferent pathway. In short latency somatosensory evoked potentials (SEP) of the median or tibial nerve a voltage step develops between the two compartments when the moving volley encounters a sudden geometric change at the border of the conducting medium (Kimura, Mitsudome, Yamada et al, 1984).

Here, each volume conductor on the opposite side of the boundary, in effect, acts as a lead connecting any points within the respective compartment to the voltage source at the partition (Cunningham, Halliday and Jones, 1985; Kimura, Kimura, Ishida et al, 1986). Consequently, the potential difference remains nearly, though not exactly, the same regardless of the distance between G1 and G2, thus allowing detection of the voltage step in far-field recording.

The designation, junctional or intercompartmental potential, differentiates this type of stationary peaks from fixed neural generators and helps specify the mechanism of the voltage step generated by the travelling impulse at a specific location.

3. Physiological and Pathological Temporal Dispersion

In nerve conduction studies, latency measure of the fastest fibers allows calculation of the maximal motor or sensory velocities. In addition, waveform analyses of compound muscle and sensory nerve action potentials help estimate the range of the functional units (Daube, 1980; Kimura, 1984; Olney and Miller, 1984). This aspect of the study provides an equally, if not more, important assessment, especially in the study of peripheral neuropathies with segmental block, in which surviving axons may conduct normally (Gilliatt, 1980; Harrison, 1976; Lewis, Sumner, Brown, et al, 1982; Miller and Olney, 1982; Sumner, 1981; Thomas, 1971). In clinical tests of motor and sensory conduction, the size of the recorded response approximately parallels the number of excitable fibers. Any discrepancy between responses to proximal and distal shocks, however, does not necessarily imply an abnormality.

The impulses of slow conducting fibers lag increasingly behind those of fast conducting fibers over a long conduction path (Buchthal and Rosenfalck, 1966; Cummins, Dorfman and Perkel, 1979; Lambert, 1962). With increasing distance between stimulating and pickup electrodes, the recorded potentials become smaller in amplitude and longer in duration; and, contrary to the common belief, the area under the waveform also diminishes. Thus, the size of the recorded response depends to a great extent on the site of stimulation. In fact, stimulation proximally in the axilla or Erb's point may normally give rise to a small or undetectable digital potential, despite a large response elicited by stimulation at the wrist or palm (Kimura, 1983; Olney and Miller, 1983; Wiechers and Fatehi, 1983). For the same number of conducting fibers activated by the stimulus, the size of sensory potentials change linearly with the length of the nerve segment (Kimura, Machida, Ishida, et al, 1986; Kincaid, Minnick and Pappas, 1988). A physiologic reduction both in amplitude and the area under the waveform may erroneously suggest a conduction abnormality between the proximal and the distal sites of stimulation.

With short-duration diphasic sensory spikes, a slight physiologic latency difference could line up the positive peaks of the fast fibers with the negative peaks of the slow fibers, canceling both. According to computer simulation (Kimura, Sakimura, Machida et al, 1988; Rhee, England and Sumner, 1990), this phenomenon alone can reduce the normal sensory nerve action potential to below 50 percent in area as well as in amplitude, a conservative figure, based on computation of a limited number of nerve fibers for analysis. Thus, a major reduction in size of the compound sensory action potential can result solely from physiologic phase cancellation. In contrast, the same temporal dispersion has less effect on compound muscle action potential (Felsenthal and Teng, 1983; Olney, Budingen and Miller, 1987; Wiechers and Fatehi, 1983) because motor unit potentials of longer duration superimpose nearly in phase rather than out of phase despite the same latency shift, resulting in less cancellation compared to sensory potentials. In support of this view, the duration change of the sensory potential, expressed as a percentage of the respective baseline values, far exceeds that of the muscle response (Kimura, Machida, Ishida, et al, 1986). As expected from the term, duration-dependent phase cancellation (Kimura, Machida Ishida et al, 1986), a physiological temporal dispersion also reduces the amplitudes of short duration muscle action potentials such as those recorded from intrinsic foot muscles substantially.

The degree of overlap between peaks of opposite polarity depends on the separation between G1 and G2, which dictates the duration and waveform of unit discharges (Buchthal and Rosenfalck, 1966). A maximal cancellation results when a waveform contains negative and positive phases of comparable size. In a triphasic orthodromic sensory potential, as compared with biphasic antidromic digital potentials, the initial positivity provides an additional probability for phase cancellation. Changes in temperature also affect the temporal dispersion influencing the fast and slow conducting fibers more or less equally in percentage, and therefore differently in absolute terms (Rutten, Gaasbeek and Franssen, 1998). The equations for the best fit lines between nerve length and other measurements in one study may not necessarily apply to another unless the recording technique conforms to the particular specifications.

If the latency difference between fast and slow conducting motor fibers increases substantially as might be expected in demyelinating neuropathy, muscle responses also diminish dramatically based solely on phase cancellation as predicted by our model (Kimura, Sakimura, Machida, et al, 1988) and computer simulation with a broader spectrum of motor nerve conduction velocities (Lee, Ashby, White, et al, 1975). This type of phase cancellation reduces the amplitude of muscle response well beyond the usual physiologic limits in the absence of conduction block. Thus, in pathological temporal dispersion associated with segmental demyelination, focal phase cancellation of the muscle action potential could give rise to a false impression of motor conduction block. This phenomenon explains an occasionally encountered discrepancy between severe reduction in amplitude of the compound muscle action potential, on the one hand, and relatively normal recruitment of the motor units and preserved strength, on the other. Thus, sustained reduction in size of compound muscle action potential may result from a pathological temporal dispersion rather than a prolonged neurapraxia (Kimura, Sakimura, Machida, et al, 1988; Miller and Olney, 1982; Rhee, England and Sumner, 1990).

Comparison between distally and proximally elicited responses often fails to differentiate physiological, as opposed to pathological, temporal dispersion, not to mention conduction block. Many variables such as electrode position and distance make the commonly held criteria based on percentage reduction nearly untenable except in entirely standardized studies (Lateva, McGill and Burgar, 1996). A simpler, more practical approach relies on a linear relationship seen in physiological phase cancellation between the latency and the size of the recorded responses. Although this calls for segmental stimulation at more than two sites to test the linearity of observed changes, it enjoys the distinct advantage of having a built in internal control for all recording variables such as inter-electrode spacing. A non-linear reduction in amplitude or area, often associated with waveform changes, indicates either a pathological temporal dispersion or conduction block. The distinction between the two possibilities must in part depend on clinical cue as stated below.

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S-03

The startle reflex, voluntary movement and the reticulospinal tract

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The startle reflex

A large body of evidence from animal studies suggests that the startle response originates in the caudal brainstem. Lesioning experiments in the rat have implicated the median bulbopontine reticular formation (Szabo, Hazafi, 1965), particularly the nucleus reticularis pontis caudalis (Hammond, 1973; Leitner *et al.*, 1980; Davis *et al.*, 1982), as a primary centre subserving the acoustic startle response. The efferent limb may be the reticulospinal and bulbospinal tracts which originate in this area (Schiebel, Schiebel, 1958; Torvik, Brodal, 1957). If the same organisation operates in man, then the startle may be a method of analysing reticulospinal function in humans.

The startle reflex in man consists of a generalised flexion response which habituates rapidly over two to six trials (Landis, Hunt, 1939). It may be generated by any form of stimulation, but is most usually provoked by a short, loud auditory tone. The absolute onset latency of the EMG responses in the startle is rather variable and depends upon the modality of the stimulus, the intensity of the stimulus, and the expectancy of the subject (Wilkins *et al.*, 1986; Matsumoto *et al.*, 1992; Brown *et al.*, 1991b) (Chokroverty *et al.*, 1992). Typical onset latencies would be of the order of 60 ms in the sternocleidomastoid muscle and 75 ms in the biceps. Although the absolute latency of the responses is variable, the pattern of activity between different muscles is usually more stereotyped. Figure 1 shows the typical pattern of activity following an auditory startle in a single normal subject, recording from muscles around the neck, face, arms and trunk.

The response appears to begin in the orbicularis oculi muscle. However, both Colebatch et al (Colebatch *et al.*, 1990) and Brown et al (Brown *et al.*, 1991b) have argued that this initial activity is not part of the true startle pattern but simply represents a blink reflex to the auditory stimulus. Three factors support this interpretation. First, it is sometimes possible to see a clear separation in the orbicularis oculi response between an early, short period of activity and a later, long lasting portion of activity. Second, the early

component does not habituate as rapidly to repeated presentation of the auditory tone as the startle pattern. Thus, presentation of the auditory stimulus on the first occasion may give a full blown startle pattern on the first trial, but after two or three presentations, the only remaining response is the initial portion of the orbicularis oculi burst. Third, EMG responses in the mentalis, another muscle innervated by the seventh cranial nerve have a longer latency than those of the first component of the orbicularis oculi response that is not explicable by a longer peripheral conduction time. This latency fits well with the presumed caudo-rostral pattern of innervation of cranial nerve innervated muscles within the startle detailed below.

If it can be assumed that the initial part of the orbicularis oculi response is a blink reflex, then the startle pattern proper begins with an activity in the sternocleidomastoid muscle. This is followed by activity in the mentalis and then the masseter muscles and then by activity in limb trunk muscles. The pattern and onset latencies of the responses in the startle are very different from those seen in the same muscles after transcranial electrical or magnetic stimulation of the motor cortex (Rothwell *et al.*, 1991). Table 1 gives a comparison of the interval between the onset of EMG activity in the sternocleidomastoid and masseter or rectus abdominus (RA) muscles, and the interval between activity in the biceps and abductor pollicis brevis (APB) muscles in normal subjects after a startle stimulus or after stimulation of the motor cortex. Three features are evident.

1) In the startle response, there appears to be a caudo-rostral pattern of innervation of cranial nerve innervated muscles that begins in the sternocleidomastoid and spreads up to the mentalis (seventh nerve) and then masseter (fifth nerve) muscles.
2) The excess latency of the rectus abdominus response over the sternocleidomastoid is some three times longer in the startle than it is after stimulation of the motor cortex. If we assume that the peripheral conduction delay is the same in both cases, then the conduction velocity of the efferent pathway within the spinal cord must be much slower for the startle than it is for the pathway activated by cortical stimulation. Since the latter is now thought to be the large diameter component for cortical spinal tract (Boyd *et al.*, 1986), the slower conduction of the startle would be consistent with a reticulospinal projection.
3) In the startle, the latency to the onset of EMG responses in intrinsic hand muscles is disproportionately long even when allowance is made for the slow conduction in spinal efferent pathway. Again, this pattern is unlike the preferential accessibility of the hands seen after activation of the cortico-spinal system and indicates that a quite different pathway is used in the startle.

In summary, this electophysiological evidence suggests that the physiological auditory startle reflex in man in mediated by an efferent system with its origin in the caudal brainstem. The spinal projections of this system are relatively slow conducting and are distributed predominantly to axial muscles. The pattern of muscle recruitment in the response is determined by the distance of each segmental level from the caudal brainstem, with two exceptions. First, an auditory reflex precedes the auditory startle reflex in the orbicularis oculi. Second, the latencies of intrinsic hand muscle responses are disproportionately delayed.

Pathology of the startle reflex

The idea that a startle reflex might arise in the caudal brainstem and utilise slowly conducting reticulospinal pathways is consistent with several pathological studies in man. Brown et al (Brown *et al.*, 1991c) studied several patients with hyperekplexia, a condition characterised by excessive sensitivity and lack of habituation to startle stimuli. Some of these patients with hereditary forms of the disease are known to have a mutation in the glycine receptor gene (Shiang *et al.*, 1993) and also show abnormalities in some spinal reflexes as well as in the startle response (Floeter *et al.*, 1996). Although the startle was more readily elicited in these patients than in normal subjects, the pattern of activation was the same in both cases. Several symptomatic cases had pathology affecting the brainstem (Brown *et al.*, 1991c).

In a further study, Vidaillhet et al (Vidailhet *et al.*, 1992) showed that the startle reflex was virtually absent in patients with progressive supranuclear palsy. Although the pathology in this condition is widespread, one of area of particularly high neuronal loss is in the lower pontine reticular formation.

Interaction between the startle reflex and voluntary motor responses.

Voluntary motor responses to sensory stimulation usually have a much longer latency than those of the startle response. For example, in muscles of the arm a startle reaction may have a latency less than 80 ms. In contrast, voluntary reaction time to a visual "go" signal is of the order of 150 ms. The reaction time to auditory and somatosensory stimuli is shorter, but even then rarely less than 100 ms (Thompson *et al.*, 1992). The difference in latency between the voluntary startle responses is thought to be due to the fact that when subjects move voluntarily in response to a reaction signal, the cerebral cortex has to play a role in identifying the sensory stimulus and releasing the instructions to move. In contrast, startle reactions are thought to be a reflex phenomenon caused by sensory inputs to the reticular formation of the brainstem activating descending reticulospinal tract projections to the spinal cord.

Recently, Valls Sole et al (Valls *et al.*, 1995) have shown that voluntary reaction times can be considerably reduced if a very loud, startling sound is given at the same time as the visual "go" signal. The degree of shortening is much greater than that observed in conventional inter-sensory facilitation (Nickerson, 1973), and presumably represents a specific startle-related effect. The question is what neural mechanisms are responsible for this phenomenon. Since the reaction times are the same as those of the startle reaction itself, the simplest explanation is that the activity observed in these experiments consists of two components: an early startle reflex, and a late voluntary response, the true onset of which is masked by the startle. However, there is one alternative explanation. It could be that the high intensity acoustic stimuli somehow releases the movement being prepared for voluntary execution at a speed far quicker than usual, perhaps bypassing cortical circuitry and activating muscles using the same pathways as the startle reaction itself.

We have therefore (Valls *et al.*, 1999) conducted experiments to test between these two competing explanations for startle-induced reaction time shortening. They examined the effects of the startling stimulus on two stereotyped EMG patterns of activity that are generally thought to be generated in the central nervous system. One was the triphasic agonist/antagonist/agonist burst of a rapid, self-terminated wrist flexion or extension movement (Hallett *et al.*, 1977). The other was the structured EMG pattern that accompanies the action of rising on tiptoes from the standing position (Nardone, Schieppati, 1988). This begins with a silence of the soleus muscle and activation in the tibialis anterior, both at which tend to bring the centre of gravity forward. After this there is a large burst of activity in the soleus muscle which pushes the heel from the ground. Both the triphasic ballistic movement pattern and the postural response are thought to be centrally programmed and can be generated without that significant contribution from peripheral afferent inputs (Sanes, Jennings, 1984; Forget, Lamarre, 1990). We postulated that if a loud acoustic stimulus shortens reaction time by superimposing a startle reflex onto the onset of the voluntary response, then there would be a disruption of the stereotyped EMG pattern for both movements. Conversely, if the startling stimulus somehow bypasses some of the normal reaction time circuitry, then the response would be sped up with no alteration of the EMG pattern.

In both types of movement, the effect of the startling stimulus is to speed up the voluntary reaction, without affecting the form of its response in any way. Thus, in the ballistic wrist movements, the relative timing and amplitude of activity of the triphasic pattern in the flexor and extensor muscles remains unchanged, but the onset of activity in both muscles is considerably reduced. The same can be seen in the postural task. Reaction to a visual cue is accompanied by an initial silence in the soleus, followed by a burst of activity in the tibialis anterior and then a final burst of activity in the soleus. The relative timing of the onset of silence, onset of activity in the tibialis anterior and the final soleus activity are all unchanged by the addition of the startling auditory stimulus. The main effect is simply to shorten the latency of the whole movement pattern, so that it begins at the normal time of the startle response rather than at the latency of a normal voluntary reaction.

The conclusion from these experiments is that a loud, startling stimulus speeds up the execution of a voluntary movement without changing its main characteristics. Since elements of the startle reflex proper were elicited in muscles not involved in the voluntary reaction, the simplest explanation is that the voluntary reaction was driven at the speed of the startle reaction whilst maintaining features of the voluntary motor program. One possible way in which this could occur is that the interaction between startle input and voluntary output occurred in the reticular formation where the startle response originates. The implication is that under certain conditions, the motor program that is being prepared for voluntary execution is triggered by activation of the same reticular structures that are responsible for the startle reflex. Preparatory, premovement activity occurs in parallel at many levels of the nervous system from cortex to spinal cord. For example, the spinal monosynaptic reflex changes before movement as well as in the preparatory period before the reaction signal is given. Motor evoked potentials to transcranial magnetic stimulation also change both in the reaction and preparatory periods before voluntary movement (Rossini *et al.*, 1988). Indeed, even the startle pattern itself can be modulated by the stance of the subject before the stimulus is given (Brown *et al.*, 1991a). Our hypothesis is that sufficient detail of the voluntary movement characteristics may be stored in brainstem and spinal centres so that, on occasion, the whole motor program can be triggered without the expected command from the cerebral cortex. This is not to deny the cerebral cortex a crucial role in preparing the response parameters, nor to exclude it from contributing to later parts of the response. However, the implication is that the cerebral cortex does not need to play the lead role for initiating voluntarily prepared responses.

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Educational Lecture

S-04

MUSCLE SOUNDS: FROM BIRTH TO NOW

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Introduction

The existence of muscle sounds produced by muscular contraction was reported for the first time in 1665 by Maria Grimaldi. It was in his De Lumine (30) that he described that when he introduced a finger in his ear, he heard low-pitched sounds if he voluntary contracted his hand or arm muscles. Up to the middle of the 17th century, muscular contraction was thought to result from " animal spirits" . It was on this basis that a muscular origin of sound was refuted a few years later by Craanen (23). Thereafter, muscle sounds were not studied during all of the 18th century. A renewal of interest for muscle sounds emerged only at the beginning of the 19th century with the work of William Hyde Wollaston (59). Wollaston reported several experiments which allowed him to calculate that the frequency range of muscle sounds was between 14 and 36 Hz. Following Wollaston's reports, the development of new technologies allowed numerous authors to publish interesting data on the relationship between the amplitude or/and the frequency of muscle sounds and the intensity of muscle contractions in healthy man or animals, and also in neuromuscular diseases (13,15,17,21,22,31,38). In fact a surprisingly large panel of work which was summarized by Bouman and Van Rijnberk (14). Nevertheless, it is only since 1980 that the research on muscle sounds has significantly grown. A stimulating paper from Oster and Jaffe appeared in 1980 (45). It was followed by reports from Brozovich and Pollack (16), Oster (44), Hufschmidt et al. (31,32) and by a series of papers published by Barry et al. (3 to 11) during the years 1985-1990, that really stimulated research on muscle sounds. The Barry et al. papers addressed the fundamental questions :

What is the exact origin of muscle sounds ?

Can muscle sounds be used to determine the muscular contraction force ?

Can they be used to evaluate the occurrence and level of muscle fatigue ?

Can they have practical applications ?

The present brief review cannot cover the great bulk of literature on muscle sounds. Its aim is to provide a survey of current answers to the above questions (see also review 37).

I - <u>The diversity of sensors and associated terminology</u>

Muscles sounds have been and are currently studied world-wide. Research teams do not use the same, unique type of sensor for recording muscle vibrations. As a consequence, muscle vibration recording is called « phonomyography » (PMG), « muscle sound recording », « myosonography » or « acoustic myography » when a stethoscope, microphone, or hydrophone is used; whereas it is called « vibromyography », « accelerometermyography » or « mechanomyography » (MMG) when recordings are made by means of accelerometers or contact sensors. Since each term should reflect the kind of sensor which is at the basis of the reported data, there is no attempt in the present paper to use a single term.

Today, muscles sounds are studied by using condenser or piezoelectric microphones inside an electric stethoscope or in small devices attached to the skin. These microphones have a large bandwidth of between less than 1 Hz and more than 1000 Hz which allows the whole spectrum of muscle sounds to be recorded. But they also have the disadvantage of detecting all sounds from the environment. For this reason, in most studies the amplifier bandwidth has been adjusted to attenuate the signals of frequencies below 1-15 Hz and those of frequencies above 50-100 Hz. This means that the recorded muscle sounds are most often more or less altered by the recording apparatus, which may explain some of the discrepancies in the data reported in the literature.

Muscle vibrations can also be detected directly by using skin sensors or by means of piezoelectric accelerometers whose bandwidth may be similar to those of microphones. Here again, there is no standard in the amplifier bandwidths. Watakabe et al. (58) conducted a detailed study to compare the signal detected by a piezoelectric contact sensor to that obtained simultaneously by a miniature accelerometer. Their results made it clear that the contact sensor allows the recording of different mechanical variables (acceleration or displacement), depending on how it is used. Several authors (12,54,58) have also shown that the amplitude of the signal obtained by the electrical sensor for evoked or voluntary contractions increases as the pressure exerted on the sensor.

Finally, it can be of great interest to use composite probes that allow the recording of electromyogram (EMG) and MMG over the same part of the muscle. Such probes have been made on the basis of a condenser microphone by Petitjean and Maton (48), or of skin contact sensors (1,33).

II - The origin of muscle sounds

The mechanism of muscle vibration is fully understood as far as contractions evoked by the electrical stimulation of the nerve are considered.

1 - Origin of evoked muscle sounds

Using a hydrophone, Barry (3), Barry and Cole (6,7), Cole and Barry (20), and Frangioni et al. (28) recorded the sounds produced by an isolated frog gastrocnemius muscle with the nerve of the muscle electrically stimulated. Their experiments demonstrated that the muscle's acoustic signal is produced by pressure waves which determine, in these experimental conditions, lateral movements of the muscle surface. A muscular twitch creates a change in pressure in the form of oscillations that increase and then decrease in amplitude and are proportional to the lateral acceleration of the muscle. These oscillations dominate large slower movements of the muscle surface, which result from asymmetries in muscle contraction and have low acceleration. Lateral accelerations of the muscle occur at the resonant frequency of the muscle which is related to the stiffness, mass, length and viscosity of the tissue. For isolated muscles, changes in muscle stiffness during the twitch may dominate the change in resonant frequency. During a tetanic muscle contraction, acoustic signal frequency increases and then stabilizes when the force plateau is reached. Meanwhile, the amplitude of the oscillations decreases progressively and becomes very small during the force plateau. Being dependent on the muscle stiffness, the amplitude of the acoustic pressure i) increases as a function of the isometric contraction force and ii) shows a relationship with muscle length which is similar to that between tension and length.

Nevertheless, the origin of the recorded vibrations may be more complicated for the muscle in situ. Indeed, the stiffness of the muscle also depends on the surrounding medium; that is, on the mechanical properties of the aponevroses, tendons and other contiguous muscles. Cross-talk between the vibrations arising from different muscles may also occur. The influence of cross-talk on MMG recordings cannot be neglected although it is generally believed to be very small (12,35,57).

In order to clarify the influence of the surrounding tissues on MMG signal, experiments have been made on humans where the nerves of hand muscles were electrically stimulated and EMG, MMG and external isometric force were simultaneously recorded. MMG amplitude was measured as peak-to-peak, root-mean-square (RMS) or integrated values (12,49,55). All these experiments indicate that the mechanism of sound generation is qualitatively the same for isolated and for in situ muscles activated by electric stimulation of the muscle's nerve.

2 - Origin of muscle sounds generated by voluntary contractions

The mechanism of muscle sound generation is less known in voluntary contraction than in electrically evoked contractions. Gordon and Holbourn (29) and Barry et al. (8) reported that muscle sounds may occasionally be associated with single motor unit (MU) activity. Petitjean et al. (47,48) demonstrated that every discharge of a MU creates an oscillation, a sound, which shape and amplitude probably depend on the orientation and location of the MU's muscle fibers within the muscle. Moreover, their data strongly suggest that, as for EMG, the oscillations produced by the diversely recruited MUs add up to give a compound signal. That both MU recruitment and firing frequency contribute to the determination of the MMG characteristics has been shown by Orizio et al. in cats (43) and man (38). Recently, Yoshitake and Moritani (60) provided data from the motor units of soleus and gastocnemius muscles that suggest i) a proportionality between the size of a MU and the amplitude of the corresponding MMG and ii) a relationship between MMG amplitude and muscle fiber type (slow/fast MUs). However, the law of summation of the oscillations from the vibrations of diverse MUs remains to be investigated.

III - Relationships between muscle vibrations and force in voluntary movements

The force which can be measured during a voluntary movement in humans is the result of the coordinated activity of several muscles. Thus, it is quite impossible to infer from this external force what is exerted by each activated muscle. This is one of the main reasons why electromyography has been developed since the beginning of the 20th century. Unfortunately, up to now EMG has provided only a means of accessing the changes in muscular excitation. The relationships between EMG and force depend on technical, histological and physiological factors that cannot be entirely known for a given individual. Therefore, a tool for measuring the force exerted by a single muscle in situ during voluntary movements remains to be elaborated. Many of the MMG studies have been devoted to achieving this goal.

1 - Relationships between MMG and isometric force.

As with EMG, there is no unique relationship between MMG amplitude (peak-to-peak or RMS value or integrated value) and external force during a static work. Most authors have described a continuous linear or curvilinear (quadratic) increase in MMG amplitude as force increases (8,35,40,50,52,56). However, for high force values, an increase in the variability of the signal amplitude has been described, and for this force range some authors (2,33,40,61) have found a decrease in MMG amplitude. Possible explanations of the increase in variability and/or of the decrease in MMG amplitude could be: i) an increase in physiological tremor; ii) that some MUs become tetanic and thus contribute poorly to the MMG signal; iii) that the relative participation of other muscles to the external torque is increased. A few experiments have dealt with isometric, anisotonic contractions. (18). In these conditions, MMG amplitude correlated with both the contraction force and the velocity of force increase. Relationships between MMG and isometric force have been also investigated in the frequency domain.

Some authors have found that the mean power frequency (MPF) of the EMG and MMG signals change in the same way: MPF may increase linearly (61) or quadratically (25) with force in quadriceps muscle, whereas in biceps brachii, as force increases until 30% MVC, the MPF increases but becomes constant for higher values of force (35). Conversely, Orizio et al. (41) described, for the same muscle, no change in MF until 20% MVC, then a slow increase up to 80% MVC and finally a steep increase beyond 80% MVC.

2 - Relationships between MMG and dynamic force

Like EMG, MMG reflects changes in force during submaximal dynamic contractions. A linear relationship between force and integrated MMG has been described (24,46,51). In the frequency domain, the MPF of the MMG signal may increase with force until a given force value and then decrease during concentric contractions, though it may remain constant during eccentric contractions (24). Conversely, data on isokinetic movements indicate a dissociation between EMG, MMG and force, when maximal torques are performed (27,53). It seems plausible that the increase in MMG amplitude with velocity could be due to a decrease in muscle stiffness, linked to a progressive unloading of slow motor units (27).

IV - Relationships between muscle vibrations and fatigue

In many fields (e.g. ergonomics, sports training, rehabilitation...) there is a need for a simple, precise and reliable tool for evaluating muscle fatigue. Electromyography alone is, so far, hardly able to reveal if a muscle becomes fatigued. In this context, Barry et al. paper (8) was particularly stimulating. Indeed, it was shown that during a maximal voluntary contraction, performed until exhaustion, the amplitude of biceps brachii muscle sounds decreases proportionally to force, while that of EMG remains approximately constant. These results suggested that by simultaneous recording of EMG and MMG, it was possible to access, within a single muscle, the dissociation of mechanical from electrical events, i.e. the loss in excitation-contraction which is the characteristic of muscle fatigue.

1 - Fatiguing maximal isometric contractions

Using experimental conditions close to those of Barry et al. (8), Petitjean et al. (46) extended the results of these authors to both biceps brachii and brachialis muscles. Moreover, they showed that while integrated PMG decreases with force, PMG-MPF shows no stable relationship with force. Orizio and Veicsteinas (42) found the same relationship between MMG amplitude and force for vastus lateralis muscle. However, their data on MMG in the frequency domain differ from Petitjean et al. results. Indeed, they reported a continuous decrease in MF over time. This discrepancy could be due to the difficulty of performing true MVC and/or to differences in the recording conditions, particularly amplifier bandwidth.

2 - Fatiguing submaximal isometric contractions

Changes in MMG during fatiguing isometric submaximal contractions of various muscles have been the matter of a number of studies from which it is rather difficult to obtain a precise idea of the usefulness of MMG to monitor muscle fatigue. In the time domain, most results suggest that MMG behaves as EMG during low levels of force, but not during high. In the frequency domain, results are also more or less contradictory. For example, studying 50% MVC isometric contractions, Maton et al. (unpublished data) found that PMG-MPF of biceps brachii muscle increased, decreased, or remained constant, whereas Orizio et al. (39) reported, for the same muscle, an increase followed by a decrease in spectral range for 60-80% MVC performed until the endurance time, and no change in MPF for lower force levels.

Finally, all available data agree with a link between MMG and MU firing rate and recruitment, since a great diversity in MU activity has been demonstrated by EMG studies on fatiguing isometric submaximal contractions (34).

3 - Muscle fatigue and evoked MMG

Taking into account that MMG evoked by electrical stimulation of the muscle nerve is proportional to force in the absence of fatigue, Barry et al. (4, 5) hypothesized that the same relation should be obtained in fatiguing muscle if MMG provides a measurement of muscle force. To test this hypothesis, they studied the AMG of isometric twitches from first interosseus dorsalis muscle of the hand evoked by ulnar electrical stimulation at different stages of a fatiguing voluntary isometric intermittent exercise. Their results (10) demonstrate that AMG amplitude was proportional to both the potentiation and reduction of force induced by the repetitive isometric fatiguing contractions. These experiments suggest that evoked AMG may be a better tool than AMG from voluntary contractions to assess muscle fatigue since this method eliminates the uncertainties as to motivation, tremor and relative contribution of the muscle to the external force.

V - Conclusion - Can muscle vibration recordings have practical applications ?

The mechanisms at the origin of MMG, although well understood for electrically evoked contractions of isolated muscles, are not fully known for in situ electrically evoked contractions and even less known for voluntary contractions. Fortunately, practical applications of a method or of a technique have often been made before having full understanding of all the parameters and mechanisms which intervene. This is currently true for EMG, and hopefully will be true for MMG. Some research has been conducted in this way.

In the sports domain for example, Cerquiglini et al. (19) showed differences in MMG frequencies as a function of athletic fitness in weightlifters. Orizio and Veicsteinas (42) described differences in amplitude and power spectra of MMG between sprinters, long distance runners and sedentary subjects. Nemchenko and Kushnienko (36) have demonstrated changes in PMG spectrum following vibrostimulation of different.

In the medical field, pioneering authors (13,14,15) were still essentially motivated by the idea of having a simple diagnostic tool. Until now, however, quantified clinical MMG data remain rare, and some authors have pooled different pathologies into a single group, thus hiding the interest of the results. Nevertheless, Hufschmidt et al. (32), for example, studied patients with peripheral nerve or root lesions. PMG amplitude from muscle tibialis anterior, stimulated at the motor point, was decreased when compared to contralateral unaffected muscles. Barry et al. (9) showed clear differences in the ratio of PMG-RMS to EMG-RMS between a group of children with neuromuscular diseases and a group of healthy volunteers. From these, he suggested that this ratio may provide significant diagnostic information. Barry et al. (11) even proposed using the muscle acoustic signal as a control signal for an electrical powered prosthesis but, to our knowledge, their suggestion has not been followed.

From these examples, it is clear that in their present state the available data, although promising, are far from being precise enough to bring significant diagnostic elements and/or to allow a precise follow-up of patients or of sports training. Nonetheless, muscle sounds should no longer be considered as a gadget but as a well-defined open field of research.

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S-05

MOTOR CONTROL AND SENSORY SYSTEM

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The precise nature of central nervous system disorder in involuntary movements is not fully understood. There are many kinds of involuntary movements. In this session, I concentrate several interesting clinical phenomena, which suggest the sensory inputs have the important role on motor execution, in a) alleviation of the increased excitability of sensory in the cortex making better in motor execution, b) the effect of one side motor control on the another side in blepharospasm and c)sensory cue and motor execution.

In dystonia, as far as the motor system is concerned, the primary abnormality is thought to be located in the basal ganglia which controls movement through the cortico-striato-thalamocortical circuit. But the many clinical and physiological findings documenting the effect of sensory inputs that the sensory system might paticipate in pathophysiology of the motor disorders.

A)ALLEVIATION OF THE INCREASED EXCITABILITY OF SENSORY CORTEX MAKING BETTER MOTOR EXECUTION

By somatosensory evoked potential (SEP) recording, abnormal results are reported in cervical dystonia, especially in tonic type of cervical dystonia. Although several studies show controversial results by using the SEP analysis of upper extremities, it is noted that patients in those studies have the cervical neck involvement without upper limb involvement.

In our studies of SEP, the accessory nerve is stimulated. Patients with cervical dystonia with tonic type are the subject in this study. The accessory nerve to the sternocleidomastoideus muscle is stimulated with skin anesthesia by the repetitive magnetic stimulation method and the evoked potentials are recorded from C_3 and C_4 of the scalp. The marked high amplitude potentials are recorded from the contralateral cortex. This high amplitude potentials are decreased by the nerve block using the lidocaine injection, and the cervical dystonia is decreased markedly clinically and electrophysiologically . The nerve block to the accessory nerve was supposed to be the effect of only motor nerve. In previous study, SEP from the patients with cervical dystonia is studied by stimulation over the upper extremities, we recorded SEP by stimulation of nech accessory nerve, which might have the proprioceptive afferent input.

And we suppose such an afferent input is reduced by the nerve block of accessory nerve. These observation could support that the inefficient sensory processing contribute to the motor impairment present in cervical dystonia.

B)THE EFFECT OF ONE SIDE MOTOR CONTROL ON ANOTHER SIDE IN BLEPHAROSPASM

In the treatment of blepharospasm, the significant reduction in EMG parameters of the treated orbicularis oculi muscles is observed after the injection of botulinum toxin or lidocaine. When we treat just one side of orbicularis oculi muscle by injection of lidocaine, we observe the blepharospasm decrease for short time bilaterally. Then we inject the phenol to the one side of nerve to the orbicularis oculi muscle, we can observe the decreased blepharospasm bilaterally with long duration. Nextly we inject the botulinum toxin (BTX) to the just one side of orbicularis oculi muscle, we can observe the same phenomena, which is decrease in the bilateral abnormal muscle discharges.

The proprioceptive afferent is not clear in orbicularis oculi muscle. But we suspect that the BTX effect is not only on the motor effect but also the effect on the intrafusal muscles. The intrafusal muscle like other muscles can be involved by BTX and the proprioceptive input to the the central motor program would work the regulation down in non-injected muscle activities.

C)SENSORY CUE AND MOTOR EXECUTION

The basal ganglia and supplementary motor area circuit (medial motor system) mainly controls self-initiated movements, whearas the cerebellum and premotor cortex circuit (lateral motor system) preferentially mediates externally triggered movements. The patients with Parkinson disease (PD) and dystonia, who are modulated by the basal ganglia and supplementally motor area circuit, are more impaired the self-initiated movements than external cueing movements. Normal subjects prerform self-initiated movement sequences faster than externally triggered movement sequences. We ask the patients with PD to use the handy auditory cue apparatus and analyze the parameter of gait and other movements. By using this handy apparatus, they can walk more rapid and regularly and they can do better by external cue than by their internal cue. This is practical apparatus and can be used for training apparatus.

As we mentioned above, the sensory inputs have the important role in movement execution. Although the involvement of the basal ganglia is supposed to be the problem of motor system, the sensory system also participate in its pathophysiology and is related to its treatment.

S-06

Effect of Electrical Stimulation on Impaired Human Function

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1:Introduction

Electrical stimulation for medical treatment has been widely used from two thousand years ago. In Rome period, electrical fishes were used to relief pain such as headache, gout and hemorrhoid. After development of electrical stimulation devices in 18th century, electrotherapy has been applied to medical treatment in various kinds of fields.

Fig. 1 electrical pain relief in Rome period

For therapeutic purpose, electrical stimulation has been applied to not only pain relief but also epilepsy, angina pectoris, bronchial asthma, urine incontinence, motor disorders due to upper motor neuron disorders etc (therapeutic electrical stimulation:TES) Restoration of impaired motor and/or sensory function by well programmed electrical stimulation is called functional electrical stimulation (FES), of which examples are a cardiac pacing, a respiratory pacing, extremity FES, cochlea stimulation and so on. It has been expected that FES and TES are a powerful means to assist or improve the patient's activities of daily living and provide them with higher quality of life.

This paper introduces and discusses application of TES and FES including our research works.

2:TES

TES applied to the peripheral motor neurons has two effects, i. e., efferent and

afferent effects. The efferent effects were elicited by stimulation of efferent fibers of the nerve supplying the effectors. Stimulation of an efferent component in a muscle branch of the nerve causes muscle contraction, and thus, resulting in morphological and physiological changes of the muscle itself such as increases in volume and contractile force of the muscle through long-term efferent fiber stimulation. Contractile properties of the muscle also changes. For example, low frequency stimulation around 20Hz causes transformation of muscle type from Type II (fatigable fast twitch muscle) to Type 1 (fatigue resistant slow twitch muscle). Effects induced by muscle contraction were also observed through efferent fiber stimulation. Peripheral circulation is markedly improved by a pumping effect of the muscle. Joint contracture is prevented through active joint movement.

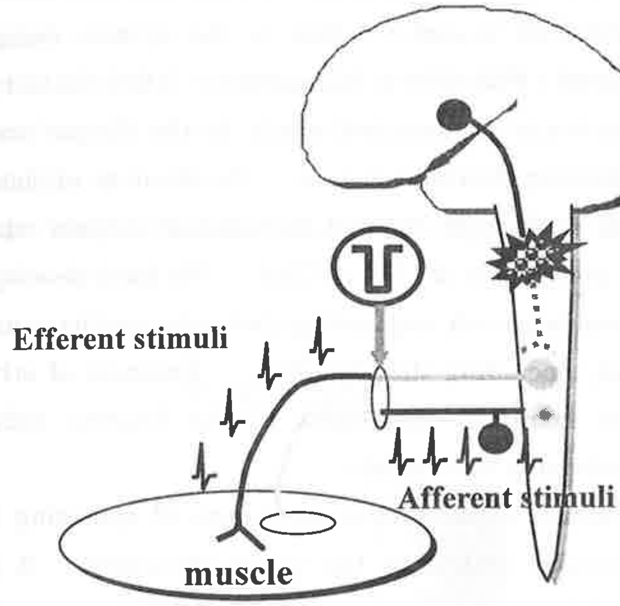


Fig.2 Efferent and afferent nerve stimulation

Afferent volleys induced by afferent nerve stimulation go up to the neuronal circuits in CNS and show therapeutic neuromoduratory effects on these neuronal circuits in either the somatic or autonomic nervous systems.. These afferent effects were usually observed very quickly even immediately after initiation of stimulation. For example, electrical stimulation applied to sever spasticity of the lower extremities in stroke, spinal cord injury or spinal spastic paraplegia, a progressive disease, reduces spasticity and improves volitional walking movement. Such afferent effects are always accompanied by carry over phenomenon. Although duration of carry over induced by initial TES application to the somatic nervous system is usually within an hour, TES to the autonomic nervous system shows long lasting carry over from 24 hours to 7 days from the first. Ventral root stimulation from S2 to S4 which include parasympathetic neurons for 10 min in a day improves urgent urine incontinence for at least 24 hours. Duration of carry over is usually prolonged by accumulation of daily TES training. Plastic changes may occur in the neuronal circuit in CNS through long-term TES.

3:FES

3-1. Upper extremity FES

Many trials have been done for restoring motor function of the paralyzed extremities. In the upper extremities, FES of the paralyzed forearm muscles can provide prehension and release in the hand. Two kinds of electrode systems are used in the hand control FES system. One is the system using surface electrode. Nathan et al. developed a FES system (Handmaster, NESS Co.Ltd, Israel) with surface electrode array which can be attached easily to the thenar and forearm muscles. Another is the implanting electrode system. Peckham et al. has developed a totally implant FES system with eight channel stimulating outputs which is commercially available under the permission of FDA in USA. We have developed a thirty channel FES system with percutaneously implanting electrodes and have used for the control of total upper extremity including the shoulder. Creation of stimulation data from EMG during upper extremity movement in the healthy subjects provides well coordinated upper extremity movements.

Such FES systems require adequate means of operating the system (control commands) for volitional control of the upper extremity A position transducer attached to the shoulder, switch buttons, a wrist watch type controller and an EMG controller have been utilized. When one of an antagonistic pair is paralyzed but another muscle is active, sustained (bias) stimulation to the paralyzed muscle provides volitional reciprocating joint movement by adjusting contractile force of its antagonistic muscle without giving any control commands. In C6 quadriplegia, the patient can abduct the shoulder but not adduct, flex the elbow but not extend, and supinate the forearm but not pronate. Fig. 3 shows bias FES applied to the paralyzed pronator quadratus to achieve volitional rotational movement of the forearm.

3-2

Standing up motion by FES in paraplegia has been utilized practically to activities of daily living. Canes attached to a wheel chair enabled the paraplegic to stand at the place where the wheel chair stopped (Fig 3-b).

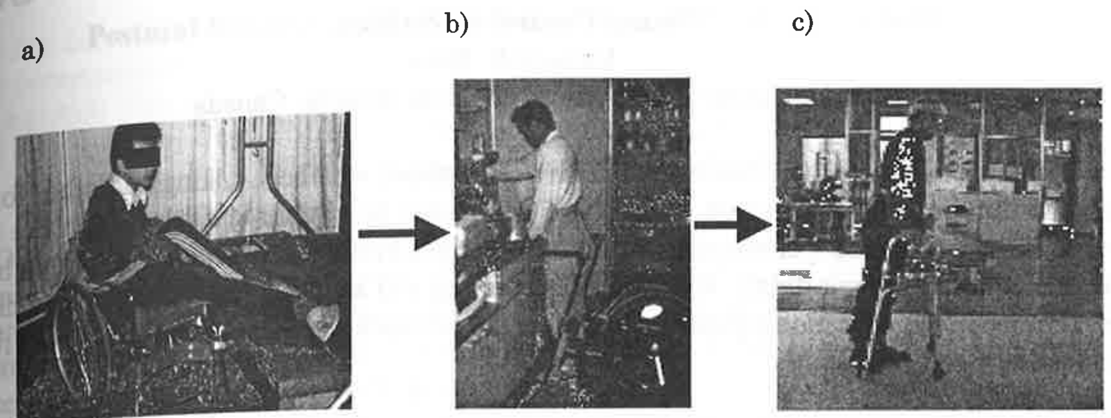
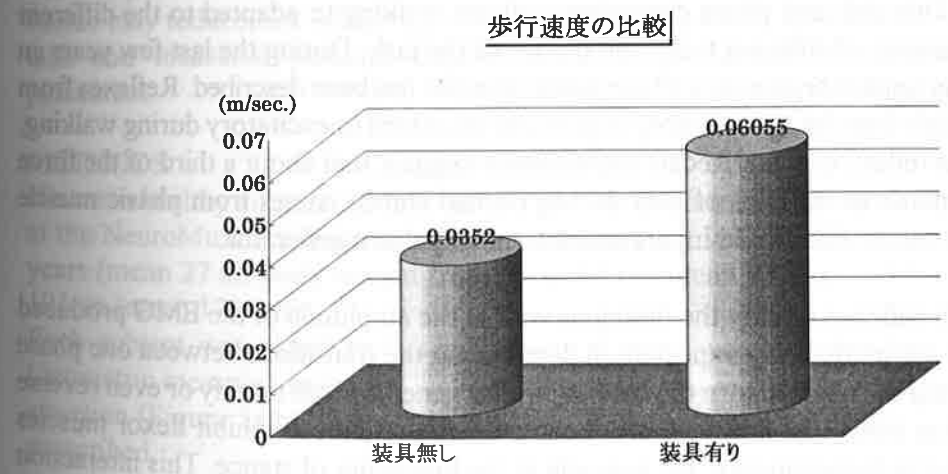


Fig. 3 FES controlled standing and walking in the paraplegics

We have controlled walking in the paraplegic by FES without using any orthosis (Fig.3-c). However, it has been pointed out that FES in combination with a orthosis (hybrid FES) provides the patient with much easier, safer and more reliable gait control with lesser fatigue and energy consumption. As shown in Fig. 4, walking speed in hybrid FES with a hip orthosis was almost twice as compared with the walking speed in FES walking without an orthosis.



a) without orthosis b) with hip orthosis

Fig.4 Comparizon of walking speed in FES with and without orthosis

S-07

Neural Control of Walking

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Over the past century there has been a controversy about whether walking and other forms of locomotion (running, swimming, flying) are controlled by circuits entirely within the central nervous system (central pattern generators) or by series of reflexes. In recent years it has become clear that both are importantly involved in generating and adapting the locomotion to different conditions. In this educational paper I will review the evidence and the interaction between reflexes and pattern generators.

The best understood example of a pattern generator for walking in a vertebrate is the swimming generator in the lamprey, but similar mechanisms have been described in a variety of other species. In mammals the evidence for a central pattern generator is less direct, but comes from experiments in the spinal animal which has also been deafferented or paralysed to remove phasic sensory input. Since EMG can not be recorded in the paralysed animal evidence comes from recording the motor nerves which continue to be rhythmically active. Recently, evidence has become stronger for the present of similar pattern generators in paraplegic humans.

Reflexes from muscle receptors contribute to and modify the centrally generated rhythm. Stretch and H-reflexes may be present in one phase of walking, such as the stance phase and absent or greatly reduced in the swing phase. The reflexes are often different in a task, such as standing than during walking and are different again during running, even when compared at the same level of EMG in the muscle. This task and phase dependence allows walking to adapted to the different biomechanical requirements of different tasks and phases of the task. During the last few years an important role of Golgi tendon organs as well as muscle spindles has been described. Reflexes from tendon organs can switch from being inhibitory in postural situations to excitatory during walking, a phenomen known as reflex reversal. Recent experiments suggest that about a third of the force produced in the triceps surae muscles of cats during normal stance comes from phasic muscle reflexes. The balance comes from tonic inputs and the spinal pattern generator.

Cutaneous and muscle reflexes modify the timing as well as the amplitude of the EMG produced during walking. They are particularly important in determining the transitions between one phase of the stepping cycle and the next. In turn the central pattern generator can modify or even reverse the reflexes. Cutaneous input that normally produces a flexion reflex can inhibit flexor muscles when excitation would be inappropriate, for example at the beginning of stance. This interaction between spinal pattern generators and adaptive reflex control is presumably required to produce the graceful, efficient movements over a variety of terrains that animals typically produce.

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S-08

Postural Responses during Manual Material Handling (MMH)

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INTRODUCTION

Falls are a common source of morbidity, impairment and even death in the working population as well as in the elderly. Such incidences constitute a serious public health problem and are associated with high health care costs[1]. As a fall is associated with loss of balance, any perturbation to upright posture may result in a fall; i.e. dramatic change of supporting surface such as slipping[2] as well as small internal perturbation associated with voluntary motion[3].
MMH tasks impose such internal perturbation to body balance amplified by transferred load[4]. An internal perturbation causes postural responses in preparation as well as during the task[5]. The postural system developed several strategies to resist such perturbations to maintain balance. Anticipatory activity in postural muscles prepares for expected perturbation before the onset of voluntary (focal) movement)[6]. Ankle strategy is used for small perturbation to maintain balance[7]. If torque produced by the ankle strategy are ineffective in increased amplitude of sway, a hip strategy is adopted[7]. Change in support strategies, such as stepping or grasping a handle are not strategies of last resort, but are often initiated well before the COM is near the stability limits of the base of support[8].
In a sagittal symmetrical MMH task, most prominent perturbation can be expected in the anterior/posterior direction[9]. Increase of stability in the anterior/posterior direction by step stance may reduce risk of falling[8]. We simulated magnitude of postural perturbation by MMH task and measured postural control strategies to reduce perturbation in different foot placement.

METHODS

Nineteen healthy subjects (5 female/14 male) with normal physical findings were investigated at the NeuroMuscular Research Center at Boston University. Their age ranged from 20 to 45 years (mean 27 a); body weight from 51 to 93 kg (mean 71 kg); and body height from 164 to 191cm (mean 179 cm).
Each subject was asked to lift and lower a load (weight = 4.6 kg) 10 times per minute (geometric measures in Figure 1). Foot placement was varied between parallel and step stance situation (Figure 5a,b). Lifting posture was unrestricted and no specific lifting technique was prescribed.

The simulation model consists of a non responding body mass, perturbed by active box lifting with two arm segments[10] (Figure 1a). The motion of the box was simplified to a combined vertical and horizontal displacement (with time lag) following the pattern $d = t - \sin(t)$. Perturbation was calculated as COP excursion at the body mass column (Figure 2a).
COP was measured by a force plate (Kistler). Motion was recorded by a position and orientation measurement system based on switched magnetic fields (Motion Star, Ascension Technology Corporation). Receiver position was at pelvis (sacrum) and at the trunk (C7 level). Timing of box contacts was measured by switches at desk and shelf rest area.

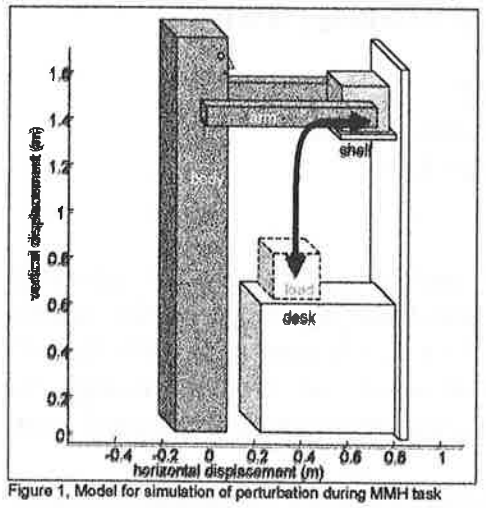

Figure 1, Model for simulation of perturbation during MMH task

RESULTS

The simulation of COP excursion exhibits four anterior peaks in COP excursion (Figure 2a). Range of perturbation is higher during transition phases than in rest phases. There is no lateral COP excursion in the sagittal symmetrical simulation (Figure 2 b).

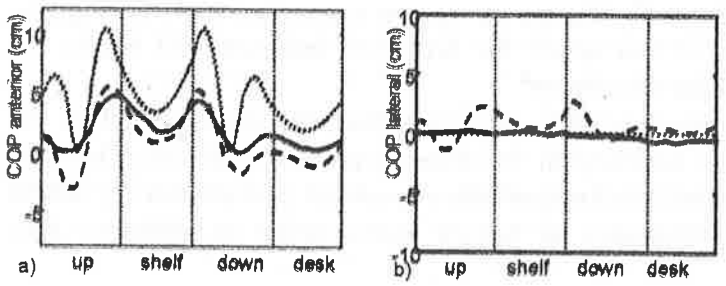

Figure 2, COP excursion in simulation (dot), step stance (dash), parallel stance (solid)

In measured COP excursion the anterior component shows similar pattern to simulation in both, parallel and step stance condition (c_{par}= 0.75, c_{step}=0.82, Figure 2 a). However, range of perturbation is significantly reduced in parallel stance during transition phases. The lateral component of COP is small in parallel stance, however, there are well developed lateral pattern detectable in step stance, correlated with anterior component (Figure 2 b).

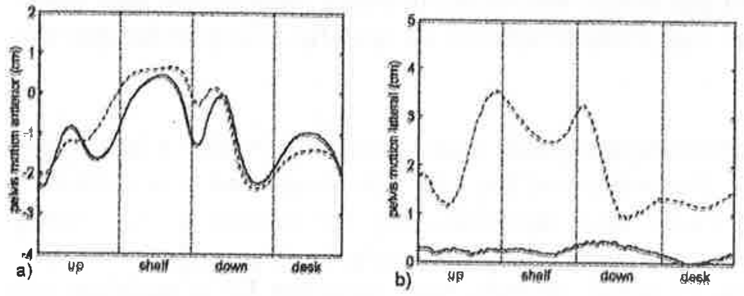

Figure 3, pelvis motion in step stance (dash), parallel stance (solid)

Range of anterior pelvis motion is comparable in both conditions, however, in parallel stance condition, there is more dynamic motion in transition phases, than in step stance condition

(Figure 3a). In parallel stance there is a posterior component in transition up and a marked anterior component in transition down. This corresponds to a spectral component at 4 times cycle frequency. This spectral component is reduced in step stance condition with increase of spectral component at cycle frequency. The lateral component of pelvis motion is small in parallel stance, and large in step stance, correlated with lateral COP (Figure 3b).

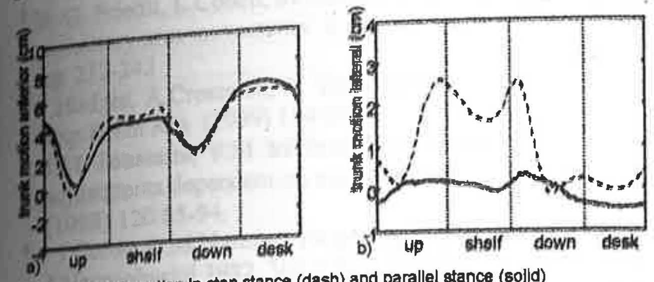

Figure 4, trunk motion in step stance (dash) and parallel stance (solid)

Range and pattern of anterior trunk motion shows no difference between stance conditions (Figure 4a). However, there are differences in correlation with anterior component of pelvis motion. In parallel stance, there is negative correlation during transition phases and positive correlation in rest phases. In step stance condition the are no significant correlation between trunk and pelvis motion, except for the desk rest phase. The lateral component of trunk motion is small in parallel stance, and large in step stance, correlated with lateral COP (Figure 4b).

DISCUSSION

The simulation predicts anterior perturbation after each lift-off and before each contact event, more pronounced at shelf than at desk level. In parallel stance the range of predicted COP excursion is reduced by sagittal hip strategy in transition phases. In rest phases anticipatory adjustments are performed in sagittal ankle strategy. In step stance pattern and range of anterior COP excursion is not reduced as compared to simulation with stiff posture. However, there are lateral weight shifting, interlocked in COP excursion, pelvis and trunk motion indicative for frontal ankle strategy.

Transition between ankle, hip and stepping strategies in response to anterioposterior perturbation, depend on "Movement strategy boundaries", that can be defined in terms of the displacement of the center of mass (COM) relative to the base of support[11] (Figure 5). This is true for well practiced trials with instruction not to step only, which was the case in our setup[8]. These boundaries are investigated for sudden perturbations to the base of support acting on subjects in silent stance. Under static conditions, mean COM corresponds to mean COP excursion. During dynamic activity COP is a better predictor of stability boundaries than COM, as COM accounts for quasi-static moments, only.

In parallel stance the amount of anterior perturbation approaches the limits of stability for ankle strategy. To reduce COP excursion during maximal perturbation, hip strategy is used in transition phases. A free motion of the pelvis is essential to adopt adequate postural response in lifting. This corresponds to some extend to NIOSH Work Practice Guide for Manual Lifting: 3. Lifting posture should be unrestricted, with no bracing of the torso. However, recommendation should not only be refined for bracing but also against restrictions in spatial motion of the pelvis.

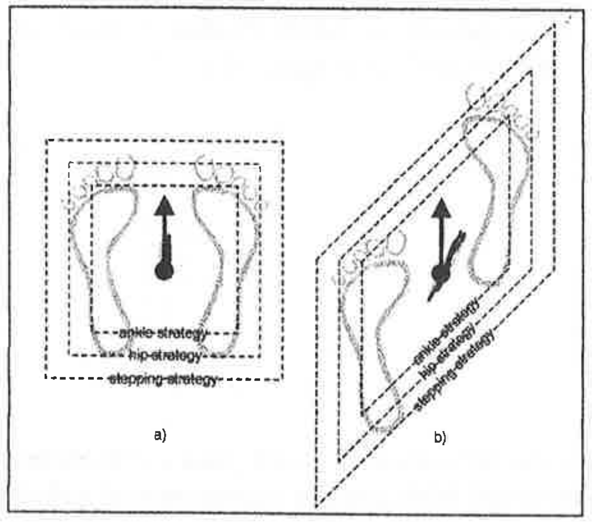

Figure 5, boundaries for postural strategies

In step stance, limits of stability are near in the left-anterior direction (Figure 5b). The supporting area is a parallelogram with maximum range of support from left-posterior to right-anterior. Thus postural responses are interlocked to lateral shift of weight to rotate COP excursion in the direction of largest range of supporting surface.

In level walking a step stance situation is maintained during double support phase. In the double support phase, weight bearing is transferred from the leg positioned posterior to the leg positioned anterior. Because, there is finite lateral separation between the lower limbs, the body rocks laterally to the weight bearing side[12]. Anterior displacement of body mass is accompanied by lateral components. Walking function is achieved by cyclic internal perturbations and corresponding permanent postural responses to keep balance. This well developed pattern also arise during perturbation derived from cyclic upper limb motion when performed with feet in step stance. The lateral acceleration of the trunk causes lateral components in GRF and may thus lead to lateral slips.

CONCLUSION

Feet position change postural responses in MMH tasks. In parallel placement sagittal hip and ankle strategies are adopted in transition and rest phases, respectively. In step stance sagittal strategies are replaced by lateral ankle strategy. The later may cause lateral slips and falls.

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S-09

Beyond Myoelectric Control: The Neuroprosthetic Arm

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INTRODUCTION

The goal of this project is to neurally interface an artificial arm to nerve stumps. For phase one of this study, Longitudinal Intrafascicular Electrodes (LIFEs) were implanted in the proximal nerve stumps of chronic (>2 months) upper and lower limb amputees undergoing elective stump surgery. Electrodes were exteriorized percutaneously. Nerve function was evaluated for two consecutive days after the patient had recovered from the anesthetic, by recording volitional motor nerve activity and by measuring sensations elicited by electrical stimulation of afferent nerve fibers.

METHODS

Electrodes were individually implanted approximately one inch proximal to the end of the nerve stump. A 1mm recording/stimulating zone was centered over the 1 cm implant region in a given nerve fascicle. Tail ends of the electrodes were exteriorized percutaneously. After the completion of motor control and sensory studies, the electrodes were explanted by applying gentle longitudinal traction along the long axis of the nerve.

Recording of efferent signals: Motor nerve fiber signals were amplified (100,000X), filtered (300-3000 Hz bandpass), relayed to an IBM compatible laptop computer and a loudspeaker. The subject was directed to attempt to make movements related to the missing limb muscles while listening to nerve activity. His task was to select a movement that provided the most audible nerve signals. The subject was then asked to control the position of a cursor on the monitor and strike a randomly appearing stationary target by modulating the activity recorded by a given electrode. To succeed in this task, the subject had to position and to maintain the cursor in the target for at least 0.5 seconds within a 6-10 second time period. Simply hitting the target, no matter on how many occasions was not enough.

Sensory feedback: Implanted electrodes were stimulated separately by electrical currents to identify the sensory channels. Stimulation parameters (pulse amplitude and pulse widths) for threshold and the upper limit (when the sensation became uncomfortable or changed in character or location) for a given sensation were identified. A pulse amplitude-pulse duration pair from the central part of this region was selected and 500 ms duration train of pulses (in the frequency range 10-500Hz, logarithmically distributed) were used for nerve stimulation in a pseudo-random order to explore the relationship between intensity of elicited sensation and nerve stimulation frequency.

RESULTS

Recording of efferent signals: Figure 1 shows results from two different trials in which a subject tried to place and hold the cursor in a target area. The top panel is an example of a failure: even though the subject hit the target several times, none of the hits lasted over 0.5 seconds. The bottom panel is an example of a success: the final hit lasted 0.6 seconds. The distance to the target did not affect the time needed to succeed in the task (Fig. 2).

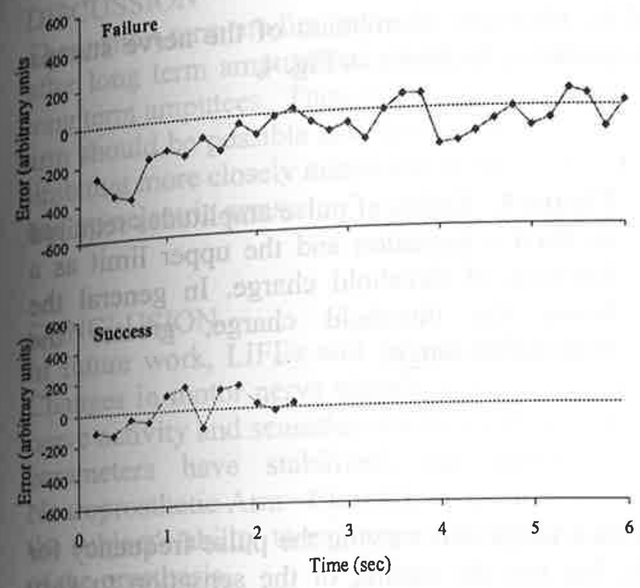

Figure 1. Cursor position relative to target location as a function of time.

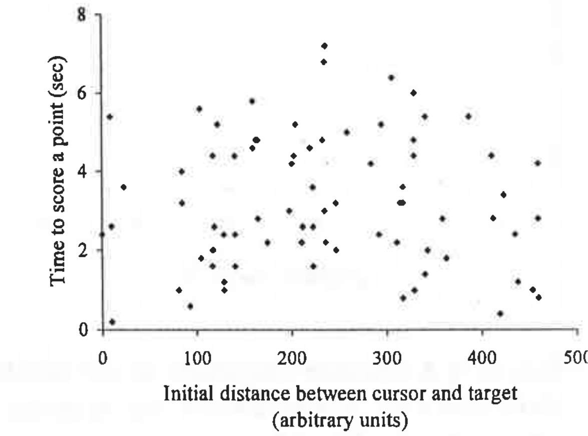

Figure 2. Time to successfully hit and hold a target as a function of the initial separation of the target and the cursor.

In contrast to the lack of an effect of distance to the target on the time to hit and hold a target, the precision with which the subjects could position the cursor did depend on time (Fig. 3).

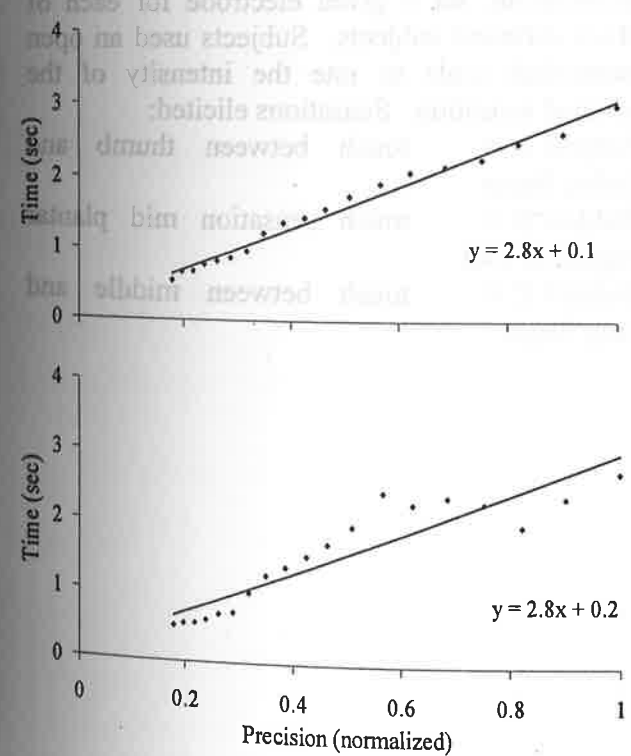

Figure 3. Amount of time subjects took to achieve a given precision (for a duration of at least 0.5 seconds), for the first and the last set of trials.

Sensory feedback:
Discrete, distally referred sensations evoked by electrical stimulation of the nerve stumps tended to be stable over a range of stimulus amplitudes, as shown in Fig. 4.

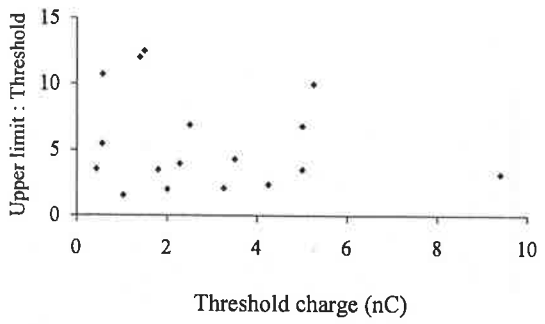

Figure 4. Ratios of pulse amplitudes required to elicit a sensation and the upper limit as a function of threshold charge. In general the lower the threshold charge, greater the stimulation range.

Selecting a stimulus amplitude in the middle of a range and varying the pulse frequency for short trains of pulses caused the magnitude, but not the nature, of the sensation to vary systematically (Fig. 5).

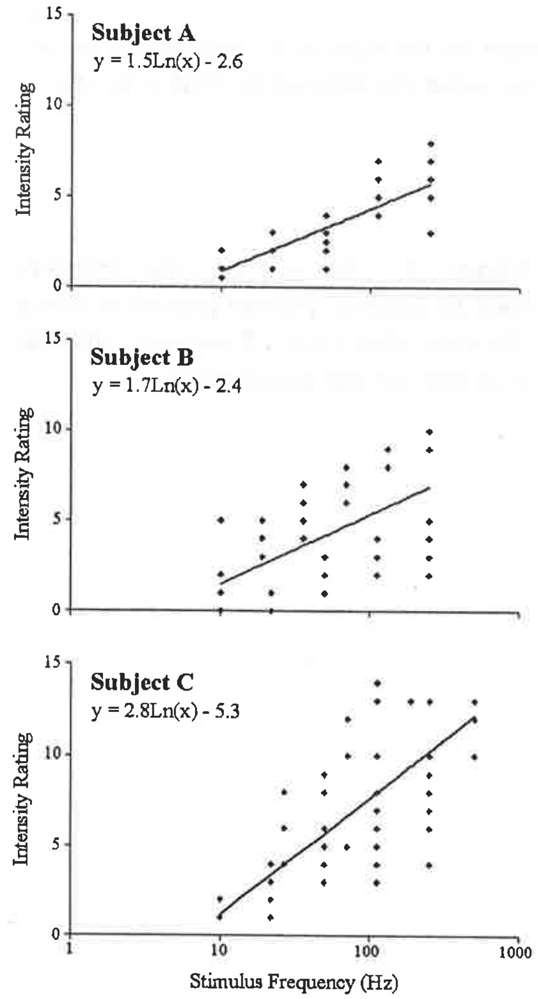

Figure 5. Intensity of an elicited sensation and its variation with frequency of nerve stimulation, for a given electrode for each of three different subjects. Subjects used an open numerical scale to rate the intensity of the elicited sensation. Sensations elicited:
Subject A = touch between thumb and index finger
Subject B = touch sensation mid plantar region of foot
Subject C = touch between middle and ring finger

DISCUSSION
These short term studies show that control of activity in severed motor axons is still possible after long term amputation. Similarly, sensory pathways in transected nerves are intact in long term amputees. Thus, real time sensory feedback and motor control of a neuroprosthetic arm should be possible and should allow the amputee to execute movements of a prosthetic limb that more closely mimic the normal limb, as compared to the control with body powered and myoelectric arms.

CONCLUSION
In future work, LIFEs will be implanted in nerve stumps for a period of up to 6 months. Changes in motor nerve signals, signal to noise ratios, subject's ability to modulate efferent nerve activity and sensation elicited with electrical stimulation will be evaluated. Once these parameters have stabilized, the subject will be asked to control a teleoperated Neuroprosthetic Arm. Closed loop control will evaluate the efficacy of sensory feedback and the subject's ability to execute coordinated limb movements related to intended real life use of the prosthesis.

Symposium

S-10

Snapshot Assessment of Fatigue during Long-Term Repetitive Exercise

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INTRODUCTION

A strategy is needed to fully assess fatigue or degeneration of functional activities during long-term repetitive physical exercise. We have proposed snapshot assessment of fatigue that should be done at any time and any location. We identified three types of variations: the periodic changes between exercise and rest, temporal changes as a function of time, and global changes as a function of the number of trials. To monitor the progression of fatigue under such conditions, it would be effective for developing snapshot assessment of fatigue before and after each trial.

We have studied physical fatigue during sustained and dynamic contractions [1] - [4]. Based on our results, we have proposed an experimental system and several new approaches for snapshot assessment of fatigue. A radio-controlled remote data acquisition system and the Internet were key techniques for measurement. On the other hand, for evaluation, we used the correlation coefficients and the ratios of evaluation parameters. The fuzzy inference was finally introduced for compensating the estimates for individual persons. We are focusing on the interaction between autonomic nervous activity and muscular fatigue [4]. In this paper, we showed examples of our methods, demonstrating applications for repetitive fatiguing exercise such as treadmill exercise [2], cycle ergometer exercise [3], and skiing exercise [4].

METHODS

We simultaneously monitored the ECG and myoelectric (ME) signals during exercise and the ECG during resting phases. Working with the vastus lateralis or tibialis anterior muscles of the individual working lower limb, we obtained three channels of bipolar surface myoelectric (ME) signals using an active 4-bar electrode pasted on the skin parallel to the muscle fibers. We selected an ME signal that was relatively less contaminated by artifact noise and innervation zones [5]. This procedure is a strong reason to use the active 4-bar electrode during dynamic contractions. ECG was measured on the chest by using disposable disk electrodes.

The radio-controlled remote data acquisition system ensures that no biosignal data is missed, even in a large area and full of ups and downs, as can occur with a telemetry system. Moreover, the measuring of the biosignals could be monitored after establishing a connection between PCs.

Regarding muscular fatigue, it is accepted that the frequency component of surface ME signals moves towards lower frequencies because of muscular fatigue. A decrease in the frequency components even during cyclic movement has been identified based on the time-frequency representation. Nonetheless, it is usually difficult to recognize peripheral physical fatigue from surface ME signals during dynamic movement. For ME parameters, we practically evaluated the conventional amplitude and frequency indices from surface ME signals: that is, the average rectified value (ARV) and the mean power frequency (MPF). We have proposed two types of muscular fatigue indices. One is the utilization of superimposed M waves during sustained contractions after each exercise [1], [2]. The feature of superimposed M wave is compared with the preceding background activity, in the frequency components, by a correlation coefficient: a correlation coefficient between the instantaneous frequency (IF) of the superimposed M wave and the MPF of the preceding background activity, ρ_{MPF-IF} [1]. The other is a correlation coefficient between ARV and MPF, $\gamma_{ARV-MPF}$, during exercise [4]. In practice, ρ_{MPF-IF} and $\gamma_{ARV-MPF}$ are estimated at appropriate short segments to identify the degree of muscular fatigue based on the time-varying behavior of ρ_{MPF-IF} and $\gamma_{ARV-MPF}$.

RESULTS

A. Treadmill Exercise [2]

Two healthy male subjects (22 yrs) executed running on the treadmill for three consecutive days. The running speed was 7.5 km/h and the incline was 0, 4.5, and 9.0 degrees on each separate day. We measured 5-min of ME signals and ECG at 30 %MVC before and after exercise. **Figure 1** indicates the MPF-IF patterns. In basic results at several contraction levels, the subject showed a high ρ_{MPF-IF} at the beginning of 70 %MVC and then became uncorrelated as muscle fatigue progressed (Fig. 1(a)). The results for field experiments were showed in Fig. 1(b). A MPF-IF scatter graph (MPF-IF pattern) before exercise on the first day showed the same as that of the low level contractions. However, it showed a sign of muscle fatigue like that at the high level contractions on the third day. The fuzzy inference will be effective to determine a final estimate of the degree of muscular fatigue by ρ_{MPF-IF} and ME parameters [1].

B. Cycle Ergometer Exercise [3]

Figure 2 shows a typical result of a 62-year-old man during cycle ergometer exercise. The workload ranged from 0 to 200 watts for the exercise at progressively increasing workload. The heart rate (HR) steady increased up to 170 bpm. The ME parameters initially fluctuated, then demonstrated the features of muscular fatigue: increase in the ARV, decrease in MPF, and the negative correlation between ARV and MPF. The $\gamma_{ARV-MPF}$ showed a negative correlation after 100 watt. Note that we did not obtain sufficient results in $\gamma_{ARV-MPF}$ by disk type disposable surface electrode. The anaerobic threshold (AT) and the lactate threshold (LT) were about 80 watt and 105 watt, respectively. Besides, the HRs were 105 and 113 bpm, respectively. Based on the results, we designed the fuzzy inference to determine the changing ratio of the workload at each time. That is, we controlled the workload based on the time-varying behavior of HR and muscular activities. The result showed that the workload increased up to 100 watt, then decreased gradually after 150 interval point due to a negative $\gamma_{ARV-MPF}$. At the same time, the HR did not show a significant variations and stayed about 120 bpm. Comparing to the LT during the exercise at progressively increasing workload, the exercise at controlled workload was maintained at a little bit lower the LT, that is around the AT, but the HR was higher than that at the LT.

DISCUSSION

In the basic experiments, the MPF and IF were uncorrelated or sometimes negative correlation at the 30 %MVC. Even the 30 %MVC, the MPF-IF pattern showed the features at high level sustained contractions. The change in the MPF-IF pattern (Fig. 1(b)) probably showed accumulated muscle fatigue. Therefore, the MPF-IF pattern will be effective for assessing muscle fatigue before and after exercise, even though it needs electrical stimulation. On the other hand, negative correlation in $\gamma_{ARV-MPF}$ was most likely a sign of muscular fatigue during exercise (Fig. 2).

We have already introduced Fuzzy inference to determine the final estimates of muscle fatigue index from the MPF-IF pattern [1]. Moreover, we used fuzzy inference to control the changing ratio of the workload from HR and $\gamma_{ARV-MPF}$. In controlling the cycling speed for subjects with paraplegia, fuzzy logic was employed recently. However, they did not handle biosignals. We showed the effectiveness of fuzzy inference for compensating the final estimates for individual persons.

CONCLUSIONS

For evaluating physical fatigue during long-term repetitive exercise from limited amount of time, we proposed snapshot assessment as a practical idea. To accomplish snapshot assessment, therefore, we developed a remote data acquisition system, then, we analyzed multivariable biosignals to find out practical fatigue indices. The correlation coefficient between the instantaneous frequency of the superimposed M wave and the MPF of the preceding background activity, ρ_{MPF-IF}, was useful for evaluating accumulated muscle fatigue. On the other hand, the correlation coefficient between ARV and MPF, $\gamma_{ARV-MPF}$, was effective for demonstrating muscular fatigue during exercise.

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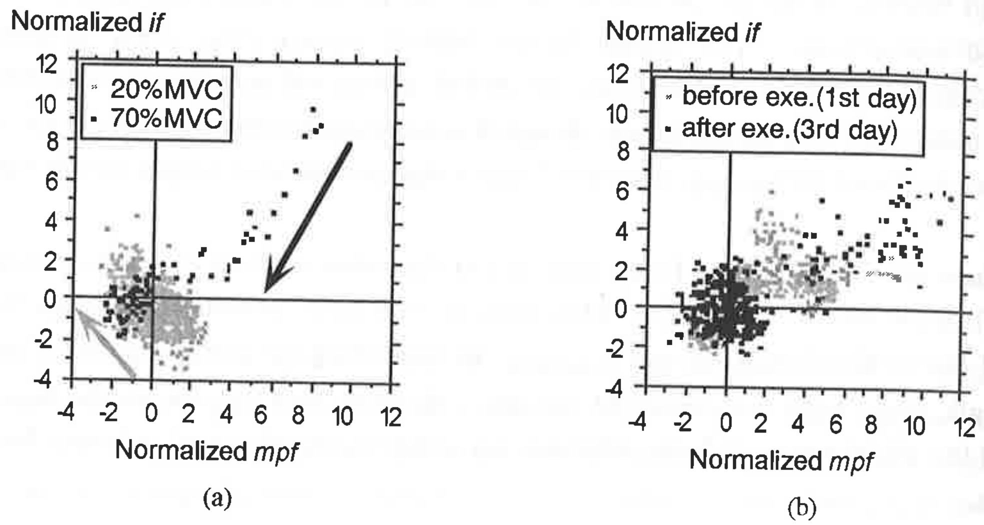

Fig. 1. MPF-IF pattern: (a) 30 %MVC and 70 %MVC; (b) 30 %MVC before and after treadmill exercise.

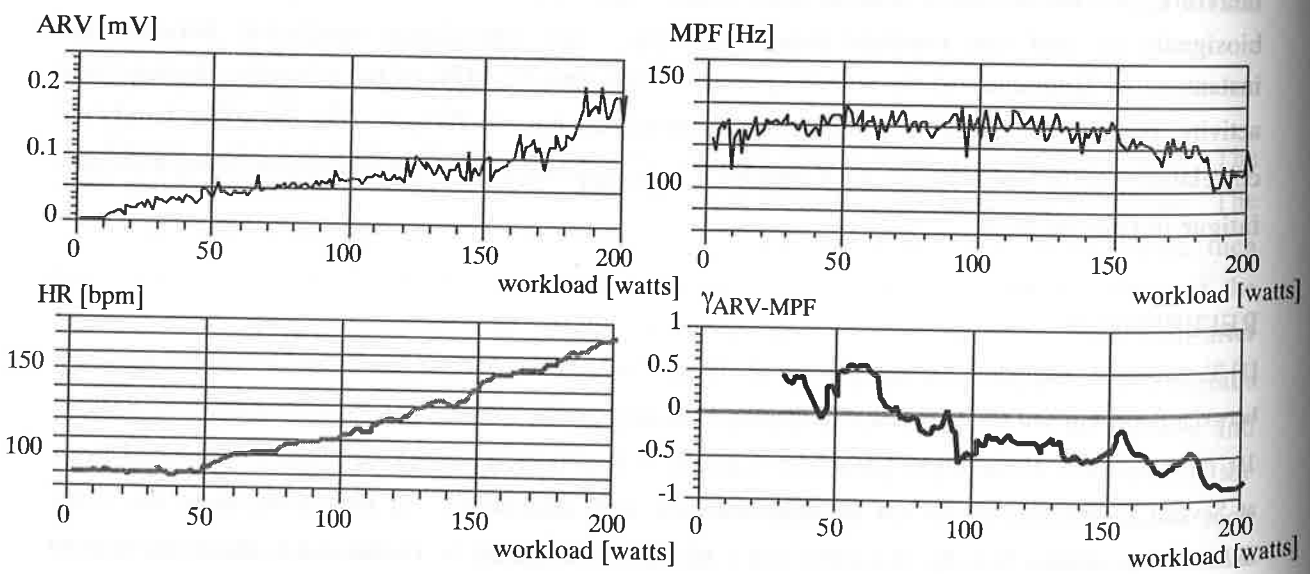

Fig. 2. Time-series of ARV, MPF, $\gamma_{ARV\text{-}MPF}$, and HR during cycle ergometer exercise at the progressively increasing workload.

S-11

Muscle fatigue evaluation: from basic research to clinical applications

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BACKGROUND

The objective evaluation of the force production capability of skeletal muscles is a central issue in clinics, sport medicine, rehabilitation, and ergonomics. Several hundreds of papers published in the last thirty years demonstrate the interest of scientists and clinicians in the various aspects of muscle fatigue.

From a functional point of view, the first question generally addressed when characterizing a muscle is measuring the maximum force that it can produce in specific conditions (i.e., isometric contractions, isokinetic contractions, ...). This is relatively straightforward, since it only requires the availability of a force transducer to be attached to the joint to be studied. If the joint is kept in isometric conditions, the design and construction of the transducer is relatively simple. When the contractile force is to be measured in dynamic conditions, the measuring system is more complicated and often requires active components as, for example, torque motors. Static transducers, either electrical or mechanical, have been available for a long time, while dynamic transducers (i.e., isokinetic devices) became common in the last twenty years.

Another important characteristic to be evaluated is muscle endurance. Usually, this is defined as the longest period of time during which a muscle can maintain the required force level. The functional implications of muscle endurance are obvious. It is also evident that the sole knowledge of endurance cannot describe the numerous and diverse processes that take place in the neuromuscular system since the very beginning of the contraction and that only eventually lead to the inability of maintaining the desired level of force. This fact was pointed out in the seventies (refer to [1] for a description of the state of the art in the early eigthies) and, since then, numerous researchers devoted their efforts to finding objective methods to track the progression of muscle fatigue during muscle activity.

In the eighties, it became generally accepted that the myoelectric signal detected by means of surface electrodes is a reliable indicator of muscle fatigue. Moreover, it was also demonstrated that the progression of muscle fatigue causes the scaling of the power spectrum of the signal towards the lower frequency end. Moreover, it was also established that either the mean or the median frequency of the power spectrum of the myoelectric signal could be considered as reliable indicators of the spectral scaling due to muscle fatigue.

Until the late eighties, most of the studies on muscle fatigue through the surface myoelectric signal were aimed at characterizing the behavior of spectral parameters as fatigue indicators, at investigating the relations between the spectral scaling and the underlying biochemical phenomena, and at attempting some preliminary clinical applications. The lack of practical techniques for estimating the spectral content of non-stationary signals forced the researchers to restrict their interests to isometric and constant force contractions. Although rather uncommon during usual daily activities, different research groups demonstrated that this contraction modality might be used successfully in research as well as in clinical studies.

THE LAST DECADE

To review the research activities in the last decade, the Medline database was interrogated with different combinations of keywords, to find the papers whose title clearly refers to the issue of muscle fatigue studied through the myoelectric signal. Although the search was not exhaustive, more than fifty papers published on international journals since 1990 testify the interest of researchers in the electrical manifestations of muscle fatigue. By also including the proceedings of international congresses held in the same period, the total number of contributions could be estimated as 200–250. Most of the authors of these works are physicians, physiologists, physical therapists, or biomedical engineers.

The papers published on international journals may be divided in three groups: the first group includes technical and methodological contributions and consists of approximately 15 works, the second group contains 28 papers that describe experimental physiological studies, and the third group consists of 11 papers relative to clinical applications.

In the nineties, the most important advancement in the field of the assessment of the electrical manifestations of muscle fatigue has certainly been the extension of the studies previously carried out on static contractions to dynamic contractions. This important result has been obtained thanks to the use of time-frequency transformations. These techniques allow studying the evolution of the spectral content of non-stationary signals. The first examples of application of bilinear time-frequency transforms to the assessment of muscle fatigue have been published in 1995 [2] and 1996 [3]. Since then, at least four other papers dealt with technical issues related to processing non-stationary signals. In particular, Knaflitz and Bonato [4] recently presented some guiding principles to be followed for applying time-frequency analysis to muscle fatigue evaluation in different experimental conditions. Karlsson et al. [5] lately proposed an alternate approach based on wavelet decomposition.

It is interesting to notice that only two out of the 28 papers that describe experimental physiological studies are relative to applications of time-frequency- or wavelet-based techniques. Most of the 28 works are related to experiments carried out in static conditions.

This is not surprising, since the first contribution that proposes processing protocols for different classes of non-stationary signals was published in 1999 [4].

What is more surprising is that since 1990 only 11 papers described clinical applications of muscle fatigue assessment. Out of these, six are just preliminary studies. In only one paper it is suggested than the assessment of the electrical manifestations of muscle fatigue could be beneficial for the treatment of the patient [6].

In conclusion, during the last decade the most important methodological achievement was the development of methods for quantifying the electrical manifestations of muscle fatigue during dynamic contractions; in fact, this allows the extension of physiological and clinical studies to contraction modalities that realistically reproduce those situations in which the subject experiences discomfort or is impaired. Most of the bibliographic contributions were relative to experimental physiological studies, and only a few contributions described clinical applications of the assessment of muscle fatigue.

FUTURE PERSPECTIVES

The arguments reported above show that, although the modern assessment of the electrical manifestations of muscle fatigue has arisen the interest of numerous researchers since the early seventies, the interest of clinicians is still very limited and the examples of clinical

applications are rather uncommon. At this time, muscle fatigue assessment is most frequently applied in experimental studies on muscle physiology.

In order to properly direct our research efforts, we should be able to understand how to improve the interest of clinicians in the quantitative evaluation of muscle fatigue. To answer this question, it is necessary to understand the reasons that justify the existing lack of interest.

In the process of decision making relative to the treatment of patients, physicians choose those tools that allow obtaining clear benefits at a reasonable cost. The key of the question is that the cost to benefit ratio, in most clinical situations, is still too high. In other terms, this means that the efforts required - training of operators, time needed to perform the exam, difficulty in using the instrumentation along with its cost and availability on the market, expertise needed to obtain reliable results and to interpret them properly, ... - are not counterbalanced by a satisfactory improvement of the diagnostic, prognostic, and therapeutic processes. It follows that to facilitate the diffusion in clinics of the quantitative evaluation of muscle fatigue, we should decrease its associated costs as well as further investigate and disseminate its possible benefits.

Although some of the adverse factors cited above are not under direct control of the scientific community – i.e., instrumentation costs and availability on the market – others may be directly affected by our research activities.

A first step taken in the direction of decreasing the time required for training the operator while increasing the reliability and repeatability of the results, was the development of a user independent method for "positioning" the detection probe over a muscle to be examined in isometric condition [7]. This research was suggested by the observation that the proper location of the detection probe is crucial for obtaining valuable results, it is strongly affected by the expertise of the operator, and it requires a considerable percentage of the time spent for the completion of test. The cited method is based on the use of a sixteen bar detection probe associated with a decision support system relying on a multicriteria method. It was demonstrated that such a system gives highly reliable and user independent results even when used by scarcely trained operators. Although the obtained results are satisfactory when working in isometric condition, this method may not be applied to dynamic contractions. The extension of the mentioned approach to dynamic contractions is certainly a necessary evolution of this study.

Another goal to be pursued in the future is the development of detection electrodes even more reliable and easy to use than those currently available. The features that should be further improved are the skin-to-metal interface stability and its related noise as well as the electrode weight and size.

A further obstacle to be removed is the difficulty of interpretation of the results, which currently requires considerable expertise both in technical and physio-pathological issues. The main problem is represented by the fact that only a multifactorial analysis of a parameter set that probably has to be different for different classes of pathologies provides clinically useful information. At this time, many decision support techniques are available for facing situations that require considering the joint behavior of many variables allowing for their uncertainty. Often these techniques take advantage of context-related knowledge and refer to large mixed databases. A challenge for the future is applying these advanced techniques to our context. This will require the joint effort of experts from different areas, as medical informatics, applied physiology, muscle pathology, biomedical engineering, and life sciences at large.

Finally, numerous clinical studies must be undertaken by focusing on pathologies that could really benefit from muscle fatigue assessment. We must bear in mind that a technique is clinically useful only if it allows the physician to significantly improve, with reasonable additional costs, at least one of the following activities: diagnosis, selection or adjustment of the therapeutic approach, patient follow-up, or, last but not least, objective documentation of the obtained results.

CONCLUSION

This paper presents a summary of the research activities in the field of muscle fatigue over the past ten years. Although the bibliographic search was not exhaustive and possibly some contributions have not been considered, the outlined scenario is representative of the state of the art in this field. Even if most technical problems have been solved satisfactorily – i.e., the availability of suitable instrumentation, the characterization of the signal processing techniques usually adopted, the possibility of dealing with dynamic contractions, ... - the clinical relevance of the assessment of the electrical manifestations of muscle fatigue is still scarce.

In the previous section, some of the issues on which researchers should concentrate their efforts to improve the clinical relevance of this discipline have been listed. The challenge for the next decade is to lessen the cost to benefit ratio of muscle fatigue assessment in clinics. Associated costs may be reduced by adapting the test protocols as much as possible to specific pathologies, by increasing the repeatability and reliability of results, and by simplifying their interpretation. Benefits must be demonstrated by promoting clinical trials focused on pathologies whose social impact is relevant, bearing in mind that clinicians will consider as beneficial just those applications that significantly improve the patient management process.

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S-12

The Reliability of Different EMG Indices Used in the Evaluation of Back Muscle Fatigue

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INTRODUCTION

Muscle fatigue is a phenomenon that can be evaluated with both the temporal and spectral domains of the EMG signal. It is expected that while a muscle is undergoing fatigue the amplitude (RMS) of the EMG signal will increase while a compression of the spectral content towards the lower frequencies of the power spectrum will occur. Consequently, for a given level of maximal voluntary contraction (MVC) maintained in time, the slope of the RMS/Time will increase while the slope of the Median (Md) frequency of the power spectrum of the EMG signal over time (Md/Time) will decrease (Roy et al. 1997). Based on these observations, indices have been proposed in order to evaluate muscle fatigue in back extensors, such as the slope of the RMS/Time and of the Md/Time. The slope of the NMd/Time or the Md frequency normalised to the value of the initial median frequency, the slope of the total power of a given band (5-60Hx) of the power spectrum over time (Band/Time) (Dolan et al. 1995) and the Area Ratio Index (ARI) of the median frequency, which is a ratio of the areas of the data separated by the Md frequency (Md/time), have also been used (Merletti et al. 1991).

Although most of these measures have been shown to be sensitive to muscle fatigue it would be of interest to know which one is the most reliable. The aim of the present paper is to report the reliability associated with these measures.

METHODS

A triaxial dynamometer developed for the purpose of the present study (Larivière et al. 2000) allowed the evaluation of back extension efforts while standing (trunk upright) with the pelvis and lower limb stabilised. This dynamometer is composed of a metal frame in which the subject is secured and where a triaxial force platform (AMTI) is mounted and positioned approximately at the T4 level. L5/S1 moments were calculated in extension, rotation and lateral bending of the trunk knowing the platform and L5/S1 joint centre locations. The EMG signals were recorded using active surface electrodes (DELSYS Inc). EMG signals from the recording sites were bandpass filtered (20-450 Hz), preamplified (gain: 1K), analogue to digital converted at a sampling rate of 2048 Hz and stored on a hard disk for later analysis. Eight pairs of electrodes were placed, bilaterally, on the Longissimus (T10 and L1), Iliocostalis (L3) and Multifidus (L5) muscles.

Twenty normal male subjects participated in the study. Their mean age was 38 years (SD=13), mean height 1.75 m (SD= .04) and mean weight 73 kg (SD= 9). None had ever suffered from a significant episode of low back pain. Each subject was evaluated on three days within a period of two weeks. Each evaluation was composed of two MVCs, three ramp contractions, a fatigue test and a recovery test. The highest MVC produced was retained as the MVC for that session. The fatigue test consisted of maintaining a 75%MVC for a period of 30 seconds (van Dieen et al. 1998) while controlling for the L5/S1 axial rotation moments. Only the data from the fatigue test are presented in this paper.

A series of 250 ms windows of data, 25% overlapped, were taken on the 30 sec data of the fatigue test. The data of these windows were quantified, over time, in RMS and in both total power (5-60 Hz band) and Md frequencies of the power spectra (1024 points, Hanning window processing, Fast Fourier Transform procedure). The five fatigue indices described above were derived from these data. The data were analysed, for each of the five indices and each of the eight back muscles, using one-way ANOVAs for repeated measures on the Day factor (3 levels). Intra-Class Correlation Coefficients (ICC) were calculated from the ANOVA results considering that one measure was obtained at each day (ICC1). In the context of the Generalizability Theory, an anticipated ICC was calculated corresponding to the mean of two trials/day (ICC2). This condition was considered because it was believed to be achievable in some circumstances.

RESULTS

Across the three evaluation sessions, the mean moments obtained in back extension were 236 Nm (SD= 48), 255 Nm (SD= 38) and 266 Nm (SD= 40). An ANOVA for repeated measures disclosed ($p<.05$) the presence of a significant difference between days, a difference that is probably explained by the testing or learning effect.

Tables 1 to 4 present the reliability results of the fatigue indices, for each muscle investigated. The "Mean" and standard deviation (SD) were computed across all subjects and sessions. The standard error of the mean (SEM) which can be used to calculate the smallest detectable difference ($1.96 \times$ SEM) was also computed. The NMd/Time slope results are not presented because the corresponding ICCs were equivalent to those of the Md/Time slope index.

Table 1. Fatigue Measured with the Slope of the EMG RMS Over Time

Muscle (Left & Right)	Reliability coefficient ICC1	ICC2	Mean (µV/s)	SD (µV/s)	SEM (µV/s)
Multifidus (L)	0,23	0,37	0,92	0,99	0,88
Multifidus (R)	0,38	0,55	0,94	1,04	0,83
Ilioc. Lumb. (L)	0,67	0,81	1,86	2,17	1,25
Ilioc. Lumb. (R)	0,75	0,85	1,82	2,07	1,06
Long. L1 (L)	0,30	0,46	1,16	1,03	0,87
Long. L1 (R)	0,39	0,56	1,39	1,24	0,98
Long. T10 (L)	0,34	0,51	1,40	1,37	1,12
Long. T10 (R)	0,45	0,62	1,62	1,36	1,03

Table 2. Fatigue Measured with the Slope of the Md Frequency Over Time

Muscle (Left & Right)	Reliability coefficient ICC1	ICC2	Mean (Hz/s)	SD (Hz/s)	SEM (Hz/s)
Multifidus (L)	0,55	0,71	-1,28	0,58	0,39
Multifidus (R)	0,76	0,86	-1,39	0,62	0,31
Ilioc. Lumb. (L)	0,59	0,74	-0,62	0,45	0,29
Ilioc. Lumb. (R)	0,56	0,72	-0,57	0,36	0,24
Long. L1 (L)	0,77	0,87	-0,83	0,48	0,24
Long. L1 (R)	0,73	0,85	-0,75	0,51	0,27
Long. T10 (L)	0,59	0,74	-0,42	0,46	0,30
Long. T10 (R)	0,26	0,42	-0,37	0,29	0,25

Table 3. Fatigue Measured with the Slope of the Total Power of the 5-60 Hz Band Over Time

Muscle (Left & Right)	Reliability coefficient ICC1	ICC2	Mean	SD	SEM
Multifidus (L)	0,83	0,91	40,65	50,72	21,16
Multifidus (R)	0,84	0,91	39,80	47,88	19,64
Ilioc. Lumb. (L)	0,90	0,95	136,39	278,75	88,32
Ilioc. Lumb. (R)	0,87	0,93	123,74	241,14	88,87
Long. L1 (L)	0,60	0,75	47,07	52,19	33,35
Long. L1 (R)	0,66	0,79	41,52	39,07	23,29
Long. T10 (L)	0,54	0,70	25,89	33,28	22,97
Long. T10 (R)	0,77	0,87	33,47	39,08	18,84

Table 4. Fatigue Measured with the Area Ratio Index

Muscle (Left & Right)	Reliability coefficient ICC1	ICC2	Mean	SD	SEM
Multifidus (L)	0,22	0,37	0,17	0,16	0,14
Multifidus (R)	0,31	0,47	0,18	0,14	0,11
Ilioc. Lumb. (L)	0,21	0,35	0,11	0,16	0,15
Ilioc. Lumb. (R)	0,31	0,47	0,09	0,16	0,13
Long. L1 (L)	0,13	0,23	0,12	0,17	0,16
Long. L1 (R)	0,00	0,00	0,11	0,15	0,16
Long. T10 (L)	0,00	0,00	0,03	0,16	0,16
Long. T10 (R)	0,18	0,31	0,07	0,12	0,11

DISCUSSION

From the present results it is obvious that the slope of the RMS/Time data is not a very reliable index of muscle fatigue. This could partly explain why this measure is not often used. The Area Ratio Index also appeared to be unreliable for all the present back muscles investigated. This ratio has recently been used successfully on the vastus medialis muscle

(Merletti et al. 1991). However, in this latter study, the fact that three trials were performed for each subject may partly explain the good reliability scores obtained.

The Md/Time and NMd/Time slopes were two measures that disclosed a good reliability level. These measures are commonly used in the literature and averaging two trials within an experimental session would increase its reliability to an acceptable level. It should also be noticed that the data of the NMd/Time measure were not superior to those of the Md/Time. The present results are partially comparable to those of previous studies (Ng et al. 1996; Oliver et al. 1996), even though the fatigue protocols used were extremely different.

The fatigue index that disclosed the best level of reliability is the Band/Time slope previously proposed by Dolan et al. (1995). This index offers the best outcome in terms of reliability for most of the muscles investigated even when only one trial can be obtained within a session. When two trials within a session can be averaged, this measure presents the highest level of reliability. This is so most certainly because it uses the part or band of the EMG power spectrum that is most significant in terms of the fatigue effect sought.

CONCLUSION

Several indices of back muscle fatigue are presently used in the literature. However, for one to use a given measure in the context of a clinical trial aiming at validating a rehabilitation program with back pain subjects, the most reliable measure should be sought. The present results indicate that both the Md/Time and NMd/Time slopes that are currently used present very good levels of reliability for most of the eight muscles we investigated. However, the Band/Time fatigue index proposed by Dolan et al. (1995) definitely appears to be superior to the others investigated. It would now be appropriate to obtain reliability estimates of these three measures or indices with back pain patients.

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S-13

ELECTRODIAGNOSIS AND MUSCLE FATIGUE

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Human muscle fatigue, an important clinical symptom, can be measured by electodiagnostic techniques. This lecture will review some of the literature, which focuses on the electrodiagnostic changes, which are found in the muscle when it is exercised. In the clinical laboratory, fatigue can be created by the use of high-frequency stimulation or by maintained contraction by the subject against a force. In the isolated mouse muscle fiber, it has been shown that the muscle action potential propagation velocity decreases in the soleus and extensor digitorum longus muscles after electrical stimulation. This was due to increased extracellular potassium concentration, low intracellular pH (1). The evoked compound muscle action potential in the rat muscle showed decreased amplitude and prolonged duration after high-frequency stimulation of the soleus and tibialis anterior muscles. This change was not apparent with low frequency stimulation (2). However, in a study which searched for the central and peripheral contribution to muscle fatigue in humans during maximal effort, the compound muscle action potential was unchanged, but the integral of the EMG signal did decrease significantly from the initial value. The study concluded that central factors contributed approximately 20% to the muscle fatigue developed, with the remainder being attributable to intramuscular factors (3).

Other studies have delineated the differences in the electromyographic changes depending on the muscle and size of the muscle. In their study of the first dorsal interosseous and adductor pollicis muscles, Zijdewind and Kernell (4) noted an initial potentiation then a decline in the compound muscle action potential amplitudes of the two muscles after electrical stimulation of the ulnar nerve in subjects with small hands. However, there was no CMAP amplitude decline in the muscles of subjects with large hands. EMG changes also have been shown to be different in the first dorsal interosseous muscle of the dominant hand compared to the non-dominant hand of the subject, with more significant changes in the non-dominant hand (5). CMAP amplitude was noted to decrease and CMAP duration to increase during exercise in the vastus lateralis muscle of the untrained individual, but there was no significant change in the trained cycler (6). It also has been shown that there is decline in electromyographic activity in muscle when the synergistic muscle is fatigued, but there is no significant change in the CMAP amplitude or area (7). Fine wire electromyographic studies in humans have demonstrated that cessation of motor unit discharge may contribute to muscle fatigue (8). These and other related studies are reviewed in greater detail and various conclusions summarized at the end of this lecture.

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S-14

Neuroanatomical substrates of lower extremity SSEP

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INTRODUCTION

Neuroanàtomical substrates of lower extremity somatosensory evoked potential (SSEP) have been less well clarified and studied as compared to those of upper extremity (median or ulnar nerve) SSEP. This presentation discusses anatomical origins of various SSEP components of lower extremity nerve and compares these with those of upper extremity (median nerve) SSEP.

METHOD

The lower extremity nerves were stimulated at the distal (tibial nerve) and proximal (lateral femoral cutaneous nerve) sites. SSEP was recorded from multiple scalp electrodes as well as from the spine surface. Topographic mapping and dipole source localization method were used for data analysis.

RESULTS

Following stimulation of tibial nerve (TN), N21 and N23 were recorded from L4 and T12 spine, respectively. Far-field potentials of P31 and N35 were registered from Fpz-C5s (fifth cervical spine) or CPi (ipsilateral in respect to the side of stimulation) – ear derivation. Additional far-field potentials of P17 and P24 were recorded from the scalp when non-cephalic (knee) reference is used. Major positive peak, P40, was registered at the vertex and CPi ("paradoxical lateralization") electrodes. Preceding P40, there was a small negative peak, N37, recorded at the contralateral (CPc) hemisphere. When proximal nerve (lateral femoral cutaneous nerve, LFCN) was stimulated, distributions of N35 and N37 were the same as those of tibial nerve SSEP, ie; N35 recorded at CPi and N37 at CPc. In contrast, P40 of LFCN-SSEP was "normally" distributed over the contralateral hemisphere, unlike paradoxical lateralization of P40 seen in tibial nerve SSEP. Topographic mapping of P40 in LFCN- and TN-SSEP showed mirror-imaged figures. Although P40 of TN- and LFCN-SSEPs had contrasting field distribution, dipole sources were localized in the contralateral hemisphere in both SSEPs but with different dipole field directions. In TN-SSEP, P40 source was in the mesial aspect of contralateral hemisphere with its dipole directing radially and obliquely toward ipsilateral hemisphere, whereas P40 source in LFCN-SSEP was in the lateral convexity of contralateral hemisphere with its dipole directing tangentially and posteriorly within the same hemisphere.

DISCUSSION

Accumulating evidences have suggested that the far-field potentials of P17 and P31 arise from the distal portion of sacral plexus and brainstem, respectively. These correspond to P9 and P14 of median nerve SSEP, respectively. Spinal potential of N24 is equivalent to N13 cervical potential of medina nerve SSEP. N35 recorded from the ipsilateral hemisphere is analogous to N18 of the median nerve. Paradoxically lateralized P40 has been thought to represent positive end of dipole field reflected by the negativity at the mesial surface of contralateral hemisphere, and has commonly been considered to be equivalent to the first cortical potentials (N20) of median nerve SEP. But more recent evidences have suggested that this is the primary positivity at the mesial cortical surface and more likely corresponds to P26 of the median nerve SSEP. The first cortical potential corresponding to N20 is then probably small and inconsistent N37 recorded on the contralateral hemisphere.

CONCLUSION

The anatomical origins of various SSEP components of upper extremity nerves have been extensively studied and well substantiated by vigorous clinical application of the study in known localized lesions along somatosensory pathways. The neuroanatomical substrates of lower extremity SSEP above discussed are still based on the indirect evidences and need to be verified by more extensive application of lower extremity SSEP to clinical patients having various neurological disorders.

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S-15

Specific and Non-specific Effects of Transcranial Magnetic Stimulation on Reaction Time Paradigms

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INTRODUCTION

Transcranial Magnetic Stimulation (TMS) can be delivered focally over different scalp position during reaction time (RT) paradigms. TMS can influence simple RT depending on timing, scalp position and stimulus intensity. Day et al. (1989) showed that suprathreshold TMS can prolong the simple RT. Pascual-Leone et al (1992) suggested that, in a simple RT paradigm, subthreshold TMS shortens RT by reducing the time required to transfer the motor command from premotor and supplementary motor area to the primary motor cortex. However, it has been a matter of debate if TMS has a specific ability to shorten simple RT (Pascual-Leone et al., 1992) or if the shortening is due to a non-specific effect of an accessory stimulus (click) closely timed with the go-signal (Terao et al., 1997). In the present paper we compared the effects of TMS in RT paradigms of different complexity (simple RT, go/no-go, choice RT). We hypothesized that the specific effect of TMS should be delayed in more complex and thus longer RT paradigms. On the other hand, the non-specific effect should occur at a similar timing around the delivery of the imperative signal even in more complex paradigms than simple RT paradigm.

METHODS

Experiment 1: Seven right-handed adults participated in this study. Subjects were asked to respond by abducting the right thumb in a warning-imperative signal paradigm. TMS was randomly delivered at variable delays to the imperative signal (IS). Three RT paradigms were studied: simple, go/no-go and choice RT.

Experiment 2: Five right–handed subjects were recruited for the study. Lateralized movement-related potentials (MRP) were recorded to link the TMS effect with the motor cortical circuitry.

RESULTS

Simple RT was significantly shortened when TMS was delivered to the left motor cortex and parietal regions simultaneously with IS. In the go/no-go paradigm, a similar trend to shorter RT was seen at a delay of 0 ms and an additional shortening was obtained at a delay of 90 ms with TMS over the contralateral motor cortex. In the choice RT paradigm, RT shortening was observed at delays of 0 and 150 ms. Lateralized MRP started about 80 ms before EMG onset in all paradigms.

DISCUSSION/CONCLUSION

Our findings support the existence of two differentiated effects of TMS on RT: (1) one non-specific effect evidenced at 0 ms delay, which can be partially explained by intersensory facilitation and (2) a motor-specific effect of TMS, unveiled in go/no-go paradigm at 90 ms delay and in choice paradigm at 150 ms delay. Lateralized MRP results suggested that TMS influences the cortical motor circuitry around 30~40 ms before the activation of the primary motor cortex.

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S-16

Facial Synkinesis: Evaluation and Rehabilitation

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INTRODUCTION

One of the consequences of severe facial paralysis with axonal degeneration is the development of facial synkinesis. Most of these patients are handicapped in social activities with facial disfigurement. The aim of this presentation is to show how to evaluate facial synkinesis electrophysiologically and to reduce it from point of rehabilitation.

METHODS

In the facial reflex, R1 and R2 reflex responses elicited by stimulation of the supraorbital nerve are usualy recorded in the orbicularis oculi muscle alone not in the other facial muscles. However, synkinetic early and late components, S1 and S2, were synchronously elicited in the orbicularis oris in patients with aberrant facial nerve regeneration. We retrospectively estimated how much axonal degeneration or aberrant regeneration developed with amplitude ratio of between R1 and S1 in the facial reflex.

Surface EMG recordings over the orbicularis oculi and orbicularis oris were also monitored at strong eye closing and whistling to measure how much aberrant axons misdirected from the orbicularis oculi to the orbicularis oris and/or from the orbicularis oris to the orbicularis oculi, respectively.

We analyzed time course of facial synkinesis in 100 patients, 40 men and 60 women. The average age of the patients was 46 years. The causes of facial paralysis were Bell's palsy 65 cases, Hunt syndrome 21 cases, tumor 9 cases, and thers 5 cases. The change of aberrant amplitude ratio was serially studied for over a couple of years.

RESULTS

Synkinesis developed in 3-4 months after the facial nerve injury, even though clinical facial recovery was good. In severe cases, facial reflex responses occurred in 5-6 months, associated with aberrant synkinetic potentials in the orbicularis oris. The aberrant amplitude ratio became higher. With time, aberrant amplitude ratio did not so much change. It was significantly correlated with misdirection ratio from the orbicularis oculi to the orbicularis oris on the surface EMG at strong eye closing. Aberrant misdirection ratio from the

orbicularis oculi to the orbicularis oris was not over 200% and misdirection ratio from the orbicularis oris to the orbicularis oculi was about a half of the previous.

On the surface EMG observation, synkinetic amplitude ratio was accentuated by strong voluntary movements, which might be due to recruitment of the aberrant axons. Conventional electrical stimulation at low frequency for prevention of facial muscle atrophy rather facilitated synkinetic circuits with facial spasm.

DISCUSSION

The less facial axons degenerate, the earlier the facial reflex responses return with small synkinetic potentials in the orbicularis oris. Misdirection developed more often from the orbicularis oculi to the orbicularis oris than the opposite.

Synkinesis is pathophysiologically due to aberrant regeneration circuits in the peripheral facial nerves. Once it is established, it is permanent. Thus, rehabilitation approach includes inhibition of synkinesis, facilitation of remaining intact circuit and development of motor learning.

Gross exercises such as "close your eyes as hard as you can" or "smile broadly" reinforce abnormal synkinetic patterns with recuruitment of aberrant axons.

Electrical stimulation also reinforces aberrant circuits of synkinesis with eventual facial contracture or hypertonia. These conventional approach may be contraindicated. In contrast, small movements preserve isolated responses by confining motor unit recruitment to targeted muscles. Slow, controlled movements are essential to new motor learning because they enable the patient to observe and modify the process of excursion as it occurs. This also allows for inhibition of the synkinesis as the movement develops. In addition, stretching of the shortening muscles may be effective for the contracture.

CONCLUSION

Electrophysiological facial reflex is indispensable to evaluate facial synkinesis. Strong facial exercise and electrical stimulation facilitate the aberrant.

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S-17

Movement Related Cortical Potentials in Recovered Hemi paresis

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INTRODUCTION

Movement related cortical potentials (MRCPs) preceding voluntary unilateral finger movement in healthy humans consists of initial negative slope Bereitschaftspotential (BP) and late negative slope NS'. BP is generated from hand areas of bilateral primary sensori-motor area (SI-MI) and supplementary motor areas (SMA), whereas NS' is from the contralateral SI-MI and bilateral SMAs. MRCPs were studied in recovered hemi paresis.

SUBJECTS

Two cases with unilateral striatocaspular vascular lesion 8 months after stroke whose paretic arm remained in synergistic movement, and a case with anterior choroidal syndrome 3 years after stroke whose paretic arm recovered well to execute isolated finger movement but severe sensory loss resulted in non-functional hand were studied.

METHODS

Each subject voluntarily extended middle finger or flexed the elbow at self-paced rate once every 5-10 seconds. They were asked to avoid eye blinks as well as not to contract shoulder or arm opposite to the movement. MRCPs were recorded form Cz, LHM (left hand motor area), RHM (right hand motor area), and others. The EOG was recorded to monitor eye blinks. The precious onset of EMG discharge recorded from the contracting muscles was used as the trigger. 100-200 trials for each arm were averaged.

RESULTS

The NS' amplitude preceding the intact arm movement showed distinct preponderance over the contralateral precentral area, whereas the NS' amplitude preceding the affected arm was symmetrically maximal at bilateral precentral area in all three cases.

CONCLUSION

Voluntary movement of paretic arm is associated with activation of not only the contralateral affected but also intact SI-MIs, whereas that of intact arm is associated maily with contralateral SI-MI. Sensory cortex was supposed to have little effects on generation of premotion potentials, as in the case of anterior choroidal syndrome all modalities of senses were lost in the affected arm.

S-18

Predicting the Optimal Threshold of Pulse Detection for Pulse Density Demodulation Processing of Electromyograms (PDD-EMG)

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PRINCIPLE OF PDD-EMG

In the processes of generation of neural pulses and observation of electromyogram (EMG), time pattern of motor commands which controls degree of contraction of a whole muscle is generated in the motor area, and is transmitted to the muscle through motoneurons as neural pulse trains. The change in the pulse density in each of the motoneurons, if superimposed over a whole muscle, corresponds to the time pattern of the motor commands smoothed by transmission characteristics in the neural passage.

When muscle fibers connected to each motoneuron contract, the action potentials propagate along the muscle fibers. The action potentials are detected with electrodes as the EMG waveform, and the time pattern of the motor command is reconstructed by measuring time change in pulse density (pulse density demodulation, PDD), after correcting the difference in amplitude among pulse trains caused by the attenuation due to the distance from the motoneurons to the electrodes (pulse shaping).

The pulse density demodulation processing of electromyograms (PDD-EMG) has been applied to the computer processing of surface electrode EMG of extremity muscles in running action, and a series of the methodological discussions were reported in the references.

A STRATEGY FOR ASSESSING THE ACCURACY

In order to assess the accuracy of the processing, a strategy using a computer simulation of the PDD-EMG was proposed in the previous papers.

Between the processes of generation of neural pulses and observation of the EMG, there are two signals, namely, the motor commands and density modulated pulse trains for a whole muscle, which correspond each other. If all the steps involved in the processes of generation of the neural pulses in the motoneurons and observation of the EMG are simulated in a computer, by introducing the neurophysiological properties as real as possible, the known generated motor commands and neural pulses serve as the reference for the detailed analysis of the nature of errors in the result obtained by the processing the real EMG.

As the result, it was shown that the reconstructed analog pattern of time change in the motor command corresponded fairly accurately to the theoretically generated one. By using this computer simulation strategy, possibility of automatizing the computer program of the PDD-EMG was discussed. The optimum value of the threshold was set in the range where the ratio of detecting correct pulse saturates, but the ratio of detecting false pulse was negligible. This setting gave the first order approximation in the automatization of the computer program for the PDD processing of the real EMG.

THRESHOLD OF PULSE DETECTION

Referring to the discussion, method of predicting the optimal threshold of pulse detection for the real surface electrode EMG in the computer program of PDD was investigated.

First, the patterns of time change in pulse density detected by shifting the threshold from low to high value were derived. From the patterns, the optimal threshold by which the time pattern contains most signal information but less noise disturbance was chosen. The EMG used was from the soleus muscle for a stride of running action. The patterns were smoothed by moving average with 40 msec time window.

The pulses were detected by a threshold in two stages; firstly, by the twice large value of the threshold for detecting larger pulses, then, by the threshold for the rest smaller pulses. After each detection of a pulse, the standard pulse shape waveform whose peak amplitude was normalizing by that of the detected pulse was subtracted from the EMG waveform. Those processes were useful to avoid detecting false pulses at the second and third phase of the detected pulse. After all the pulses larger than the threshold was detected, the residual waveform was differenciated, and very small peak amplitude pulses which had been hidden in the steep slope of the large pulses were detected from the differenciated waveform by setting the threshold just above the noise level.

By detecting as many number of pulses as possible in this way, the artifact fluctuation in the pattern of the time change in pulse density decreased, and the signal information of the motor command was reconstructed more accurately.

PREDICTING OF THE OPTIMAL THRESHOLD

The optimal threshold which separate the signal component from the noise component on the pattern of time change in the pulse density was predicted from the frequency distribution of the peak amplitude of conventionally detected pulses in the whole duration of the objective EMG waveform.

On the regression curve of the frequency distribution of logarithmic number of peaks vs. peak value, tangents at the peak values of 50% larger than the average and of 50% lower were drawn. Those tangents represent the tendency of distributions of the signal and noise components, respectively. The peak value at their cross point indicates the boundary between those two components.

The optimal threshold chosen in the patterns of time change in the pulse density corresponded to the peak value of 10% larger than the boundary.

Use of this method of predicting the optimal threshold to the EMG observed in different conditions is currently being examined.

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S-19

Motor unit firing behavior in health and disease

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Studies on motor unit firing behavior in health and disease by the decomposition technique will be presented. De Luca and colleagues originally developed the decomposition program. In all muscles examined the higher the recruitment threshold of the motor unit, the lower the rate at which it fired at the target level even at ballistic contraction. Smaller muscles, such as those in the hand, recruit their motor units at 0-50% MVC and rely exclusively on firing rate increases to augment force output at 50-100% MVC. Larger muscles, such as those in the leg or arm, recruit motor units at least to 90% MVC, and possibly higher. Smaller muscles rely primarily on firing rate and larger muscles rely primarily on recruitment to modulate their force. The explanation can be found by considering the anatomy and function of the muscles. Small muscles have relatively few motor units. If recruitment were the only means by which additional force could be developed, small muscles would be incapable of smoothly contracting. Smaller muscles are generally involved in performing precise movements. Larger muscles, on the other hand, have many motor units and do not require fine force gradation to accomplish their task. Thus, the firing rates of such muscles do not require continual regulation and do not possess the highly dynamic characteristics seen in smaller muscles.

High cross-correlation functions in firing rate behavior within a muscle were observed between individual motor unit firing rates at constant force isometric contraction. Thus the nervous system does not control the firing rate of motor units individually. Instead, it acts on the pool of homonymous motoneurons in a uniform fashion wherever the motor units are in the muscle.

The relationship between macro-EMG and motor unit recruitment threshold was studied in the first dorsal interosseous muscle of normal young and aged subjects. Motor units with high recruitment thresholds have large macro-EMG amplitudes and show a linear correlation. In older subjects the size principle basically held, but the correlation coefficients were significantly lower than in young subjects. Motor unit sprouting associated with a loss of motoneurons or motor axons can increase with age, especially over 60 years old. Motor units in older subjects have a larger number of muscle fibers. Thus, each motor unit has a larger twitch force than the motor units in young subjects at comparable recruitment threshold. This study indicates that sprouting does not occur equally in low threshold motor units and high threshold motor units. Thus, the older subjects were not able to increase force smoothly. Older subjects may have difficulty in controlling precise finger movement due to motor unit loss and a larger twitch force of each motor unit. These patients' motor units do not strictly demonstrate 'size principle'.

In the paretic muscle, the motor unit firing behavior was different from that in the normal muscle. In normal triceps brachii muscles, each motor unit was found to rise its firing rate up to a common maximum level soon after it recruited. On the other hand, in the paretic triceps in patients with cervical cord injury, motor units with the lower recruitment threshold were found to be with the larger maximum firing rate. Motor units in the weaker muscles were found to have the higher firing rate.

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S-20

Fatigue-related Changes of Trunk Motor Control During Repetitive Lifting

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INTRODUCTION When people perform tasks that involve a repetitive movement, it is expected that they will modify their posture and weight distribution to compensate for muscle fatigue. Such compensation may result in a modification of joint loading, which may predispose the person to back injury. Back injuries in the workplace are most prevalent in jobs that require repetitive or forceful lifting [Pope 1996]. The objective of this report is to describe recent investigations by our group to determine whether motor control of the body, as measured by kinematics and kinetics, are adversely modified during a standardized lifting task, and whether such modifications are associated with the development of paraspinal muscle fatigue as measured by the surface electromyographic (EMG) signal. Recent applications of this work to the clinical environment are also described in which newly developed surface EMG procedures for assessing muscle fatigue are applied to standardized lifting tasks in the hopes of improving current assessment procedures for patients with low back pain (LBP) undergoing multidisciplinary functional restoration.

BACKGROUND Surface EMG techniques have played a major role in our understanding of the normal functional interaction between concurrently active trunk muscles when specific static postures or movements take place. Furthermore, the technique has provided a useful means of documenting how normal paraspinal muscle functioning is altered in the presence of chronic or acute LBP. This measurement capability has resulted in an approach to back muscle assessment that is based on indices of muscle fatigue derived from spectral estimates of the surface EMG signal. Laboratory and clinically-based studies by our group [Roy et al 1995] and others [Biedermann et al. 1991] have shown that by simultaneously monitoring changes in spectral parameters from multiple surface EMG electrode sites, it is possible to evaluate the relative contribution of individual paraspinal muscle groups during a sustained extension of the trunk. Because muscle dysfunction is a common result of injury, pain, and disuse, paraspinal muscles compensate for these deficits, resulting in a relative alteration in their EMG spectral activity during induced localized muscle fatigue.

A primary limitation to existing EMG signal techniques is that the quantification procedures for spectral analysis assume that the signal is *wide sense stationary*. During a dynamic contraction, changes in muscle force, muscle length, and the location of the electrode with respect to the active muscle fibers result in signal nonstationarity and variations of the frequency content of the EMG signal. It is for this reason that spectral EMG techniques have been traditionally limited to isometric, constant-force contractions. The limitation of the procedure to constant-force isometric contractions seriously compromises its clinical usefulness, since many dynamic activities, such as lifting, are commonly associated with LBP injury. Recent developments in the field of signal processing have provided a mechanism to overcome this limitation by the use of the Cohen Class and Cohen-Posch Class of time-frequency transforms [Knaflitz and Bonato 1999, Bonato et al. 1999]. These transforms allow us to estimate instantaneous frequency parameters of the EMG data that may be used to monitor muscle fatigue.

Protocols and analysis procedures from two studies in progress, one laboratory-based and the other clinically-based, are described. Preliminary findings from each of these studies are summarized and compared. The interpretation of these results is discussed in terms of their relevance to LBP research and clinical management.

METHODS Laboratory Studies. Following informed consent, data was collected to describe the kinematic and kinetic changes associated with repetitive lifting from eight male subjects without a recent history of low back pain (mean age = 26 ± 4 yrs.). Body kinematics during repetitive lifting was measured using a four camera infrared system (*Elite, BTS, Milan, Italy*). A force platform (*Kistler Instruments AG, Winterthur, Switzerland*) monitored changes in the ground reaction forces during the task. Surface EMG electrodes (*Delsys, Boston, MA*) were placed at 8 paraspinal muscle sites (bilaterally at spinal levels L5, L2, T10, and upper trapezius). The lift protocol was standardized so that the weight of the box was set to 10% of the subject's static one-lift maximum, the repetition rate was set to 12 lifts per minute for a total of 4 minutes, and a "free-lift" was utilized allowing flexion at knee and trunk for lifts from mid-shank to waist height. Biomechanical variables describing the kinetic and kinematic progression of the exercise were compared to time-frequency parameters of the surface EMG signals.

Clinical Studies: Male and female LBP subjects (n=10; age range of 18-55 years) were recruited from a multidisciplinary work rehabilitation program following informed consent. Inclusion criteria comprised a minimum absence of 1 month from work due to a non-specific LBP syndrome and a lifting capacity characterized as *light* according to the Physical Work Performance Evaluation (PWCE) [Lechner et al. 1994]. Exclusion criteria included radiculopathy with decreased reflexes, spinal fractures, infection, cancer, and significantly disabling co-morbidities. The test protocol was based on the laboratory protocol described above except that the load was set to 50% of the maximal safe lift value derived from the PWCE, and trunk kinematics (sagital flexion-extension, lateral flexion and rotation) was monitored using electrogoniometers (*Biometrics Ltd, Gwent, UK*) instead of the camera based motion system. Lifting cycles were determined from the box position on the shelves using contact switches. Results were compared to n=10 control subjects with no history of LBP.

For both laboratory and clinical studies, a method recently introduced by us based on Cohen-Posch time-frequency transforms [Bonato et al. 1999] was used to derive the instantaneous median frequency (IMDF) of the EMG signal. Muscle fatigue was measured by selecting specific portions of the lifting cycle and then plotting the IMDF values over successive cycles during the exercise [Roy et al. 1998]. Overall trends of the IMDF as well as its time-course during the task were studied.

RESULTS AND DISCUSSION Laboratory Studies: Preliminary results demonstrate that the biomechanics of the movement changes while subjects fatigue. *Figure 1* describes the changes in mean box acceleration in the vertical (Y) and fore-aft (X) directions. Acceleration curves from each minute of the lifting exercise are superimposed (*Figure 1A*) and the corresponding changes in mean peak acceleration are plotted for each of these curves in *Figure 1B*. The figure indicates a significant increase in vertical acceleration of the box over time during the initial part of the lift cycle. It appears that the subject changes the lifting strategy by utilizing the box`s inertial properties to facilitate the task. However, this strategy may be a cause of injury due to the increase in the spinal loads.

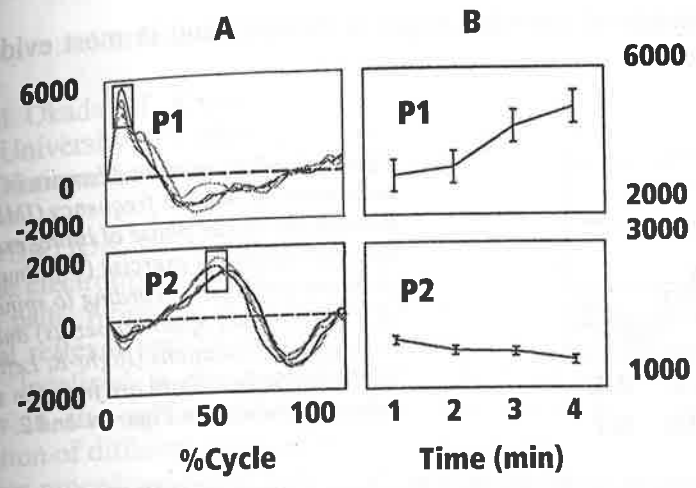

Figure 1A) Mean acceleration curves from 4 consecutives lifting cycles in the vertical (Y) and fore-aft (X) directions taken at the 1, 2, 3, 4 minutes of the lifting exercise. Curves are normalized as % of the lifting cycle. Each curve is the mean of 4 lifting cycles for each time periods. Peak values are contained within the superimposed window.
***1B)** Mean ± standard error of peak acceleration values extracted from the curves depicted in 1A. Data are from one subject.*

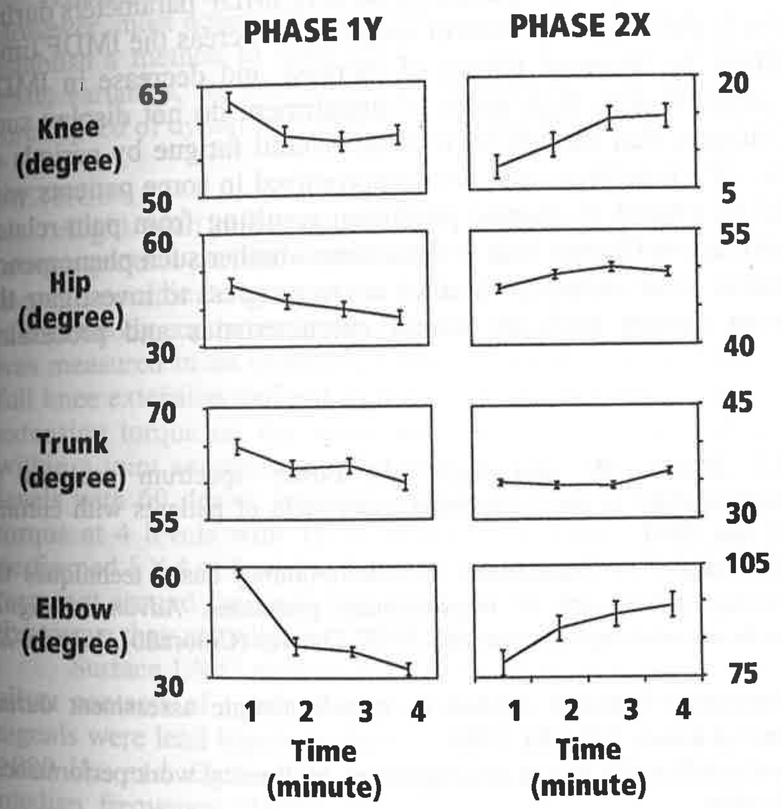

***Figure 2** Absolute changes in joint angles during the four minute lifting task. Mean and standard error are computed from 4 consecutives lifting cycles taken at 1, 2, 3, 4 minutes of the lifting exercise. Plots are presented from top to bottom for knee, hip, trunk and elbow joint angles for both peak phases (P1, P2) depicted in Figure 1A. Data are from the same subject presented in Figure 1.*

There are significant changes in joint angular displacement (JAD) during the peak acceleration phases (*Figure 2*). For the phase of the lift cycle corresponding to peak vertical box acceleration (Phase 1Y), all of the JADs decrease significantly over time, indicating that the subject uses fewer degrees of freedom to perform the task. JADs during Phase 2X significantly increase at the elbow and knees, indicating that the subject may be placing the extensor muscle on greater stretch to facilitate force development at the elbow and knee when displacing the box towards the shelf at waist height. Overall trends in the changes in IMDF used to monitor localized fatigue are summarized in *Figure 3*. The percentage decrease in mean IMDF calculated between the beginning (1st minute) and end (4th minute) of the lifting exercise demonstrates that paraspinal muscle fatigue is present, and is most evident in the lower lumbar region (R-L L5).

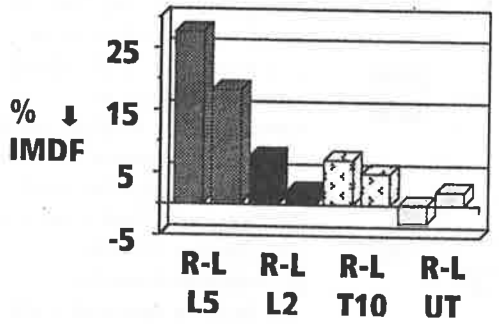

Figure 3. Mean percent decrease in instantaneous median frequency (IMDF) between the initial phase of lifting exercise (1st minute) and end of exercise (4th minute). Bar plots are arranged according to spinal levels (L5, L2, T10 and upper trapezius) and contralateral locations (Right-R, Left-L) of the EMG electrodes. Data are from the same subject presented in Figure 1 and 2.

Clinical Studies: Preliminary results indicate that the time course of IMDF parameters during repetitive lifting in LBP subjects is different than control subjects. Whereas the IMDF time-course in controls is characterized by alternate phases of increase and decrease in IMDF during repetitive lifting, LBP subjects with high levels of impairment do not display such variations. These differences suggest that the ability to limit overall fatigue by periods of recovery during the performance of a repetitive task, are compromised in some patients with LBP. This phenomenon could be related to muscle inhibition resulting from pain-related behavior [Roy et al. 1998]. There is insufficient data to determine whether such phenomenon is related to the patient's functional work capacity. Studies are in progress to investigate the dependence of such findings on factors such as patient characteristics and processing procedures.

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S-21

Surface EMG Variables as Influenced by Force and Speed in Isokinetic Contractions

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INTRODUCTION

The electromyogram (EMG) is a tool to grasp the central motor command in the final common path. While the recruitment and firing pattern of the motor unit as modulated with the spinal reflexes can be monitored by using the intramuscular electrodes, this method is invasive, localized in the recording area, and unfitted for dynamic contractions. Recent advances in the surface EMG studies have enabled us to noninvasively estimate the organization of different types of motor units and their behavior in average[1,2].

These procedures were hitherto developed under a condition of isometric contractions. However, most actions in our daily life involve dynamic contractions. Thus, as an attempt to establish a method to infer the motor control in dynamic contractions through the surface EMG variables, we examined in this study the relationship between these variables and the force/speed of dynamic contractions strictly controlled by using an isokinetic training device.

METHODS

Eight adult males aged 23 to 32 performed isometric and concentric knee extensions using a general purpose isokinetic training device (Cybex770-NORM), sitting on the device so as to coordinate the axes of knee joint and a rotatory lever arm of the device, with the relevant body segments firmly fixed. Torque with the maximum voluntary contraction (MVC) was measured in an isometric knee extension at a joint angle of 60 deg., with the angle at a full knee extension defined as 0 deg. In the concentric knee extension, the subject exerted an extension torque on the lever arm repeatedly rotating at a predetermined angular velocity within a joint angular range between 40deg. and 100 deg. The extension speed was set at 5 levels with 60 deg./s. intervals between 0 deg./s (isometric) and 240 deg./s., and the target torque at 4 levels with 10 % intervals between 40 % and 70 % MVC. Thus each subject performed $5 \times 4 = 20$ trials of dynamic contraction. Subjects were instructed to exert the target torque at around the knee joint angle of 60 deg, by visually monitoring the target torque and the torque they actually exerted. Sufficient time interval was taken between each trial.

Surface EMG signals were detected with an active surface electrode (DEM) having 4 silver contacts of 1 mm thick, 10 mm wide, and 10mm separated. Three channels of EMG signals were lead bipolarly from pairs of adjacent contacts, amplified at a band-width of 5 to 1000 Hz, and digitized at a frequency of 5 kHz. The average rectified value (ARV) and median frequency (MDF) were calculated by conventional procedures. The muscle fiber conduction velocity (MFCV) was obtained as a ratio of conduction distance of 10 mm and conduction delay between the EMG signals from the neighbouring two channels. The conduction delay was estimated by the time shift between the signals that gave the maximum cross correlation coefficient. Since surface EMG variables are affected by changes in the joint angle[3], comparisons among different conditions were made for the variables measured at a joint angle of 60 deg. in each exertion.

RESULTS AND DISCUSSION

The torque actually exerted approximated with the target torque in % MVC, and a significant negative regression between the torque exerted and the speed of extension was found for a given target torque. These results indicate that the exertions were performed properly as aimed. The ARV increased significantly with the level of target torque, and also increased significantly with extension speed for a given target torque, as reasonably predicted from previous studies[4]. Considering that the force yielded decreased with the speed, the augmented recruitment and/or firing rate appears to be exclusively used to enhance the extension speed. The MDF showed no clear relationship with the torque and speed, except that MDF in the isometric condition was significantly higher than in dynamic conditions. This absence of clear trend, however, was presumably due to a greater variance of MDF in dynamic conditions where the sampling time at the given joint angle was not long enough to yield a steady spectral profile.

The cross correlation coefficient between EMG signals from the neighbouring channels exceeded 0.9 in average, and was not significantly affected by the extension torque and speed. These results mean that propagation of the EMG signal was successfully registered, and that quality of the signal was excellent in general. ANOVA and regression analyses indicated that the MFCV was significantly greater in the extension with a higher target torque, as reported previously for isometric exertions[5], although the difference appeared minimal between 50% and 60%MVC. On the other hand, the MFCV pooled regarding the target torque was not significantly affected by the speed of exertion. It was noted, however, that the mean MFCV tended to increase with the speed in exertions at 40 % MVC, while an inverse tendency was observed at 70 %MVC.

Combined with the findings on the ARV, these results on the MFCV suggested the following; increasingly larger number of the fast motor units were recruited at 40 %MVC level to cope with increasingly faster exertions; thereafter at 50 to 60 %MVC, the size principle being fully attained, an achievement of higher torque and speed was done through a nonselective recruitment; at 70 %MVC, the recruitment having been completed, the necessity to produce the torque and to increase the speed of exertion was met by raising the firing rate; since, however, dynamic exertions at this loading level approach the maximal working capacity of the muscle, occurrence of the fatigue may have suppressed the MFCV.

CONCLUSION

Surface EMG variables were successfully determined during controlled dynamic contractions of the vastus lateralis muscle, by using an active array electrode and an isokinetic training device. The average rectified magnitude and propagation velocity of the EMG signals, registered during the knee extension with different levels of torque and speed, allowed us to infer that selective recruitment of motor units according to the size principle occurred in exertions up to 40 %MVC, whereas exertions achieved by using increased firing rate began at 70 %MVC.

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S-22

Mechanisms of Plasticity in Human Motor Cortex studied with transcranial magnetic stimulation

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Practicing movements results in improvement in performance and in plasticity of the motor cortex. To identify the underlying mechanisms, we studied use-dependent plasticity in human subjects premedicated with drugs that influence synaptic plasticity. Use-dependent plasticity was substantially reduced by dextromethorphan (an NMDA receptor blocker) and by lorazepam (a GABAA receptor positive allosteric modulator) and it was partially blocked in some individuals by scopolamine, while remained unaffected by the antiepileptic lamotrigine. These results identify NMDA and muscarinic receptor activation as well as GABAergic inhibition as mechanisms operating in use-dependent plasticity in intact human motor cortex and point to similarities in the mechanisms underlying this form of plasticity and long-term potentiation (LTP). Understanding of mechanisms of plasticity in humans could contribute to develop more rationale strategies to promote recovery of function in health and disease.

S-23

THE USE OF MOTOR EVOKED POTENTIALS IN REHABILITATION OF LOCOMOTOR DISORDERS

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The technique of transcranial stimulation is a painless and easily applicable technique to investigate the central motor conduction properties of various muscle groups, both in healthy humans and in patients with various neurological disorders. Since the MEP-latency times and central motor conduction times (CMCT) show a good reproducibility and a very small variability, these variables can be used as parameters in the diagnosis and follow-up of these diseases. For the MEP-amplitudes on the other hand, some caution needs to be taken into account, since they show a much higher variability. Here, left to right comparison is necessary, on condition that electrode placement is correct and similar for both sides and that stimulus parameters are the same bilaterally.

MEPs can be useful in physical therapy and rehabilitation. After the acute phases of several locomotor disorders, MEPs can be a useful tool to document rehabilitation progress. It not only gives important information about the prognosis and rehabilitation techniques to be used, but also can be applied as a quantitative measurement during the rehabilitation period. This allows the health professionals (such as the physical therapists and rehabilitation staff), who are dealing with either restoring the impaired spinal cord functions or compensating for the losses by enhancing the residual functions, to direct and evaluate the therapeutic procedures throughout the course of the rehabilitation. On the other hand it provides a helpful tool to motivate the patients, which may eventually lead to a better outcome result.

In *stroke* patients for example MEPs are a quantitative and objective method to document motor activity recovery, as they parallel improvement of motor function. Therefore, MEPs can be used as a qualitative and quantitative measurement of motor function and motor control at follow-up during rehabilitation.

In chronic *spinal cord injury* patients there are short and long latency MEP. Short and constant delay in MEP latency time can be explained by impaired conduction of long descending axons. Long and variable MEP latencies on the other hand probably result from the interposition of a spinal interneuron system between upper and lower motor neurons. In these patients transcranial motor cortex stimulation is a simple and non-invasive method to not only provide insight into the status of suprasegmental influence below the spinal cord lesion in subjects with residual motor control and to describe the supraspinal innervation pattern for locomotion, but also can be applied to document the evolution of motor control control in follow-up studies, particularly when different therapeutic or restorative procedures or interventions are applied.

In high cervical spinal cord injuries, as well as in several neuromuscular disorders, such as amyotrophic lateral sclerosis, Guillain-Barré syndrome, muscular dystrophies, myasthenia gravis, brachial neuritis, critical illness neuropathy, leprosy, metabolic disorders etc., often in the critical care unit, the respiratory muscles can be affected. To measure central conduction in order to assess the integrity of the corticospinal tracts and central respiratory drive magnetic transcortical and nerve root stimulation of the respiratory muscles now also can be performed.

S-24

New Clinical Applications of Transcranial Magnetic Stimulation

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INTRODUCTION

Transcranial magnetic stimulation (TMS) is a non-invasive technique for activating brain through the skull which has been widely used as diagnostic and scientific purposes to evaluate the neurophysiological characteristics of sensorimotor cortex, cerebellum, upper and lower motor neurons and higher brain functions. Recently, repetitive transcranial magnetic stimulation (rTMS) which induces lasting effects on cortical excitability, has been shown to have therapeutic potential without opposite effect in patients with depression or Parkinson disease. However, the induction seizures by rTMS in normal subjects is the important problem for clinical applications. The safety issue is a major concern to the human utility of rTMS.

We studied motor evoked potentials (MEPs) recorded from tongue and paraspinal muscles and cortico-cortical evoked potentials (CCEPs) by single TMS to evaluate clinical applications in normal subjects and patients with neurological disorders. Furthermore, we investigated clinical usefulness of rTMS for the treatment in major depression.

METHODS, RESULTS and DISCUSSION

1. <u>Tongue MEPs</u>

To evaluate objective motor functions of the tongue, MEPs induced from the tongue muscles have been recorded by single TMS over the motor cortex of tongue and by magnetic or electrical stimulation at the hypoglossal nerve in normal subjects. The hypoglossal nerve was stimulated at the mandibular angle electrically or at the posterior lateral skull magnetically. The purpose of this study is to investigate a clinical usefulness of our new method to stimulate the hypoglossal nerve using a special double cone coil, and to establish a normative mapping of the motor cortical output to the tongue muscles using the double cone coil or a figure of 8-shaped coil.

We examined 10 right-handed healthy volunteers. Tongue MEPs were recorded from the surface electrodes fixed with a clip on the both sides of tongue. The hypoglossal nerve at the mandibular angle was stimulated magnetically placing a center of the special double cone coil. The optimal site of cortical magnetic stimulation to elicit maximal contralateral tongue MEPs

was a point at 11 cm lateral and 3 cm anterior from Cz. Our results were the same as the past studies on the amplitudes and the latencies of tongue MEPs, and on the motor conduction times from the motor cortex of tongue to the proximal part of hypoglossal nerve. The MEP amplitudes after the stimulation of left motor cortex were significantly larger than those after the stimulation of right motor cortex. In addition, there were prominent fascitatory effects of vocalization for tongue MEPs after the stimulation of left motor cortex.
From these data, we speculate that functions of corticobulbar tracts have interhemispheric differences between left and right motor cortex.

2. Paraspinal MEPs

We investigated the clinical usefulness of paraspinal MEPs following single magnetic stimulation over the motor cortex. Subjects were 7 healthy volunteers, 5 patients with multiple sclerosis (MS) and 4 patients with HTLV-1 associated myelopathy (HAM). Paraspinal MEPs at the Th 3, 6, 9 and 12 vertebral levels were recorded from surface electrodes placed over the paraspinal muscles and concentric needle electrodes inserted into the deep paraspinal muscles (multifidus muscles). Paraspinal MEPs were evoked by the stimulation of contralateral motor cortex during slightly voluntary contraction of the back muscles.
Paraspinal MEPs recorded from the surface electrodes in normal subjects were poorly elicited even when the maximum strength of the magnetic stimulation was applied, and their onset latencies were not correlated to the distance from the motor cortex. Conversely, paraspinal MEPs recorded from the needle electrodes were elicited clearly, and their onset latencies increased linearly in accordance with the distance from the motor cortex.
There were no induction of paraspinal MEPs below the spinal cord lesions or significantly delayed onset latencies in patients with MS. Laterality of paraspinal MEPs was also recognized in these patients. In the patients with HAM, onset latencies of paraspinal MEPs were significantly prolonged bilaterally.
These results indicate that paraspinal MEPs after cortical magnetic stimulation recorded from the needle electrode at multifidus muscles are very useful to detect the lesions in thoracic cord.

3. Cortico-cortical evoked potentials (CCEPs)

Event-related potentials (ERPs) have demonstrated as an electrophysiological method for evaluation of the human higher cortical function. However, this examination needs cooperation of the patient. The purpose of this study is to develop the methods of recording brain evoked responses (cortico-cortical evoked potentials: CCEPs) after single magnetic stimulation of the primary sensory cortex in human.
White noise was given to both ears of the subjects to prevent the sound effects of the magnetic stimulator. The recording electrodes which were special shape with less influences by the magnetic field, were placed on Fz, Cz, Pz, C3, and C4 (international 10-20 system). Single TMS using a figure of 8-shaped coil was delivered over the sensory and visual cortex at an intensity of the motor threshold.
The CCEPs in normal subjects were clearly recorded in reproducibility, and consisted of N100 and P200 components which distributed widely over the scalp, with those prominent potential at the vertex (Cz). On the other hand, the patients with dementia or disturbance of consciousness showed significantly delayed latencies, low amplitudes or no responses of CCEPs.
This method does not need cooperation of the subjects and is not influenced by the dysfunctions of afferent pathways to the cerebrum. The mechanisms of abnormal CCEPs in these patients with dementia could be related to the higher brain dysfunctions.

4. Effects of left prefrontal repetitive transcranial magnetic stimulation in the patients with drug-resistant major depression

Several investigations have indicated that daily left prefrontal repetitive transcranial magnetic stimulation (rTMS) might have antidepressant effects because the pathophysiology of depression may include synaptic hypoactivity of left prefrontal cortex.
This study assessed changes in clinical characteristics of depression, neurotransmitter levels and immunological activities associated with daily left prefrontal rTMS in five patients with drug-resistant major depression. rTMS was applied in 40 trains of 20 stimuli (20 Hz for 2 s, intertrain interval of 2-3 minutes) at an intensity of 90% of the motor threshold for ten days. We measured the effects of left prefrontal rTMS on depression scores, plasma 5-HIAA concentration and NK cell activities. The patients who received rTMS had a significantly greater improvement in depression scores.
After daily left prefrontal rTMS treatment for two weeks, the scores on Hamilton Rating Scale for Depression decreased in about 20-60% in comparison with those before the treatment. On the other hand, significant increases in plasma 5-HIAA concentration and NK cell activities were admitted in the patients by whom rTMS had shown the good responses for depression,.
These data suggest that left prefrontal rTMS improves the mood in patients with drug-

resistant depression, and there is a correlation between mood improvement and increases of plasma 5-HIAA concentration and NK cell activities.

CONCLUSION

Tongue and paraspinal MEPs and CCEPs evoked by magnetic stimulation are non-invasive and very useful techniques for evaluating the functions of corticobulbar and corticospinal tracts at the tongue and paraspinal muscles clinically. Furthermore, our controlled study provides for therapeutic efficacy of daily left prefrontal rTMS in patients with drug-resistant major depression, and rTMS induced changes in brain neurotransmitter levels and immunological functions in these patients. Left prefrontal rTMS may alter brain activity at sites remote from the stimulation.

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S-25

Air-puff-induced motor cortical facilitation in humans

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Introduction

Well somatotopically organized interaction has been demonstrated in the hand sensorimotor area of the Macaca mulatta monkey[1]. In the present communication, we studied whether a similar interaction is present in humans using a magnetic stimulation method[2]. Another aim of this study is to investigate the pathway responsible for such interaction by studying patients with descrete lesions in the brain.

Subjects

We studied 10 normal volunteers to obtain the normal values and 27 patients with descrete lesions in the brain (16, 9 and 2 patients with a lesion in the cerebral cortex, thalamus and medulla, respectively).

Methods

Electromyographic (EMG) responses to the electrical or magnetic cortical stimulation were recorded from a few hand muscles with surface cup electrodes. These motor evoked potentials (MEPs) without air stimuli (conditioned trials) were compared with those with air stimuli to the tip of several fingers (conditioned trials). Randomized conditioning-test paradigm was used in the experiments.

Results

Normal subjects (Fig 1,2)
Air stimuli applied to the tip of one finger facilitated mainly the magnetically evoked MEPs of a muscle attached to that finger even though they did not affect the electrically evoked MEPs of the same muscle. This indicates that the facilitatory effect is produced at the cortical level.
Patients (Fig 3)
Facilitation was absent in patients with lesions involving the primary sensory (S1) or motor cortex (M1) or both of them, including a patient who had only a SEP component reflecting the direct thalamic input to the motor cortex (P22)[4], and a patient with a small subcortical lesion involving corticocortical projection fibers adjoining M1 and S1. In contrast, facilitation was preserved in patients with cortical lesions sparing M1 and S1. The effect was not affected even in a patient with a large lesion involving the right medial frontal and parietal cortices and the corpus callosum (primary motor cortex isolation[5]). Facilitation was abolished with thalamic lesions totally destroying the nucleus ventralis posterolateralis (VPL), but was preserved with lesions sparing it. In patients with Wallenberg's syndrome (lesions in the medulla), facilitation was preserved.

Discussion

We have shown a well-organized human sensory-motor cortical interaction similar to that demonstrated in primates. The results of patients with cortical lesions suggest that the intact M1 and S1, especially its anterior portion (area 3 and 1), are requisite for this facilitatory effect. The results of the patient with preserved p22 of SEP and patients with Wallenberg's syndrome indicate that neither the direct thalamic inputs into the motor cortex nor the spinothalamic tract contribute much to this effect. Based on these, we conclude that the facilitation is mainly mediated by sensory inputs that ascend the dorsal column and reach the cortex through VPL and that these are fed into M1 via S1.

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Fig 1 (Ref. 2)

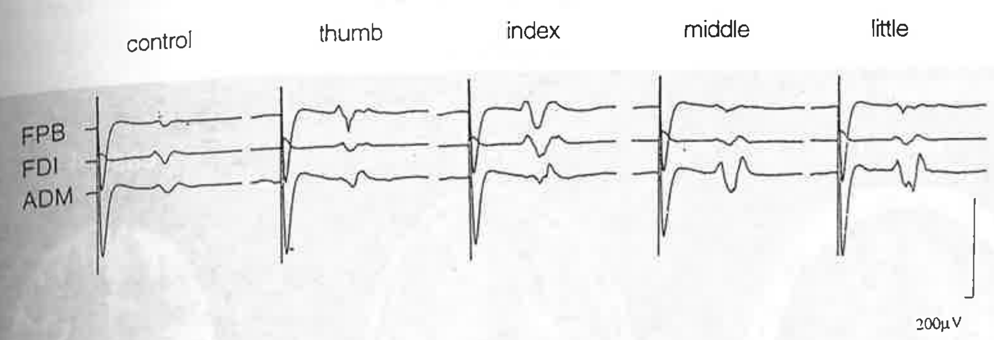


Fig. 1. Typical pattern of facilitatory effect of air stimuli on magnetically evoked MEPs. The average responses of 10 trials for each condition evoked in 3 finger muscles, flexor pollicis brevis (FPB), first dorsal interosseous (FDI) and abductor digiti minimi (ADM) are shown in the first to third rows. The first to fifth columns, respectively, show the control responses and the conditioned responses with air stimuli applied to the tip of the thumb, index, middle and little fingers. The MEP of FPB was facilitated when air was applied to the thumb and index finger, but not when air was applied to the middle and little fingers. Likewise, facilitation was observed for FDI when air was applied to the index finger, and for ADM when air was applied to the middle and little fingers.

Fig2 (Ref. 2)

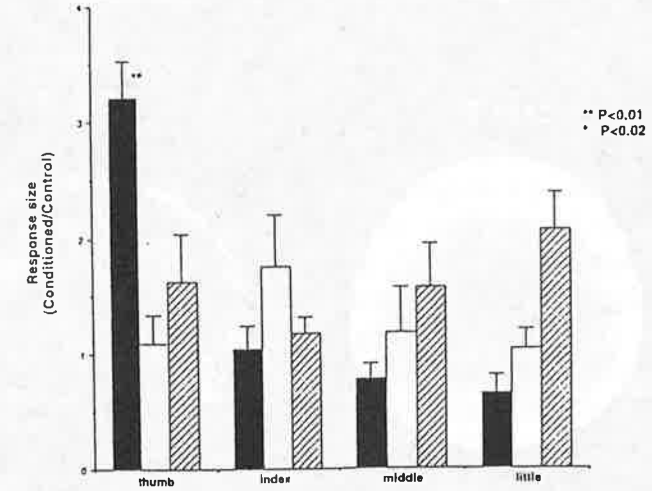
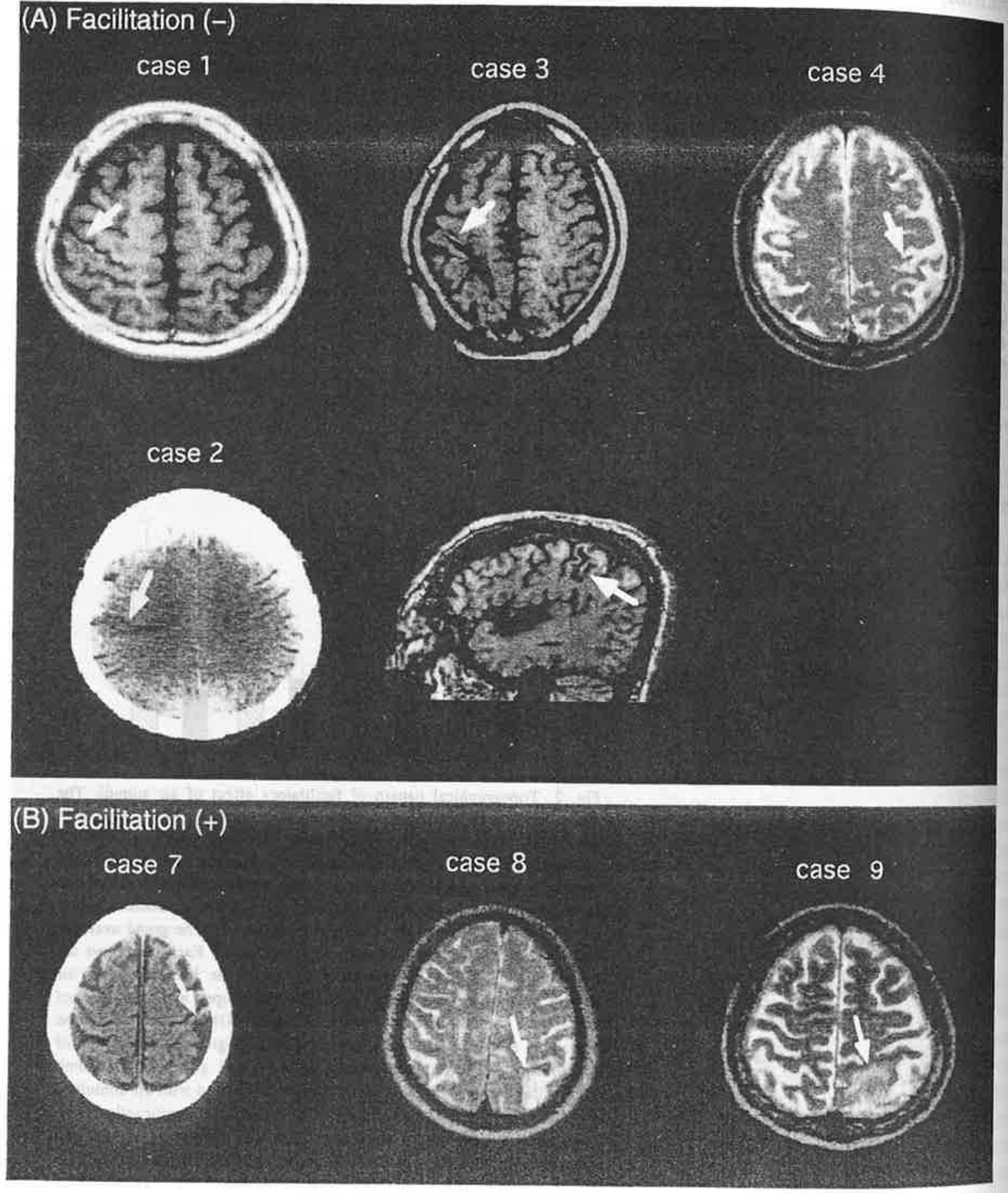


Fig. 2. Topographical pattern of facilitatory effect of air stimuli. The above mentioned pattern of facilitation was common to 4 subjects in whom all 3 muscles were investigated. The trial which showed the maximal facilitatory effect was selected as a representative trial for each muscle in each subject. The ratios of MEP amplitudes of conditioned to control responses in such selected trials under different conditions were calculated as representative values for each subject. The grand averages and standard errors of these values were calculated. Each bar shows the mean ($\pm$S.E.) of these representative values for the 3 muscles when air stimuli were given on different sites. The filled, open and cross-hatched bars stand for responses in FPB, FDI and ADM, respectively. The horizontal axis gives the site of air stimulatión. Significant facilitation of the MEP of FPB was observed with air stimuli given to the thumb ($P < 0.01$), while there was no significant facilitation with air stimuli to the other fingers. Likewise, the MEP of ADM was significantly facilitated only by air stimuli applied on the little fingers ($P < 0.02$). In general, no significant facilitation was observed for FDI, regardless of the site of air stimulation. In some subjects, however, air over the index finger facilitated the FDI responses.

Fig3 (Ref. 3)



S-26

The physiological meaning of the surface mechanomyogram during voluntary and stimulated muscle contraction."

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During muscle contraction the mechanical activities of the recruited fibres is commonly investigated using the force (F) signal. In the last two decades it has been explored the possibility to follow the mechanical activity of the motor units (MUs) by means of transducers (microphones, accelerometers, piezoelectric contact sensors) detecting the muscle surface displacement due to the pressure waves generated by the dimensional changes of the active fibres within the muscle. In this paper it will be referred to the electrical outcome of the transducers as surface mechanomyogram (MMG)[25]. Moreover, for sake of clarity the physiological meaning of the MMG during voluntary and stimulated contraction will be considered separately.

Voluntary contraction. Recent papers [26, 34, 44] confirm that the surface mechanomyogram can be considered as a biological signal in which the muscle surface oscillations due to the mechanical activities of the recruited motor units are reflected. This is evident in figure 1 (redrawn from [25]) where the electrical (upper trace) and the mechanical (lower trace) activities of the recruited motor units from the extensor digitorum brevis are reported. Due to the longer duration of the mechanical event the MMG presents an interferential pattern while the action potentials of the single motor units are still isolated. What's reported above suggests that the MMG properties may be influenced by the number, the type and the firing frequency of the active motor units. It is known that larger limb muscles and small hand muscles recruit MUs up to 60-80 % and up to 30-50% of the maximal voluntary contraction [9], respectively. Higher effort levels are reached increasing the MUs' firing frequency. The use of high firing rate to generate force, determining a fusion-like situation with little dimensional changes of the active MUs between one motor command and the following, should be monitored by clear reduction in the amplitude and increase in the spectral mean frequency of the MMG. This has been reported for the biceps brachii [2, 19, 21], rectus femoris [3, 39], soleus [44] and jaw elevator muscles [40]. *It can be concluded that from low to high levels of effort the behaviour of the parameters related with the time and frequency domain analysis of the MMG reflect the MUs activation pattern.* As a consequence the MMG has been used to investigate the MUs activities also in muscles affected by specific diseases [1, 5, 27, 38] or during fatiguing contractions [4, 12, 13, 14, 15, 16, 17, 20, 22, 23, 37, 38, 41, 45].

Stimulated contraction. The dimensional changes of a supramaximally stimulated muscle was generate muscular surface oscillations that can be recorded by means of a microphone [11, 33, 35, 36, 42], a piezoelectric contact sensor [6, 10, 18, 24], an accelerometer [7, 8, 28, 30, 43] or by a laser distance sensor [29, 31, 32]. *All the above reported papers provide data supporting the conclusion that the surface mechanomyogram reflects the contractile properties and specific mechanical responses of the investigated muscle.* In particular data from the accelerometer detected MMG suggest that this signal is related with specific aspects of muscle mechanics. Indeed in their study Orizio et al.[30] compared the MMG and the force signal characteristics before and after a fatiguing stimulation as well as during a recovery period of 6 minutes. At fatigue, during the single twitch, the force peak, the peak rate of force production and the peak of acceleration of force production (d^2F/dt^2) decreased while the contraction time and the ½ relaxation time (½ RT) increased. In the mean time the MMG peak to peak (p-p) also decreased. As reported in figure 2 (redrawn from [30]) a high correlation between MMG p-p and d^2F/dt^2 was found in un-fatigued muscle and during recovery. The AA concluded that MMG can be a tool to follow the changes of the muscle contractile properties during localised muscle fatigue. Recently the muscle surface displacement has been studied by a laser distance sensor. Aim of these studies [31, 32] was to compare the force and the muscle transverse diameter dynamics during electrical stimulation of the motor nerve of cat medial gastrocnemius. In four cats the exposed motor nerves of the medial gastrocnemius were stimulated in order to obtain different levels of activities of the MUs' pool increasing the firing frequency (eight separate trials at fixed firing rates (FR): 5, 10, 15, 20, 25, 30, 40 and 50 Hz (9 s duration, supramaximal amplitude)) or increasing the number of recruited (REC) MUs stimulated at 40 Hz. Moreover it was verified if the laser detected MMG was suitable to estimate a frequency response and if this last was comparable to the one retrieved by the force signal at the tendon level. The frequency response was investigated by sinusoidally changing the number of orderly recruited motor units, in the 0.4 - 6 Hz range, able to respond at a fixed stimulation rate of 30 Hz. The induced force oscillation at the reference 0.4 Hz frequency was between 20 and 80% of the maximal output tension. It resulted that a) a non-linear force vs MMG relationship is always present (with low and steep slope for low and high levels of MUs ' pool activation, respectively) (see figure 3, redrawn from [31]); b) it was possible to model the force and MMG frequency response by a critically damped second order system with two real double poles and a pure time delay. The poles were at 1.83 Hz (with 22.6 ms delay) and at 2.75 Hz (with 38 ms delay) for force and MMG, respectively (see figure 4, redrawn from [32]). From the above reported results it can be concluded that a) the force and the lateral displacement are not linearly related, b) the MMG appears to be a reliable tool to investigate the muscle frequency response during stimulated isometric contraction. The different behaviour of F and MMG, from low to high level of the MUs' pool activation and in the values of the parameters of the dynamic frequency response, suggest that the force generation and the muscle dimensional changes processes are influenced by different components of the muscle mechanical model.

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Figure 1

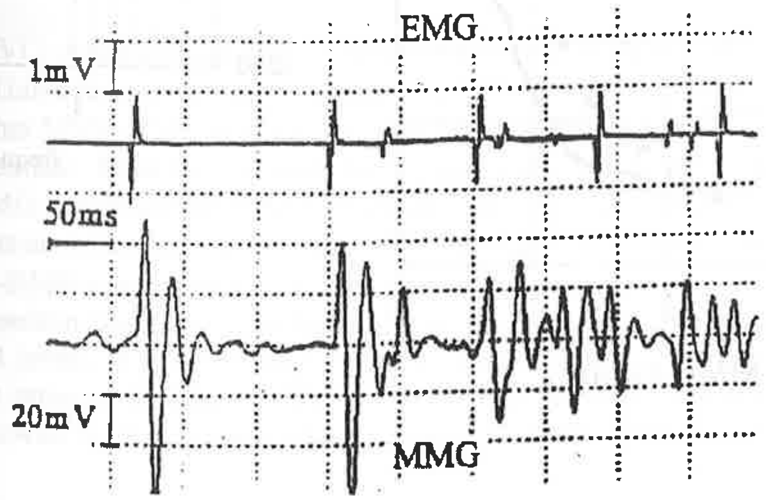


Figure 2

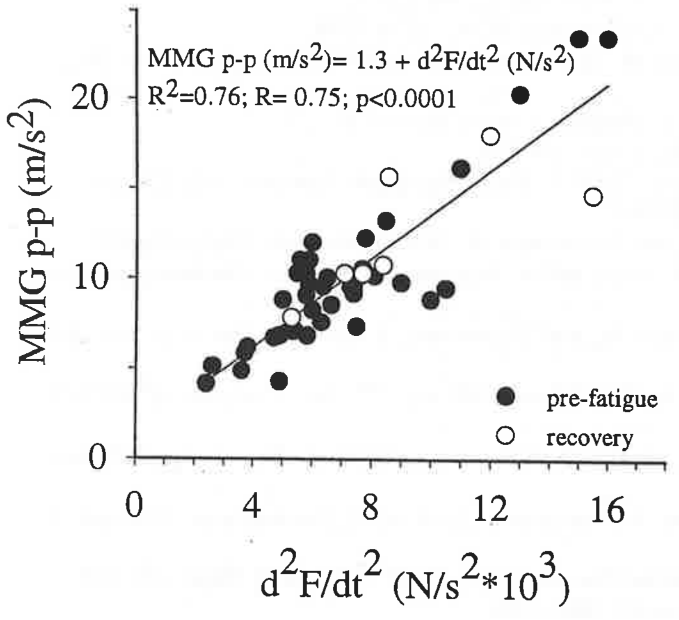


Figure 4

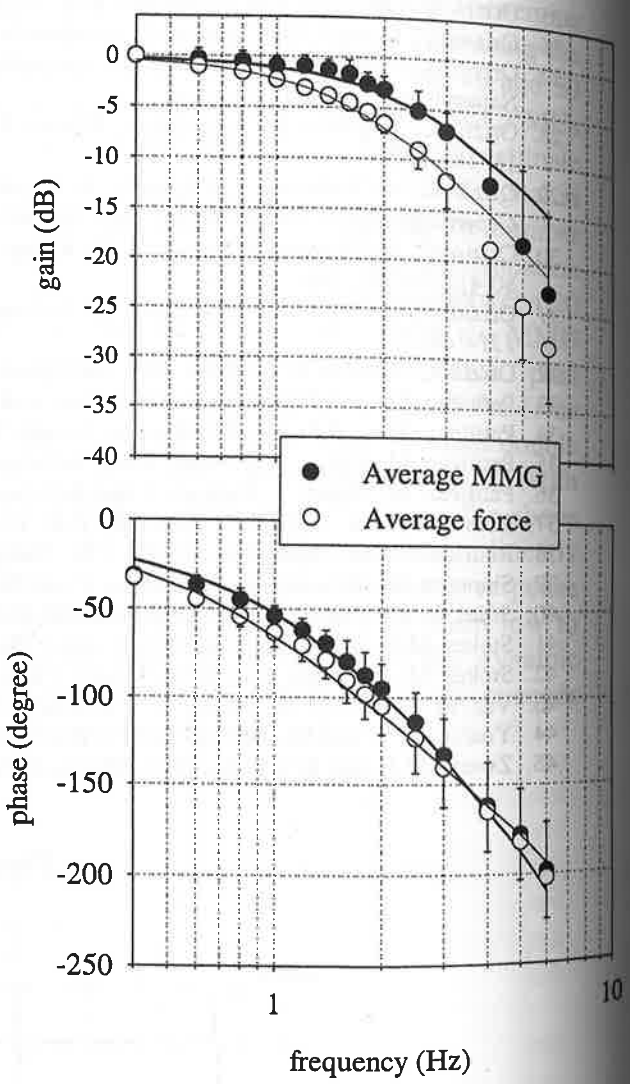
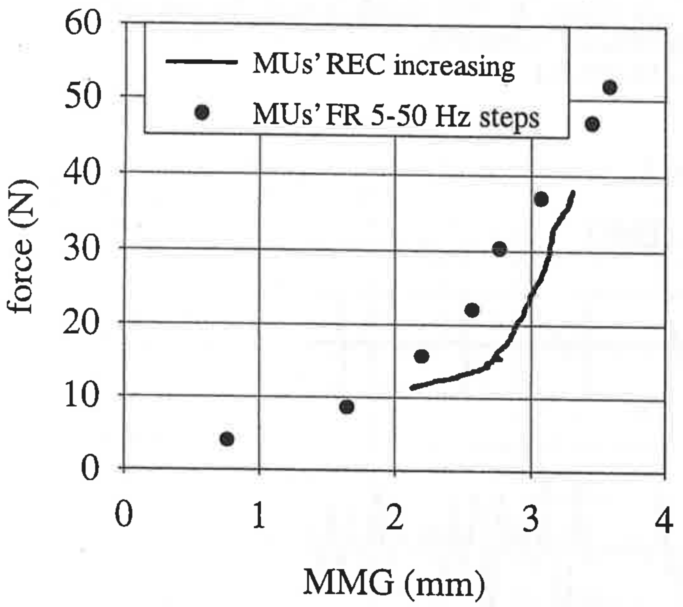


Figure 3



S-27

Muscle sounds recording during fatigue and Muscle equivalent concept

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INTRODUCTION

Since Barry et al. pioneer work (1) many authors have investigated the relationship between mechanomyographic signal (MMG) and muscle fatigue. Today, there is a consensus on Barry et al. proposal that acoustic myography (here called MMG) may be « a non invasive monitor of motor unit fatigue ». However, it must be pointed out that in all studies performed in man, MMG was evaluated as a function of the force measured at the extremity of a limb segment, as if this force resulted from the only muscle underlying the MMG sensor. That means that all the authors have implicitly admitted the Muscle equivalent concept: i.e: the force exerted by one muscle is proportional to that of the other agonistic muscles (2,4). In the present study it was hypothesized that if MMG is a valid index of the force exerted by the recorded muscle and if the Muscle equivalent concept is valid, then the MMG from different agonistic muscles should vary in the same way during fatiguing voluntary contractions.

METHODS

Experiments have been performed on 8 healthy men, aged 30-48 years. Subjects were seated with the forearm fully supinated and strapped to a mechanical system which could rotate in a horizontal plane around a vertical axis. The elbow axis was made coincident with that of the mechanical device. When elbow was flexed at 90 degrees, a strain gauge was attached to the system allowing static measurement of the external force. Surface EMG from muscles Biceps brachii (BB) and Brachioradialis (BR) were recorded simultaneously with MMG. MMG was actually an acoustic signal recorded by mean of a microphone inserted in a small device strapped to the skin. After amplification, all signals were digitized and analyzed off-line by using a PC microcomputer. In a first set of experiments, subjects had to perform maximal voluntary contraction of the elbow flexors and then tried to keep the maximal voluntary force (MVF) at its initial value until it fell under 50 p.cent of this value. In a second set of experiments subjects were asked to perform a 50 p.cent MVF as a long time as possible, i.e. until the endurance time. MMG and EMG RMS values were calculated over 1024 ms periods of time, every 10 seconds following the onset of the task.

RESULTS

1) Fatiguing MVC: After a short time of MVC, the force exerted by the subjects decreased progressively. This decrease was always accompanied by a drop in both BB and BR MMG amplitude, so that MMG-RMS was significantly lower at the end of the task ($p \leq 0.001$). The relationship between MMG-RMS and force was best fitted by a parabolic function. Meanwhile, EMG amplitude showed a more or less important decrease or increase. As a consequence, the statistical comparison made on the whole of the experiments between initial and final EMG-RMS values revealed a poor difference ($p \leq 0.05$) and only for muscle BB. A statistical comparison made between the MMG normalized RMS values of BR and those of BB at different levels of force during the force decrease did not revealed any significant difference. The same comparison, made between EMG normalized RMS values of BR and those of BB showed no difference for forces ranges 100-80% MVC and 60-50% MVC but a

significant difference (p≤0.01) for the forces range 80-60% MVC. This complex evolution in EMG amplitude expressed important differences between and within experiments.

2) Fatiguing 50 p.cent MVC: For every experiments, MMG and EMG have been studied over the time where the force exerted by the subjects remained constant. Whatever the muscle, MMG-RMS mean value remained approximately constant during the task but with a non-negligible variability. At the opposite, EMG-RMS from both BB and BR increased progressively from the onset to the end of the task.

DISCUSSION

The relationship which is found here between MMG and force for fatiguing MVC is similar to that described in the absence of fatigue for the same muscles, in the same experimental conditions (5). Furthermore, it is shown that BB-MMG and BR-EMG amplitudes behaved in the same way. Thus, the data converge on the idea that MMG amplitude expresses the force exerted by a muscle in the presence as well as in the absence of fatigue. EMG changes over time appeared more variable. This could be related to the subtle changes in firing frequency and recruitment of the alpha motoneurones pools which intend to compensate for the loss of mechanical efficacy of fatigued motor units. During fatiguing submaximal contractions the absence of statistical difference between MMG-RMS mean values measured at the beginning and at the end of the task may be interpreted as another proof of a proportionality between MMG amplitude and muscular force. However, the variability of MMG in the presence and in the absence of fatigue (5,6) remains disturbing. It may be explained by a variability of the force exerted by the muscle or by influences of tremor or/and by influences from remote muscles. The relationships between EMG-RMS and elapsed time which were found here for 50 p.cent MVC were similar to those previously described (3). The whole of these data are in good agreement with the Muscle equivalent concept and reinforce the idea that MMG reflects the force exerted by the muscle underlying the sensor whereas EMG reflects motor units excitation.

Nevertheless more experiments are needed before using MMG amplitude as a measurement of the voluntary force exerted by the muscle from which the signal is recorded.

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Mechanomyographic behavior of biceps brachii muscles during linearly increased voluntary contractions

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INTRODUCTION

It has been reported that the mechanomyogram (MMG) reflects the motor unit (MU) activation strategy associated with their recruitment and firing rate. Namely, the amplitude of the MMG elicited by electrical stimulation increased as a function of the recruitment level of the MUs, whereas higher firing rate induced a decline in the MMG amplitude due to the fusion of the MU mechanical activity. This indicates that the MMG is influenced by both the number of active MUs and their firing rate. The time and frequency domain parameters of the MMG during voluntary contractions was also found to reflect similar interaction between the MU recruitment and firing rate.

These physiological findings were estimated on the basis of the MMG recordings during sustained or stable voluntary contractions at separate levels of submaximal force (referred to as *separate contraction* in this paper). The frequency domain analysis of the MMG during separate contractions was performed by the conventional fast Fourier transform (FFT) algorithm under the assumption that the signal was stationary. Thus, there was a limit in the force resolution in the MMG-force relationship. The non-stationary MMG during dynamic force exertion is considered to enable to offer more detailed information on the MU activation strategy.

The aim of this study is to determine the time and frequency domain parameters of the MMG during a linear progression of submaximal isometric contractions using the short-time Fourier transform algorithm and to discuss the contribution of the recruitment and firing rate of the MUs to their activation strategy.

METHODS

The experiments were performed on twelve healthy male subjects (25±2 yr). The purpose and procedure of the experiment was informed to all the subjects then their consent was accepted. Each subjects was seated in a chair with the right arm positioned on the horizontal platform. The elbow was flexed at 90 degrees, the forearm was maintained in neutral, and the wrist was fixed by a metal plate with the hand opened. Each subjects was asked to exert isometric elbow flexion force so as to pursuit a target force on a computer screen. The target pattern consisted of stable contractions at 5% MVC for 3 s followed by linear progression of submaximal contractions from 5% to 80% MVC at a constant rate of 10% MVC/s. This contraction was referred to as *ramp contraction* in this paper. The force output exerted was superimposed real-time on the screen to provide feedback to the subject.

The measurement of the elbow flexion force was allowed by a force transducer with a strain gauge which was coupled to a metal frame attached at subject's wrist. The force signal was amplified through a strain amplifier. The MMG was detected with an accelerometer with the frequency response of DC to 150 Hz, which was secured with adhesive tape over the belly of biceps brachii muscles. The MMG signal was amplified and filtered by an AC amplifier with a bandwidth of 5-100 Hz. The MMG signal was recorded together with the force signal on a digital audio tape recorder, then stored on a personal computer disk after being digitized at a sampling rate of 5,000 samples/s.

In order to determine continuous change of the MMG with linearly increased force, the short-time Fourier transform was used. Namely, from a time series of the MMG recording, short segments with length of 0.6 s were cut every 0.1 s using the Gaussian function window with the standard deviation of 0.3 s. The power spectral density function (PSD) of each data segment was estimated by the fast Fourier transform algorithm. The root mean squared (RMS) amplitude and mean power frequency (MPF) were computed from the PSD.

RESULTS

Inter-individual means and standard deviations of the RMS amplitude and MPF of the MMG are presented as a function of submaximal force level in Fig. 1. The RMS amplitude for each subject are normalized by his maximal value prior to the statistical processing (averaging). The RMS amplitude changed four times compared with that the initial force level. There were two inflection points in the RMS-amplitude-force relationship. The RMS amplitude increased slowly up to approximately 20% MVC then this trend was accelerated. Beyond 60% MVC a progressive reduction of the RMS amplitude was observed. The MPF changed between 15 and 40 Hz with increasing force. The MPF-force relationship included three inflection points. A relatively rapid increase in the MPF up to approximately 30% MVC was followed by a slow change. Then, a rapid increase above 60% MVC was accompanied with a temporary reduction around 50% MVC.

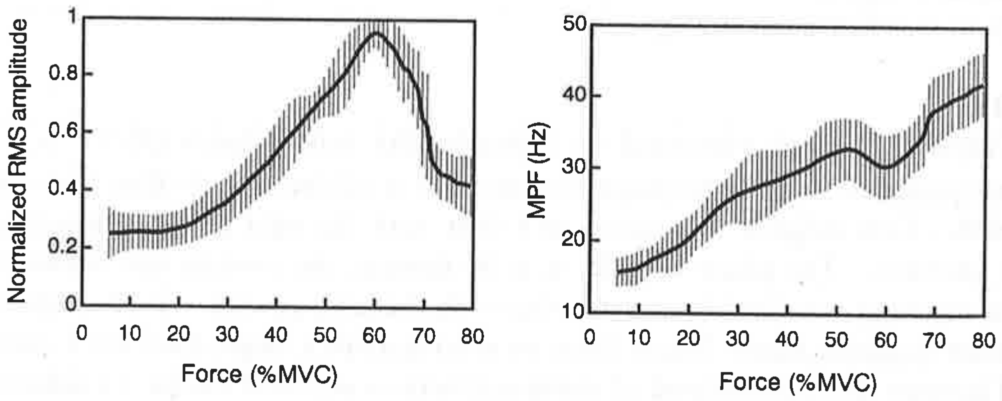

Fig. 1 Inter-individual means and standard deviations of the RMS amplitude and mean power frequency of the MMG as a function of submaximal force.

The inflection points in the RMS amplitude and MPF were determined quantitatively by introducing the rate (differentiation) of the RMS amplitude and MPF with increasing submaximal force (Fig. 2). The force level A_1 was defined when the rate curve of the RMS

amplitude intersected zero level and it was 19.9±4.5% MVC (inter-individual mean±SD). Particularly a slight temporary decrease of the RMS amplitude was observed before the force level A_1. The maximal RMS amplitude occurred at 59.9±2.5% MVC, that was defined as the force level A_2. The rate curve of the MPF demonstrated greater positive changes up to the force level F_1 (30.4±5.4% MVC), then became slow. After that, a temporary reduction in the MPF from the force level F_2 (51.3±2.6% MVC) was followed by its greater increase from the force level F_3 (59.9±2.5% MVC), that was almost identical to the force level A_2.

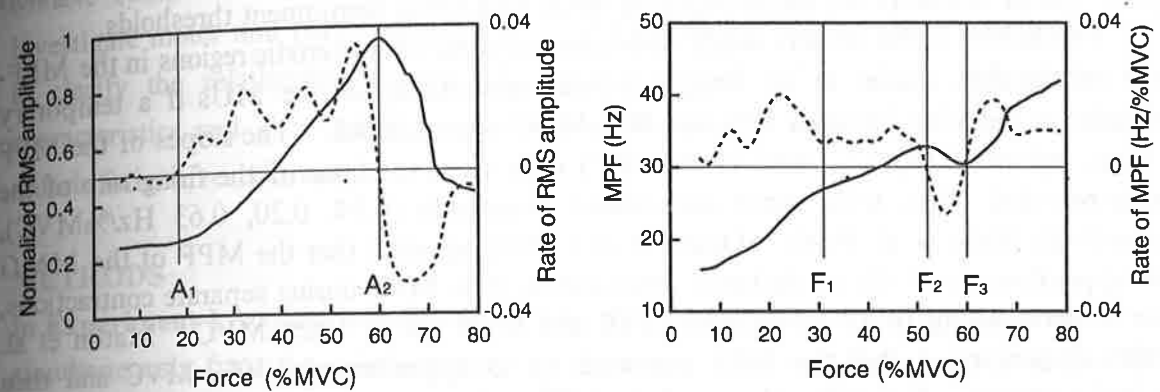

Fig. 2 RMS amplitude and mean power frequency of the MMG (solid lines) and their rate (dotted lines) as a function of submaximal force.

DISCUSSION

The relationship between the amplitude of the MMG and force during ramp contractions was almost similar to that during separate contractions reported previously, i.e., a parabolic increase up to 60% MVC followed by a decrease (Orizio et al. 1989; Akataki et al. 1999). In addition, a slight temporary decrease of the RMS amplitude between 10% and 20% MVC was estimated by negative values in the rate curve of the RMS amplitude. This temporary depression has not been reported yet. Although small increment of the MMG amplitude below 30% MVC was reported during separate contractions, it seems to be difficult to determine the sight and short reduction by separate contraction trials with low force resolution.

The continuous change in the MPF of the MMG during ramp contractions was almost identical with that in the firing rate of single MU recorded during similar ramp contractions at 10% MVC/s. The firing-rate-force relationship for each MU of tibialis anterior muscle was characterized into three contiguous regions (De Luca and Erim 1994). In the first region up to 20% MVC, the firing rate elevated rapidly as force increased. The next region was one where the MU increased its firing rate slowly with force. The boundary between the second and the third region coincided with the force level (60%-70% MVC) at which all MUs were fully recruited. The firing rate in this last region increased much faster than that in the previous region. Clamann (1970) also reported similar relationship between the firing rate and force in single MU of biceps brachii muscles.

Furthermore, the MUs were divided into three groups depending on the recruitment threshold : low (0-20% MVC), medium (20-50% MVC) and high (above 50% MVC) threshold (Erim et al. 1996). The earlier-recruited MUs with lower recruitment thresholds started their firing at lower initial rates than the later-recruited counterparts with higher thresholds. The higher-threshold MUs had more rapid slopes in the first region of the firing-rate-force relationship and followed the firing-rate behavior of the earlier-recruited MUs. Then the firing rate tended to converge to a same value at the maximal force level independent of the recruitment threshold (De Luca and Erim 1994; Erim et al. 1996). Thus the overall firing-rate behavior of all the active MUs might be also characterized by three contiguous regions similar to that of the earlier-recruited MUs with lower recruitment thresholds.

The MMG in the present study demonstrated three characteristic regions in the MPF-force relationship similar to the firing-rate-force relationship of the MUs if a temporary reduction in the MPF between 50% and 60% MVC was excluded. The slopes of the MPF in three regions (0.49, 0.31, 0.67 Hz/%MVC) were close to those of the firing rate of the earlier-recruited MUs with lower recruitment thresholds (0.54, 0.20, 0.63 Hz/%MVC), respectively (Erim et al. 1996). Orizio et al. (1990) reported that the MPF of the MMG was approximately 11 Hz at the lower levels below 20% MVC during separate contractions, then it increased up to 15 Hz at 80% MVC and to 22 Hz at 100% MVC. Maton et al. (1990) demonstrated that the MPF increased up to approximately 30% MVC and then reached a plateau. Generally, change of the MPF with increasing force is smaller compared with that of the amplitude. The different MPF characteristics between the previous reports and the present study may be associated with each experimental contraction pattern, particularly because of low force resolution in separate contraction trials.

CONCLUSION

The time and frequency domain parameters of the MMG was investigated during ramp contractions using the short-time Fourier transform algorithm. The RMS amplitude increased slowly up to 20% MVC, then this trend was accelerated. Beyond 60% MVC a progressive reduction of the RMS amplitude was observed. The MPF-force relationship included three inflection points. A relatively rapid increase up to 30% MVC was followed by a slow change, then a rapid increase above 60% MVC was accompanied with a temporary reduction around 50% MVC. Theses results suggest that the MMG during ramp contractions provides more detailed information on the MU firing strategy.

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Analysis of Muscle Sound Properties during Voluntary and Electrically Induced Contractions and its Application to Low Back Muscle Fatigue

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INTRODUCTION

Muscle sound has recently gained considerable attention as a new noninvasive tool to investigate motor unit (MU) activity[1) 2) 3)]. The purpose of the present investigation was 1) to clarify the relationship among MU activity, muscle fiber types, and muscle sound characteristics and 2) to apply soundmyogram analysis to study the etiology of low back muscle fatigue, respectively.

METHODS

In Experiment I, soundmyogram (SMG) and electromyogram (EMG) signals were recorded simultaneously from the relatively fast medial gastrocnemius (MG) and slow soleus (SOL) during voluntary isometric plantar flexion at 20, 40, 60, and 80% MVC for 4 sec and electrically induced contractions at 5, 10, 15, 20, 25, and 30 Hz, in random order, respectively[4)]. Using a spike-triggered averaging technique in six subjects, the averaged the elementary sound and corresponding MU spikes were also obtained from about 35 different MUs identified.

In Experiment II, we investigated the etiology of low back muscle fatigue by means of simultaneous recordings of EMG, SMG, and near infrared spectroscopy (NIRS). Eight male subjects performed back extension isometrically at an angle 15° with reference to the horizontal plane for a period of 60s. Surface EMG, SMG and NIRS signals were recorded simultaneously from the center of the belly of L3. NIRS were measured to determine the level of muscle blood volume (BV) and oxygenation (Oxy-Hb).

RESULTS

Experiment I. The rms-SMG of MG increased as a function of force ($P < 0.01$). On the contrary, these values for SOL increased up to 60% MVC ($p < 0.01$), but decreased at 80% MVC. The relationship between the peak to peak amplitude of SMG and MU spike indicated significant positive correlations ($r = 0.631 \sim 0.657$, $P < 0.01$). During electrical stimulation at 5Hz, the SMG power spectral peak frequency (PF) was matched with stimulation frequency in both muscles. At higher stimulation frequencies, e.g., > 15 Hz, only in the MG, was SMG-PF synchronized with stimulation frequency; the slow SOL did not show such synchronization

Experiment II. The root mean square amplitude value (rms) of EMG significantly increased at the initial phase of contraction and then fell significantly while mean power frequency (MPF) of EMG was significantly and progressively decreased as a function of time during fatiguing contractions. There were also significant initial increases in rms-SMG that was followed by progressive decreases at the end of sustained contractions. MPF-SMG remained unchanged. BV and Oxy-Hb dramatically decreased at the onset of the contraction and then remained almost constant throughout the rest of contraction.

DISCUSSION

Our data from the **Exp. I** suggest that the SMG frequency components might reflect active motor unit firing rates, and that the SMG amplitude depends upon mechanical properties of contraction, muscle fiber composition, and firing rate during voluntary and electrically induced contractions.

The results obtained in the **Exp. II** demonstrate that restriction of blood flow due to the high intramuscular mechanical pressure is one of the most important factors to evoke the muscle fatigue particularly in low back muscle. Nearly constant MPF-SMG and progressive decrease in the SMG amplitude suggest that low back muscle MUs were most likely firing at the constant rate, but slowing of contractile elements decreased dimensional changes of the fibers of active MUs, leading to diminished "muscle sound". EMG recording with simultaneous SMG and NIRS analyses could potentially offer much more detailed and reliable information regarding the mechanism(s) of low back muscle fatigue based upon the electrophysiological, mechanical and metabolic characteristics.

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S-30

Energy Cost of Walking and Locomotor Impairment

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The need for simple and reliable methods to quantitatively assess locomotor impairment and the consequent disability is obvious in the clinical setting. The aim of the present paper is to show the utility of the energy cost evaluation during walking in neurological and orthopaedic patients before, during and at the end of their rehabilitative therapy to assist with the diagnosis and to judge the efficacy of the rehabilitation. This paper will show also that energy data can be useful in designing an appropriate rehabilitative program. In particular, we will refer to our 10-year experience in research both on the physiological and biomechanical characteristics of the gait of subjects with locomotor impairments and on the rehabilitative efficacy of new therapies.

In these studies, the subjects, healthy people and patients with different kinds of disorders, were evaluated assessing the energy expenditure while walking both in the open field and on the treadmill. The energy expenditure was assessed measuring oxygen consumption ($\dot{V}O_2$), carbon dioxide output ($\dot{V}CO_2$) and heart rate (HR) using a portable metabolimeter (K4RQ, Cosmed, Italy), which besides being accurate and reliable is also unobtrusive and very light. Different approaches were used to have a quantification of the mechanical work while walking.

Paraplegic people with complete spinal cord lesion, who have been rehabilitated to stand and walk with special orthoses, probably experience the most fatiguing way of walking. We studied one of the most popular orthoses: the Reciprocating gait orthosis-RGO (Bernardi et al., 1995). A quantification of the muscular work requested of the subjects in order to walk was obtained by measuring (in standing position and during walking) the metabolic energy requirement (joules per min and per kilogram of body mass), which is calculated on the basis of $\dot{V}O_2$ and $\dot{V}CO_2$. These figures were compared with their maximal aerobic power. From these data it was found that the energy requirements of paraplegic subjects is much greater than that of able-bodied subjects walking at the same velocity. To explain the causes of this drawback, we assessed the efficiency of walking in 6 patients by measuring the ratio between the mechanical vs. metabolic energy changes in the whole body. To obtain an estimate of the mechanical energy changes of each body segment, the subject's body was modelled in a stick diagram. The mechanical energy changes were measured as the sum of potential and kinetic energy changes of each stick. An optoelectronic device (Costel LogIn, Italy) was used to measure position, velocity and acceleration of the segments thus estimating the energy variations. Efficiency assessment revealed to be fundamental in explaining the reasons why the RGO-patients can walk only at a very limited speed. First, the mechanical work done to move RGO+body system resulted many times greater than that of normal subjects walking at the same speed. Secondly, the metabolic energy need to obtain a unit of mechanical work resulted much greater than in able-bodied subjects. Furthermore, in RGO-patients the work required to walk increases exponentially as the walking speed increases with a trend that is much steeper than in the controls. Thus, even with a minimal increase in speed, the walking metabolic energy would easily reach the maximal aerobic power of the subjects. These results demonstrate that in order to enable RGO-patients to obtain a normal walking speed, either a new very efficient orthosis must be designed or an external source of energy must be supplied.

In most of the studies on walking, a sort of gross reverse of efficiency is estimated considering the metabolic energy cost per unit of distance (meter) and per kilograms of body mass, which is referred to as energy cost of walking (ECW). This measurement must be assessed in a steady state condition (the evaluation has to be at least 5 minutes long) by dividing energy expenditure (Joules per kg and per second) by walking speed (meters per second). This quantity can be considered the reverse of efficiency, i.e., the lower the cost the higher the efficiency. Obviously this way of evaluating efficiency offers the advantage of being simple and economical.

It is well known that in able-bodied subjects ECW depends on walking speed following a U curve relationship. The minimum ECW corresponds to the speed (economy speed) which the subject spontaneously adopts as the most comfortable speed (MCS). When increasing or decreasing speed, ECW increases exponentially. To evaluate the diagnostic capability of the ECW in quantifying locomotor impairment, we measured this variable in 82 patients with neurological or orthopedical disorders (Bernardi et al. 1999). Also HR was included in the routine protocol, to assess a cardiac cost of walking (CCW). These figures were compared with the results of clinical tests and scales. Also in the patients a U curve relationship between ECW and speed was found. The MCS of the majority of the patients resulted lower than that of normal subjects (controls). Nevertheless, many patients had an ECW comparable to the controls, when the latter walked at the same slow speed. Only the most impaired patients (35 out of 82), who were able to walk only at a very slow speed, displayed a much greater ECW than normal subjects walking at the same speed. These patients displayed a very pathological gait as demonstrated also by canonical clinical tests. The low efficiency was correlated with the asymmetry of the stride and defective kinematics of the movement of body segments. In normal subjects a reduction in muscular work (energy saving mechanisms) can be obtained with an efficient transfer of mechanical energy between body segments as well as with an efficient transfer of kinetic to potential energy and vice versa in the same segment (Cavagna and Kaneko, 1977). Another way to save energy (Cavagna and Kaneko, 1977) is to exchange kinetic and potential (positional) energy into eccentric contracting muscles (energy stored in the elastic components of the muscle) and return it during the successive concentric phase of contraction. Defective kinematics and muscular rigidity explain the low efficiency of the patients with the very high ECW. Conversely, we can assume that a very high ECW is indicative of very impaired walking biomechanics. More generally, in all patients the ECW value was consistent with the other clinical data and furthermore offers the advantage of being well quantifiable and easily obtainable. Therefore it can be used in assessing the effects of a rehabilitative regimen.

ECW is speed dependent (U curve relationship) and we expect its reduction as far as the MCS increases. Therefore to compare the walking efficiency of two periods of the rehabilitation, it is necessary to take the measurements when the speed is controlled, which is easily obtainable on the treadmill. In this way a reduction of the ECW at the same speed testifies an improved walking efficiency. Recently, we adopted the treadmill as a means of rehabilitating disabled patients. We first adopted this technique in rehabilitating paraplegic patients walking with RGO and ARGO orthoses (Felici et al., 1997). We suggested this way of rehabilitate patients in consideration of the following hypothesis. The treadmill, moving

the support leg backward, would induce a forward movement of the swinging leg via the reciprocating device of orthosis. In other words, the treadmill would behave as an external source of energy that is added to the patient's muscular work. This hypothesis was confirmed by the fact that the ECW, when walking on the treadmill, corresponded to half the EWC measured when walking in the open field at the same speed. The training regimen was found to be very effective as a rehabilitative procedure. Indeed the ECW, assessed when the patients walked in the open field at their MCS, decreased by 27% after two months of treadmill rehabilitation.

Treadmill has been incorporated in a new walking assistance and rehabilitation device (WARD). In this system, designed by some of our group (Gazzani et al., 1996), the patient is partially supported by a harness connected with a body weight unloading (BWU) apparatus. The WARD system is connected to a personal computer which controls the treadmill speed and the percentage of the patient's body weight to be unloaded. The BWU apparatus exerts the programmed upward force constantly, regardless of the position of the body's centre of gravity. We applied a 1-2 month long WARD training to 7 neurological patients with locomotor impairment (Gazzani et al., 1999). These patients can be considered as chronic patients and entered into the WARD program after a long period from the beginning of their pathology. At the beginning of the WARD training 4 out of 7 patients were unable to walk independently. At that time 2 patients were completely wheelchair-bound (Wb). The comparison between the measurements before and after the WARD training period demonstrated an impressive improvement achieved by all patients. Indeed firstly, all patients improved their scores based on a clinical scale. Secondly, it was possible to progressively reduce the BWU in all patients during the rehabilitation. Thirdly, the patients increased their MCS in the open field and their preferred walking speed on the treadmill. The open field improvement was very impressive considering that also the 2 Wb patients were able to walk at the end of the training. Since their MCS increased, the reduction of ECW resulted highly significant. These improvements were paralleled by an increase in walking efficiency. Indeed, the ECW was much lower when the patients were asked to walk, at the end of the training period, under the same WARD conditions (same speed and BWU) they had adopted at the beginning. Furthermore, a reduction in heart rate and in pulmonary ventilation paralleled the increased walking efficiency at the MCS. WARD was also used to rehabilitate patients with severe orthopaedical locomotor impairment (Castellano et al., 1997).

An appropriate comprehensive rehabilitation can include also a cardiovascular reconditioning program. In other words, rehabilitation can be aimed at improving also the patient's physical fitness when his/her ECW has reached a satisfactory reduction. The cardiac cost of walking (CCW), expressed as heart rate (number of beats per minute) divided by walking speed (meters per minute), must be related to the ECW (Gazzani et al., 1999). A physical fitness improvement is reached when after training, at the same oxygen consumption (and in turn at the same speed) measured before training, the patient displays a reduced heart rate. The training has to respect characteristics of appropriate intensity, frequency and volume to be able to induce real cardiovascular and respiratory adaptations. The intensity of the exercise must correspond to a mean energy expenditure equal to or above 50% of the maximal oxygen consumption. The frequency of the training sessions must be of at least three times per week. The volume of the training, which includes both the duration of a single training session and the duration of the whole training period, must be longer, the higher the previous physical fitness status of the subject. After six months of treadmill training, 6 paraplegic patients walking with RGO had improved their physical fitness, while their ECW had been already almost levelled after 2 months of rehabilitation (Felici et al., 1998). Spinal cord injured patients with incomplete lesions rehabilitated through treadmill and WARD at the end of about 2 months of a rehabilitation designed to reduce the ECW did not show a statistically significant improvement of the physical fitness (Gazzani et al., 1999, Figure 4)

The above results clearly illustrate that the energy assessment enriches diagnostic power of the clinical tests. A successful comprehensive rehabilitation program will be reached when at the end of the therapy the patient will show:
Reduced energy cost of walking (energy expenditure per meter of walking)
Increased efficiency of walking (energy cost at the same speed)
Improved physical fitness (cardiac cost at the same energy cost).
To accomplish these purposes, the rules and advice quoted in the present study must be followed. Furthermore: 1. The characteristics of the metabolimeter (light, accurate and with continuous data sampling) must allow the operator to monitor during walking both the steady state conditions and the physiological relative intensity of the workload (HR and $\dot{V}CO_2$.and $\dot{V}O_2$ ratio); 2. Speed of walking must be exactly controlled and controls must walk at the same speed as the patients.

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S-31

Gait Studies and Dynamic Electromyography – Past, Present and Future

A. Nene, H. Hermens, and G. Zilvold

Since antiquity we have been interested in human anatomy. The earliest records of the formal study of anatomy date from the time of Hippocrates (460-370 BC). He wrote extensively on medical matters. Plato elaborated the humoral pathology of Hippocrates. Aristotle (384-322 BC), a pupil of Plato, studied locomotion without a knowledge of muscular action. He believed that the extremities were activated by animal spirits. In spite of his lack of knowledge of anatomy and physiology, he described fundamentals of muscular actions. Galen (131-211 AD) made major advances in the knowledge of human anatomy. The knowledge of human anatomy mushroomed in the following millennium. Advances in knowledge of mechanics occurred through works of Galileo Galilie (1560-1642) and then of Isaac Newton (1642-1727). Newton laid down the foundations of modern dynamics with his three laws of motion.

However, the distinction of being the father of modern biomechanics must go to Giovanni Borelli (1608-1679). He considered bones as levers. He analysed movements of lever arms and the relationship between muscle forces and the angle of application. He concluded that the muscles worked on mathematical and geometrical principles. He was the first to determine the centre of gravity, which is of fundamental importance in the calculation of the events of locomotion. He described the forward displacement of the centre of gravity beyond the supporting area and the manner in which the forward swinging of the limbs saves the body from loosing balance. This concept of propulsion and restraint in human gait, as described by Borelli, is considered to be one of the foundations of the development of our knowledge of human gait.

Following this, very little was accomplished in the study of locomotion until in the first half of the nineteenth century when Weber brothers observed and measured the alteration of swing and support phases, trunk inclination during these phases, and the relationship between step length and step duration. They also investigated muscle effort involved in propulsion and restraint. Considering how primitive their experiment means were the accuracy of their observations is unbelievable. Following years saw use of photography in the locomotion studies.

Marey was the first to use photography in analysing movements during locomotion and to register the movements of selected points of the body. The subject wore a black body suit with white stripes that indicated the pathways of these points. Muybridge, Anschütz and Londe also made a steady progress in the art of photographic recordings. Once photography was established as a means of recording the phases of gait, calculative investigations such as velocities, accelerations, forces could be carried out. Braune and Fischer presented in 'Der Gang des Menschen' (1895) a calculative analysis of the essential factors of human gait. They used a method similar to that of Marey. They substituted Geisler tubes for the white stripes. They ascertained using photography the pathways of different points during locomotion. By relating the photographs to a three-co-ordinate system they could tabulate the actual values of the pathways of human gait using trigonometric computations. Subsequently, Fischer alone studied the pathways of the centre of gravity. From these pathways the velocities could be calculated, from the velocities accelerations could be calculated. The final objective was to ascertain the force behind acceleration, velocity and the pathways. Following the work of

Braune and Fischer comparatively little advance was made in the study of human locomotion until the role played by individual muscle was studied. Richard Scherb first defined the sequence pattern of muscle action using purely palpatory methods on the treadmill. With the introduction of Electromyography these sequence patterns could be refined.

The use of electricity for therapeutic purposes began in the first century and became more refined as the properties of electricity became more understood. Franklin, Galvani, Volta, contributed to this knowledge. However, muscle contraction generates electrical potential was not known until early twentieth century. Although Carlo Matteucci first showed that electrical currents originate in muscle, as early as 1838, development of the string galvanometer by Einthoven in 1901 set the stage for the development of clinical electromyography. The development of cathode-ray oscilloscope in the 1930s made possible major and rapid advances. Presently electromyography is used either as a diagnostic tool for various neuromuscular disorders or as a tool to study function.

In more recent years the interest in gait analysis has turned to the dynamic side of the problem. Analysis of dynamic muscle signal is most useful in the gait studies. Verne Inman studied actions of individual muscles in various different situations. His pupils, Jacqueline Perry and David Sutherland have furthered and refined our knowledge about muscle actions during locomotion. However, presently dynamic electromyography reveals only the precise phase relationship of various muscles during locomotion, but gives only qualitative information regarding forces generated within the muscle. Many practical problems of measurement of muscle signal during locomotion have been solved; however, many analytical problems such as force-length relationship, force-velocity relationship, changes in the recorded signal due to muscle movement remain unsolved.

Our knowledge of neuromuscular control of human gait has made considerable progress over the years; particularly our knowledge of gait kinematics is well advanced. Two techniques are being used to explain the observed kinematics, namely, electromyography and kinetics. Electromyography pinpoints the temporal and amplitude contributions of individual muscles. Kinetics reveals net joint moments as well as net mechanical power. However, our knowledge falls short in explaining the 'cause-effect' relationship between external moments and internal moments producing the observed net moments, i.e., ascertaining precise role played by the muscles of the lower extremities. Unfortunately, it has been difficult to quantify muscle forces and impossible to measure muscle length changes based on the electromyogram. In addition, the incredible complexity and apparent redundancy of the musculo-skeletal system has made analysis of muscle action during locomotion extremely challenging. Recently, through technological advances in imaging techniques and advanced modelling, attempts have been made to gather this information and incorporate it into forward dynamics and inverse dynamics models to uncover fundamental rules about muscle contribution to locomotion.

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S-32

Negative and Positive Stiffness of Human Elbow Flexors with Constant Muscle Activation in Isovelocity Movements

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1. INTRODUCTION

It is well known that the contracing muscle has elastic-like and viscous-like properties, which change widely with the level of muscle activation [1]. Zeffiro [2] reported that the torque generated by the contraction of triceps brachii muscle increased with an increase in elbow angle in monkey, which was the same as an elastic spring. Recently we have investigated torque-angle relations in flexor and extensor muscles of human elbow under static conditions. The relation of the extensor was similar to Zeffiro's results. However, the relation of the flexor did not show a simple elastic-like property; torque increased and then decreased with increasing the elbow angle.

Viscous-like property of the muscle could be explained in terms of force-velocity relation. We estimated the torque-angular velocity relation in elbow extensor muscles [3]; the torque decreased with increasing the angular velocity of extension, which was in agreement with common force-velocity relations of the muscle.

There were few investigations on torque-angle relations of the flexor muscle in voluntary flexion movements. The relation would be key for understanding the control mechanism of upper arm posture. The purpose of the present study was to obtain and to examine the relations with the constant muscle activation. It is almost impossible for the subject to keep the constant muscle activation during the flexion movements. We have utilized a new technique of artificial network to overcome this difficulty. In the present study, the torque-angle relations of the elbow flexor muscles showed very fascinating aspects; the stiffness (torque / angle) was negative at the zero velocity and positive at non-zero velocity of flexion.

2. METHODS

2.1 EXPEREIMENTAL METHOD

The experiments were performed with three normal subjects (male, aged 22-25) given the informed consent. Each subject sat on a chair (Fig.1). The task was isovelocity flexion of the the elbow joint in a horizontal plane at the height of his shoulder. Almost a constant torque was applied to the joint with a hung weight. His elbow joint angle and the target angle were displayed as thin and thick lines on CRT. At first, the subject was asked to hold the elbow joint at a fully extended position (elbow angle was almost zero) against the load torque, and then to flex the elbow joint at a constant velocity by watching the CRT to about 120 deg. In the holding experiments, he was asked to hold the forearm at the desired angle against the load torque. He was asked to minimize the coactivation of the extensor muscles. Surface electromyograms (EMGs), elbow joint angle, and torque were measured.

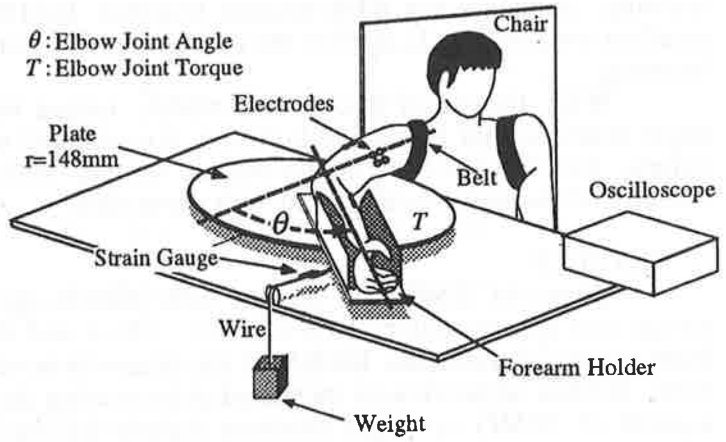

Fig. 1 Experimental setup

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The angle was observed with a potentiometer. The force was observed with strain gauge, and the torque was calculated as a product of the radius of the turning wood plate and the observed force. Applied torque were approximately 0, 5, 10 and 15 % of MVC (maximum voluntary contraction at the angle of about 90 deg). The flexion velocity were 30, 60 and 90 deg/s. The measurements were repeated, at least,10 times for one experimental condition. EMGs were recorded from six muscles; brachialis(BR), caput longum bicipitis brachii (BIL), caput breve bicipitis brachii (BIS), brachioradialis (BRD), caput laterale triceps brachii (TRA) and caput longum triceps brachii (TRI). A pair of Ag-AgCl surface electrodes (10mmϕ) were put on the skin over each muscle. It was confirmed that innervation zone did not enter between the pair of electrodes during the flexion movements. EMGs were full-wave rectified and then low pass filtered with cut off frequency of 35 Hz. In order to obtain IEMG, this filtered signal was further running averaged over the time span during which the joint angle changed approximately 0.5 degree. Note that in the present study, steady state behaviors were examined.

2.2 MODEL CONSTRUCTION

A three-layer artificial neural network in Fig. 2 was constructed where inputs were the elbow joint angle, the flexion velocity and six -channe lIEMGs, and the output was the elbow joint torque. The activation function of the input units was linear, and that of the hidden and output units was sigmoid. Appropriate number of the hidden units was determined by varying both the number and the initial connection weight with BP (Back propagation) learning as follows. The normalized error NER in Eq. (1) was used.

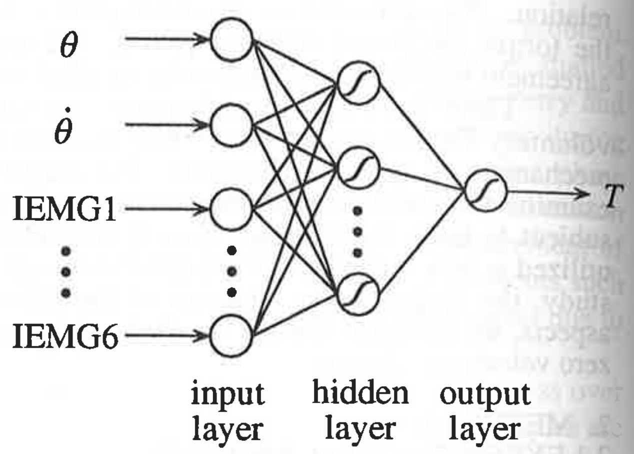

Fig. 2 Artificial neural network model

$$NER = \sum_i (T_i - T_{mi})^2 / \sum_i T_i^2 \qquad (1)$$

where Ti is observed torque, Tmi model output torque and i the sample number. BP learning stopped when NER became less than 0.04%. We chose the model that gave the smallest error of Eq.(1) against the test data which were different from the data used for BP learning.

With the aid of this chosen model, torque was calculated to estimate the torque-angle relation; that is, fixing both the six- channel of IEMGs and the velocity at certain values, we calculated the model output, torque, with varying the angle. Similarly, torque-velocity relations were calculated with the model.

3. RESULTS

Observed IEMGs of flexors were plotted against the elbow angle in Fig.3, where torque was approximately 10% of MVC. Mean and standard deviation (s.d.) were obtained from twenty experiments. IEMGs of the extensors were very small, so that they are not given here. IEMGs of the flexors increased as increasing the velocity. It is showed in Fig. 3 that aspects of IEMG vs. angle relations slightly differed between zero velocity and non-zero velocity, in particular over the range of small values of angle. These were also found at other loads, 5 and 15 %MVC in three subjects.

Torque estimated from the model was plotted against the angle in Fig. 4 where solid line is for 0 deg/s, dotted line for 30 deg/s and broken line for 60 deg/s. Values of IEMGs which were actually measured at the angle of 40 deg in (a) , 60 deg in (b) and 80 deg in (c)

and at each velocity were used in the estimation. Therefore, torque maked at closed circles was approximately equal to the measured value. Estimation was done over a small segment of angle in terms of the better reliability. It is showed at the zero velocity and 30 deg/s that torque increased and then decreased as increasing the angle. However, torque decreased with an increase in angle at the velocity of 60 deg/s.

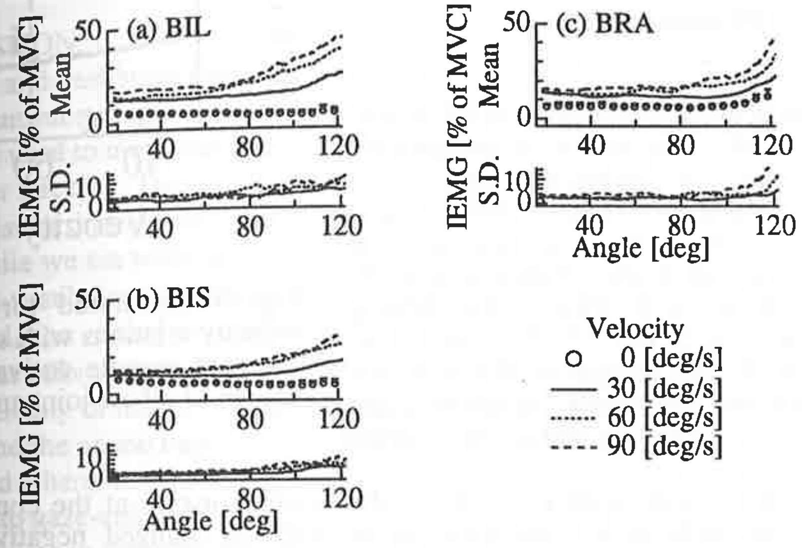

Fig. 3 IEMG-elbow angle relations measured from flexor muscles; four different flexion velocities against load torque of 10% MVC. Each curve is an average of twenty trials of Sub.SY.

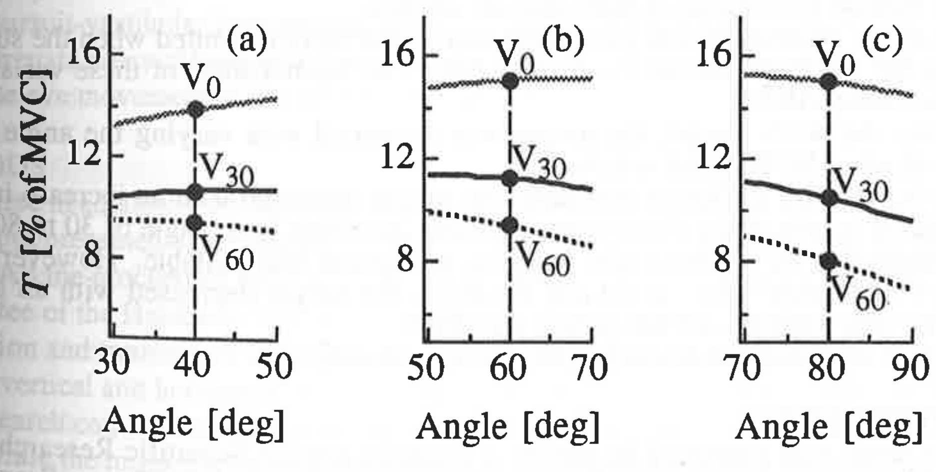

Fig. 4 Estimated torque-angle relations at three different velocities; each curve is with constant muscle activation and constant flexion velocity.

It is of great interest that as the flexion velocity increased from zero to 30 or 60 deg/s, the slope of torque/angle changed from positive to negative in Fig. a and b. It implies that the system changed from unstable to stable; the positive slope means negative stiffness and an unstable system, because the increase in elbow joint angle means the decrease in muscle length of the flexor. These characteristics were found in three subjects.

Estimated torque-velociy relations were showed in Fig. 5, where values of the IEMGs which were measured at the angle of 40 deg and the velocity of 60 deg/s against the load of 5 (L_5) and 10% MVC (L_{10}) were used. Torque decreased as increasing the velocity; this property was generally showed in most of the muscles.

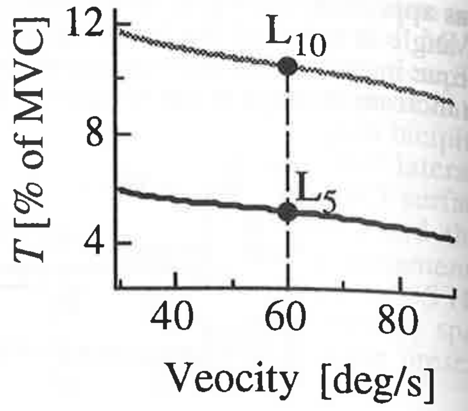

Fig. 5 Estimated torque-flexion velocity relations with two levels of constant muscle activation at 40 degree of elbow joint angle.

4. DISCUSSION

I is of significance for understanding clearly the position control of upper arm to investigate the torque-angle relations in voluntary movement. In a previous study, we showed that static and dynamic behaviors of the elbow extensors were almost the same in terms of torque-angle relations, and the system should be stable on the basis of the stability analysis. Namely, when the elbow was in an extension movement, the torque of the extensor muscles increased with increasing the elbow angle at the constant muscle activation and at the constant angular velocity.

However, the torque-angle relation of the flexor muscles at the constant muscle activation was not the same as the extensors, and the stiffness changed negative to positive, with the change of contraction from static to dynamic conditions. The actual mechanism of this change was not clear.

5.CONCLUSION

With the aid of an artificial neural network (ANN) technique, we investigated relationships between the torque and the elbow joint angle at constant muscle activation in isovelocity flexion movements in three normal subjects.

1) EMGs of six muscles, elbow joint angle and torque were measured when the subject was flexing the elbow at almost constant speed. The relationships of these variables were modeled using ANN.
2) By using the ANN model, the torque was estimated with varying the angle and with fixed values of IEMGs and velocity.
3) When the velocity of flexion was zero. the torque increased with an increase in angle (a decrease in length of the flexor muscles) over an elbow joint angle of 30 to 80 degrees. This means that the stiffness was negative; the system was unstable. However when the velocity of flexion were at 30 and 60 deg/s, the torque decreased with an angle; the stiffness was positive and the system was stable.
4) The torque decreased as increasing the flexion velocity.

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S-33

Ocular Tracking of a Slowly Moving Object: Role of the Frontal Eye Fields (FEF) in Pursuit-Vestibular Interactions

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INTRODUCTION

Visual and vestibular senses are essential for our adequate behavior in space. Several eye movement subsystems are used to obtain adequate visual inputs. The smooth pursuit subsystem is used to move the eyes at the appropriate velocity with a target of interest during ocular tracking. This system does not work independently, but interacts with the vestibular system during head and/or whole body movement such as walking. For example, while we are walking we can read facial expression of another walking person. Such pursuit-vestibular interactions are necessary for normal gait and stable posture, and require calculation of target-velocity-in-space using retinal image-velocity, eye-velocity and vestibular information. This estimate is converted into gaze-velocity commands to match the velocity of the eyes-in-space (gaze) to target-velocity (Robinson 1981, 1982). To understand the neural basis for maintaining normal gait and posture, it is first necessary to understand where in the brain and how target-velocity-in-space is calculated and converted into gaze-velocity.

Retinal image-velocity and gaze-velocity signals are found in the posterior parietal cortex, particularly in the medial superior temporal (MST) area (e.g., Sakata et al. 1983; Their and Erickson 1992). However, the origin of eye-velocity signals in the MST is still unknown. The periarcuate cortex near the frontal eye fields (FEF) contains many pursuit-related neurons with eye-velocity information (MacAvoy et a. 1991; Gottlieb et al. 1994; Tian and Lynch 1996; Tanaka and Fukushima 1998). To understand the role played by the FEF in pursuit-vestibular interactions, we examined activity of pursuit-related neurons in the periarcuate areas of head-stabilized Japanese monkeys during visual tracking tasks that dissociate eye movement in the orbit from that in space.

METHODS

Three head-stabilized Japanese monkeys (Macaca fuscata) were trained to pursue a laser spot presented on a tangent screen during whole body rotation for apple juice reward. All the procedures were evaluated and approved by the Animal Care and Use Committee of the Hokkaido University School of Medicine. Our methods for animal preparation and training are described in detail elsewhere (Fukushima et al. 1999, 2000). Briefly, vertical and horizontal components of eye movement were recorded using a scleral search coil method. Extracellular recordings were made in and near the arcuate sulcus while the monkeys tracked the target during sinusoidal whole body rotation. Once responding single cells were encountered, pursuit responses were tested in various directions to determine a preferred direction for activation of each neuron without chair rotation.

To dissociate eye movement in the orbit from that in space, we employed two tracking conditions; 1) the monkeys tracked a target that moved in space with the same amplitude and phase as the chair and in the same plane. This condition requires the monkeys to suppress the vestibulo-ocular reflex (VOR) so that the eyes remain virtually motionless in the orbit and gaze therefore moves with the chair (VOR suppression); 2) the target stayed stationary in space during chair rotation and the monkeys were required to continue fixating it, which requires perfect VOR and no gaze movement (VOR x1).

For many cells, responses to a variety of frequencies were examined for each of the tracking conditions.

To examine whether periarcuate pursuit-related neurons receive retinal image-information about target movement, the stationary monkeys were rewarded for fixating a stationary laser spot (1st target) while a second laser spot moved sinusoidally. Effects of extinguishing the tracking target (blanking) were also examined for many neurons.

Having mapped the FEF pursuit areas, we examined the effects of chemical deactivation by injecting a GABA agonist muscimol (10-15 μg) dissolved in physiological saline (10 μg/μl) unilaterally into a single area where we recorded many pursuit-related neurons. Smooth pursuit and VOR suppression tasks with or without blanking were examined before and after muscimol infusion.

The data were analyzed off-line. Gaze-velocity was calculated by adding eye-velocity and chair-velocity. Position signals were differentiated by analog circuits (DC-50 Hz, -12 dB/octave) to obtain velocity. Cycle rasters and histograms were constructed for the discharge of each cell by averaging 10–30 cycles. A least-squares method was used for fitting a sine function to cell- and eye- or gaze-movement responses to calculate phase shift and gain (re stimulus-velocity) after deleting saccades. Velocity-sensitivity of a cell's response was the slope of the linear regression fit to the amplitude of modulation vs eye- or gaze-velocity. Recording locations were histologically confirmed by making iron deposits produced by positive current through the electrodes.

RESULTS

We analyzed over 100 pursuit-related neurons in the periarcuate cortex. The activity of almost all of them was modulated during VOR suppression. The majority of them (28/43=~65%) responded to chair rotation without a target in complete darkness, suggesting that they receive vestibular input.

We classified pursuit-related cells as "gaze-velocity" if they met the following criteria (Lisberger and Fuchs 1978; Fukushima et al. 1999): 1) modulation occurred for movements of the eye (smooth pursuit) and the head (VOR suppression) in the same direction, 2) modulation during one of these two tasks was less than twice that during the other, and 3) modulation during the VOR x1 was less than that during VOR suppression. The majority of periarcuate pursuit-related cells (66%) were classified as gaze-velocity with preferred directions of individual cells uniformly distributed. The remaining cells (34 %) were classified as eye/head-velocity, since they also responded during VOR suppression.

Eye-velocity sensitivity and gaze-velocity sensitivity of the two groups of cells were similar; mean (±SD) was 0.53 (±0.30) and 0.50 (±0.44) spikes/s/°/s, respectively. Gaze-velocity (but not eye/head-velocity) neurons showed significant correlation between eye-velocity sensitivity and gaze-velocity sensitivity, and both groups maintained their responses when the tracking target was briefly (200-400ms) extinguished. When a long duration (800 ms) blanking was applied before the target changed the direction, pursuit-related neurons responded appropriately during blanking.

When the monkeys fixated a stationary target, over half of cells tested discharged in proportion to the velocity of retinal motion of a second laser spot (mean velocity sensitivity = 0.20 (±0.16SD) spikes/s/°/s). Preferred directions of individual cells to the second spot were similar to those during pursuit. Visual responses to the second spot movement were maintained even when this spot was briefly extinguished.

After muscimol infusion, eye-velocity during pursuit decreased and catch-up saccades frequently appeared. Mean eye-gain decreased to nearly half after muscimol

infusion. Effects of muscimol infusion were also tested when a long duration (800 ms) blank was applied before the target changed the direction. The monkeys were required to perform the task without a tracking target. Before infusion, the monkeys performed smooth eye movement with changing the direction fairly well even without the target in complete darkness. After infusion, however, the monkeys were virtually unable, in many trials, to generate smooth eye movement without the target. Instead, they performed the task with saccades.

The monkeys' performance of the VOR suppression task was also severely impaired after muscimol infusion. Before infusion, VOR was virtually abolished during the suppression task (gain ~0.01). However, after infusion they were unable to suppress the VOR with gains ~0.3, and corrective saccades appeared frequently to compensate for impaired VOR suppression. In contrast, the monkeys' performance of the VOR (x1) task was not clearly affected by muscimol infusion.

DISCUSSION

Our results indicate that single periarcuate pursuit-related neurons carry gaze-velocity and retinal image-motion signals. Our results also show that these neurons discharge appropriately during blanking when the monkeys are required to initiate smooth gaze tracking by changing the direction without the tracking target. This task condition requires an estimate of target-velocity. These results suggest that periarcuate pursuit-related neurons are involved in initiation of slow eye/gaze movement by using an estimate of target-velocity-in-space. Inability to perform gaze movement after muscimol infusion, particularly during blanking (but not the VOR x1 task that does not require gaze movement), is consistent with our interpretation.

Properties of gaze-velocity and retinal image-motion-related responses of periarcuate pursuit neurons seem similar to those of MST visual tracking neurons (Sakata et al. 1983; Thier and Erickson1992), although the exact comparison is not possible since the latter cells are not examined in the task conditions we used. Nevertheless, the existence of reciprocal connections between the FEF pursuit-related areas and the MST (Tian and Lynch 1996) suggests that retinal image-velocity signals of our cells may come from the latter areas.

Retinal image-velocity and gaze-velocity signals are found in the cerebellar vermis as well (Kase et al. 1979). The existence of gaze movement-related signals in such multiple regions suggests that these signals could be computed in multiple areas in the brain or that they could be computed by the circuits distributed among these structures (Fukushima 1997).

CONCLUSIONS

Single periarcuate neurons carry various signals, particularly velocity, for eye, head (vestibular), retinal image and gaze. Chemical deactivation of these areas severely impair smooth gaze tracking. These results suggest that the FEF region coordinates its various inputs to provide an estimate for target-velocity-in-space and accurate gaze-velocity command (Robinson 1982; Fukushima 1997).

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Luncheon Seminar

S-34

Recent Advances in Biomagnetics

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Biomagnetics is an interdisciplinary field where magnetics, biology, and medicine overlap. Three types of biomagnetic approaches to the understanding of the functional organization of the human brain and the effects of intense static magnetic fields on biological systems and materials are reviewed in this paper. Examples from studies obtained primarily in the author's laboratory in recent years are used.

1. Transcranial Magnetic Stimulation

Transcranial magnetic stimulation has become an important tool for the study of the functional organization of the human brain. Most of the studies using transcranial magnetic stimulation are related to the mapping of the cerebral cortex. These mapping studies were achieved by a method of localized and vectorial magnetic stimulation using a figure eight coil that the author developed. Transcranial magnetic stimulation is noninvasive and less painful than direct electric stimulation through surface electrodes placed on the head. It is useful not only for measurement and diagnosis but also, for the treatment or potential cure for mental illnesses and central nervous system diseases such as depression and Parkinson's disease.

2. Effects of intense static magnetic fields on biological systems and materials

(a.) Moses Effect

We investigated the dynamic behavior of water in high gradient magnetic fields. Exposure to an intense magnetic field of 8Tand a field gradient of 50T/m caused the surface of water to be pushed back. This phenomenon was labeled as the 'Moses Effect.' We analyzed the diamagnetic properties of 100ml of water under these conditions at room temperature and found that the magnetic force reaches 0.28N, one-third of the earth's gravity. By applying the Moses effect to magnetophoresis, we might possibly be able to control the movement of dia-paramagnetic biological materials using strong magnetic fields.

(b) Magnetic Orientation of Biomaterials

Magnetic orientation of fibrin fibers and collagen has been observed under strong magnetic fields. Exposure to a magnetic field causes parallel orientation of fibrin fibers to the field, whereas, collagen orients perpendicular to the field, partly due to anisotropy and the magnetic susceptibility of the materials. Red blood cells and platelets are also oriented in magnetic fields. Such magnetic orientation may have many potential medical applications.

3. Magnetoencephalography

Magnetoencephalography (MEG) has proven to be a useful method for the localization of circumscribed regions of brain activity through noninvasive means. Compared with EEG, MEG is primarily sensitive to intracellular currents that flow tangentially to the scalp surface. These current sources represent pyramidal cell activation in the fissural cortex and can be localized within 1-2 mm accuracy for transient brain events. Our research involves the source estimation of MEG activities associated with short-term memory task and mental rotation task using spreading source model estimation based on multiple signal classification (MUSIC) algorithms.

4. Electrical Magnetic Resonance Imaging

MRI techniques have become important tools in medicine and biology. Conventional MRI, however, produces no information about the electrical properties of the body. New methods to visualize electrical impedance distribution and neuronal current distributions based on MRI techniques have been proposed.

(a) Impedance Magnetic Resonance Imaging
A new method for impedance tomography is introduced based on MRI techniques. The basic idea is to use shielding effects of induced eddy currents in the body on spin precession. Two types of methods are proposed. One proposed method to visualize the conductivity distribution of living organisms is to use very large flip angles. The method is used to obtain conductivity-enhanced MR images at the given Larmor frequency. Another proposed method is to apply an additional time-varying magnetic field parallel to the main static field B0. The magnetic field is produced by the third coil, "Bc" coil. The method is used to obtain conductivity-enhanced MR images at an arbitrary frequency.

(b) Direct Neuronal Current MRI
A new technique to visualize the distribution of neuronal currents in the human brain has been developed. Measurements of the internal magnetic field deformation caused by an electric current dipole moment of 100 nAm in a phantom were performed and a method based on the microscopic magnetic resonance imaging technique was used. Neuronal current MR images of human brain activity associated with motor function was obtained.

S-35

Task-related activation changes after constraint-induced rehabilitation therapy

GF Wittenberg, R Chen, K Ishii, E Croarkin, S Eckloff, LH Gerber, M Hallett and LG Cohen

To determine the efficacy and mechanisms of rehabilitation after stroke, we enrolled stroke patients in a trial of constraint-induced movement therapy (CIMT) late after stroke onset. We sought to: 1. retest effectiveness 2. compare CIMT to a different control therapy regimen, and 3. measure therapy-related changes in cerebral activity and excitability.

Motor recovery after stroke is greatest in the first several weeks after onset, and is thought to plateau at 1 year. In chronic stroke patients, CIMT induces lasting changes in upper extremity function, challenging the assumption that a plateau in natural recovery precludes intervention. Still, the mechanism of these interventions is unclear.

Patients with moderately impaired motor function in one upper extremity that were > 1 year after subcortical infarction were eligible for this study. They were randomized to one of two interventions: CIMT or "standard" control therapy. CIMT involved the wearing of a splint and sling on the unaffected upper extremity for the waking hours, and intensive occupational and physical therapy designed to achieve self-care goals with the affected upper extremity. Standard Control therapy involved passive range of motion of the affected upper extremity, and practice in self-care using the unaffected upper extremity. Both interventions were performed for 10 days on an inpatient basis. Cerebral activation with 1 Hz finger extension was determined by PET and transcranial magnetic stimulation of motor cortex was performed, both before and after the intervention.

CIMT resulted in a significant ($p<0.04$, Wilcoxon signed rank, N=8) improvement in the sum of Wolf Motor Function Scores. Standard Control therapy resulted in a non-significant ($p=0.14$, N=5) improvement in the same score. Motor thresholds in the affected hemisphere did not show any significant changes, as measured by transcranial magnetic stimulation. Before intervention, PET showed larger activations in bilateral primary sensorimotor cortices with affected-side movement, compared to healthy volunteers. This excessive activation diminished after CIMT, partly due in an increase in resting bloodflow in that area. There were no such changes in activation related to movement on the unaffected side. Standard Control therapy led to only a minor reduction of sensorimotor cortical activation, and no increase in resting bloodflow.

Constraint-induced movement therapy is an effective means of improving motor function late after stroke onset. Its effect on brain physiology may result in more effective, but not grossly larger, activation of primary motor cortex, with increased resting levels of activity. However, others forms of rehabilitation late after stroke may have effects on both motor function and physiology.

S-36

The clinical effect of rucksack therapy on osteoporosis (from bone metabolism,electrogravitiogram, and electromyogram)

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[Introduction]
Osteoporosis will be further accentuated by the increase in life expectancy. As a risk factor vertebral and hip for fractures in the elderly, osteoporosis is a major cause of morbidity and mortality. After age 60 the age-specific fracture rate accelerates dramatically, approximately doubling with each decade and increasing even more rapidly after age 80. Immobilization and weightlessness have been well documented as leading to an increase in urinary Ca loss and a decrease in bone mineral.

Futher more, a number of studies on bone mass in athletes have demonstrated increased bone mineral content compared with the normal population. In order to examine bone metabolism we measured blood Ca, iP, ALP, PTH, BGP, and urinary Ca, iP, and creatinine in 3 stages of gait ability. As the deterioration in the quality of life following fracture may be catastrophic, the prevention of falls is an important factor in reducing the incidence of osteoporotic fracture. In order to protect against falling, the maintenance of good posture is extremely important. We developed and prescribed the use of a functional extention brace for spinal deformities in the osteoporotic patient about 30 years ago. In consideration of the posture assumed with gait, we have adviced the use of rucksack therapy while walking since about 8 years ago. Therefore, I would like to describe the results of rucksack therapy in terms of bone metabolism and clinical assessment.

[Methods] 1) In order to examine bone metabolism, we measured blood Ca, iP and, creatinine in 3 grades of the gait ability. Blood and urine were colleged at 9 a.m, and urine was collected immediately after the subjects awakened. After use of the Treadmill and 1 hour bed rest, blood and urine collecting was carried out. PTH and BGP ets, measurements were taken using a h-PTH53-84 and BGP Kit made by CIS using the RIA method.

2) Clinical assessments were classified according to 5 grades. 3) We recorded the electrogravitiogram during the stance phase, and also measured the discharge of paravertebral muscle and quadriceps during this phase by the surface electromyogram.

[Results] 1) The excretion of urinary Ca and iP in collected Creatinine in aged women of inpatient status under mainly conditions of bed rest was significantly higher in valce compared to that in aged men. The blood PTH also showed higher values in women. The excretion of urinary Ca and iP was suppressed after bearing weight while walking and blood PTH was slightly high in value in elderly outpatients. 2) In a survey of clinical assessment via questionnaire, 82% of patients found the treatment to be effective and 4.8% considered it to be in effective.

3) In the gravitiogram, the contact surface of foot soles decreased during the stance phase after rucksack therapy, and the discharge of paravertebral muscle decreased significantly in the surface electromyogram.

[Conclusion] Rucksack therapy can be safely improve the clinical symtoms and the balance of posture in patients with osteoporosis.

Satellite Seminar

S-37

Muscle Sympathetic Nerve Activity in Humans

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INTRODUCTION

Muscle sympathetic nerve activity (MSNA) is efferent sympathetic nerve traffic leading to skeletal muscles. This activity can be recorded using microneurography technique from human peripheral nerves *in situ*, The present lecture aims to review how MSNA traverses human posttganglionic sympathetic fibers and responds to changing posture, exercise, aging, and therapeutic maneuvers, based on our original findings obtained from 145 healthy men and women ranging in age between 16 and 80. Details concerning microneurographic recording of MSNA in humans have been described elsewhere (Refs. 1 and 2).

MICRONEUROGRAPHIC RECORDING OF MSNA

A tungsten microelectrode was used for microneurographic recording of MSNA from the tibial or peroneal nerve at the popliteal fossa. The identification of MSNA was based on the following criteria. (1) pulse-synchronous spontaneous and rhythmic efferent burst discharges recorded from muscle nerve fascicle; (2) modulation by respiration; (3) increase by a fall and decrease by a rise in systemic blood pressure; and 4) enhancement by maneuvers increasing intrathoracic pressure such as Valsalva's maneuver. Multi-fiber discharges of MSNA were full-wave rectified and integrated to be observed as mean-voltage neurogram. Spontaneous discharge characteristics of MSNA and its responses to changing posture, handgrip exercise, aging (and gender) as well as therapeutic maneuvers (acupuncture, anesthetic block and near-infrared irradiation of stellate ganglion) were analyzed concomitantly with related functions.

SPONTANEOUS DISCHARGE

One of the characteristics of MSNA was rhythmic spontaneous discharges which were synchronous to the heartbeat. It has been suggested that pulse-synchronous rhythmicity of MSNA is dependent on afferent input from arterial baroreceptors related to the heartbeat, being facilitated by the unloading, while inhibited by the loading of baroreceptors. MSNA also presented slower modulations corresponding to “tertiary” fluctuation of the systemic blood pressure, including Mayer's wave (blood pressure fluctuation with the period around 10 sec). Simultaneous recording of MSNA and systemic blood pressure clearly showed that MSNA was enhanced when blood pressure is lowered, being suppressed when blood pressure is elevated, depending mainly on baroreflex functions.

RESPONSES TO CHANGING POSTURE

Changing posture against terrestrial gravity markedly influenced MSNA. When the subject was passively tilted up from a horizontal supine to an upright posture, MSNA was gradually enhanced with increasing the tilt angle. The burst rate of MSNA showed a significant positive correlation with the sine function of tilt angle (gravity component from the head to the foot; +Gz). These findings may indicate that when changing the posture from lying to standing, MSNA responds to +Gz stimuli, to counteract venous pooling in the legs and a decrease in venous return to the heart, which reduces stroke volume and unloads baroreceptors. Thus MSNA responds to postural changes through baroreflexes to maintain hemodynamic homeostasis.

RESPONSES TO EXERCISE

Static handgrip enhanced MSNA recorded from the tibial or peroneal nerve in the lower limb depending on the duration and intensity of the exercise. The MSNA enhancement during handgrip persisted after the discontinuance of the exercise, when the blood supply to the contracting muscle was occluded. MSNA response to exercise was related to subjective fatigue sensation of the contracting muscle. These findings may indicate that MSNA responds to exercise mainly through muscle metaboreflex depending on afferent inputs from muscle metaboreceptors and plays a role in regulation of blood flow and metabolism in contacting muscles to counteract muscle fatigue.

RESPONSES TO AGING

MSNA was markedly influenced by aging. The basal level of MSNA expressed as the burst rate while in the supine resting position increased with age. There was a significant positive correlation between the age of subjects and the basal level of MSNA. Regarding the MSNA response to head-up tilt, the slope of the regression line between +Gz and MSNA burst rate was lower in old subjects than in young ones. There was a negative correlation between the age of subjects and the slope of the regression line between +Gz and MSNA. These findings may indicate that aging increases the basal MSNA but may reduce its responsiveness to postural change. There was also age-related gender difference in MSNA. MSNA was higher in young men than in young women, but this gender difference disappeared in older people over 50 years old.

RESPONSES TO THERAPEUTIC MANEUVERS

MSNA recorded from the peronal nerve was enhanced by manual acupuncture applied to Tsusanri acupoint in the ipsilateral lower leg. MSNA recorded from left tibial nerve was also enhanced by left stellate ganglion block with local anesthetic (1% mepivacaine). MSNA recorded from left tibial nerve responded to near-infrared irradiation of right stellate ganglion with Super Lizer (Tokyo Iken), which has been reported to provide similar therapeutic effects as the stellate ganglion block. However MSNA was enhanced by near-infrared irradiation of the stellate ganglion only in a half of the subjects, while being suppressed in another half. Exact mechanisms underlying these effects on MSNA are yet unknown, but these actions may be related some therapeutic effects of the maneuvers

CONCLUSION

MSNA plays important roles to maintain blood pressure homeostasis via baroreflex mechanisms for example against changing posture and to counteract muscle fatigue during exercise via muscle metaboreflex. The aging and gender influence MSNA. Therapeutic maneuvers such as acupuncture, anesthetic block and infrared irradiation of stellate ganglion can modify MSNA which may be related to some therapeutic effects of these maneuvers.

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S-38

SUPER LIZER IRRADIATION THERAPY

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INTRODUCTION

The polarized infra-red light irradiation system (SL: Super Lizer HA-550; Tokyo Iken Co.) was devised to generate the therapeutic infra-red light by using optical filters. The range of the wave - frequencies was wide (0.6～1.5 μ m) and almost all LASRE(He-Ne, CO_2, semiconductor etc.) belong to the range of this SL infra-red wave. This machine was used as the intra-red radiator for thermal therapy to joints and muscles. SL could produce 1800mW high-energy effect, and the power was stronger than other LASRE irradiation (60mW etc.). Recently it was reported that polarized light irradiation near the stellate ganglion was one of the good methods to block sympathetic nerve function and that it showed clinical advantage to reduce severe pain (Herpes-Zoster eruption, Complex regional pain syndrome type II etc.).

METHODS

Each investigation was hold in quiet atmosphere at 25℃ temperature, 50% humidity controlled room (artificial meteorological room). Thermal response was recorded by thermography (NEC Co., TH1101) and thermister(Techno-Seven.Co.) every one minute.

Study 1

In ten collagen diseases suffering from Raynaud's phenomenon, we once gave the SL irradiation (70% power, intermittently 1 second on- 2 seconds resting cycles) near the left stellate ganglion for ten minutes in spine position. Then we got the thermography of both hands before and after the SL irradiation. The data of finger temperature are plotted by the thermographic patterns.

Study 2

In ten healthy volunteer (23-42 years old), two acupuncure points(He gu(WHO LI4) and) and Wai guan(WHO SJ5)) of right hand are treated 10 minutes by needle or Super Lizer irradiation. Each volunteer are randomly tested the following four trial; (i) Needles at the acupuncture points (ii) Needles at two damy points of right hand. (iii) Super Lizer at the acupuncture points (iv) Super Lizer at the damy points.
The acupuncture needles are 0.25mm diameter. Super Lizer is irradiated intermittently 1 second on – 1 second off. The temperature of fingers (both middle hand fingers and II toes) were recorded with thermister (Techno-Seven.Co.) every one minute for 15 minutes after the treatment.

RESULTS

In collagen disease, the finger temperature of the irradiated side became higher after the irradiation than before the irradiation of the stellate ganglion. At 10 minutes after the irradiation, the temperature of the finger of the irradiated side is significantly higher than that of the pre-irradiation. Seven of 10 patients subjectively felt the relief of pain, cold-feeling in both fingers. No patients complained the reverse effect (figure 1).

In 10 normal volunteer, the acupuncture of needles decrease the temperature just after 2 minutes by pain stimulation. But the temperature of fingers increased at 10 minutes and continued high temperature. The irradiation of the acupuncture points didn't show the decrease just after the treatment, and the temperature of 10 minutes irradiation also increased. There were no significant change by the irradiation of damy points(figure 2).

CONCLUSIONS

We examined the irradiation of polarized infra-red (SL; super lizer) to the stellate ganglion in collagen disease (stellate ganglion) and normal volunteer(acupuncture points) to improve the autonomic (sympathetic) nerve disorder as the method of sympathetic nerve block. The SL irradiation improved the peripheral blood flow, reduced the pain and improved cold-feeling without side effect in patients. This light therapy is effective in the peripheral vascular disorders of collagen disease. The irradiation therapy improve the other (non-irradiated)side and both feet. Both acupuncture and the block of stellate ganglion with injection showed pain and have some risks in some patients(tendency to bleeding), but the irradiation theraphy showed the broad effect (hands and feet) and no side effect.

It was considered that the polarized light therapy is one of the useful methods for treatment of pain and peripheral blood flow in high risk patients as the collagen diseases.

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Figure.1 Temperature of fingers in collagen diseases after the polarized infra-red irradiation near the stellate ganglion

Average temperature of 10 patients. The temperature of 10 min. after the irradiation is significantly higher than that before the irradiation.

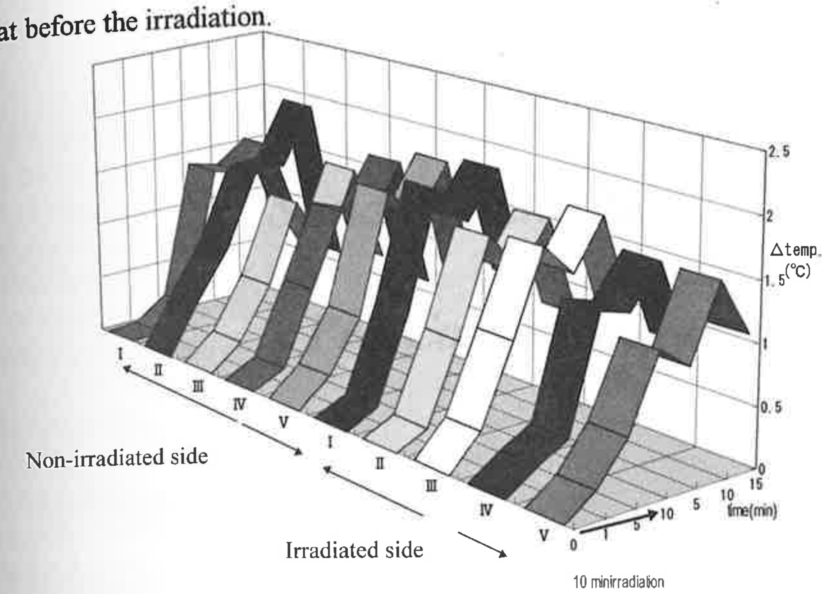
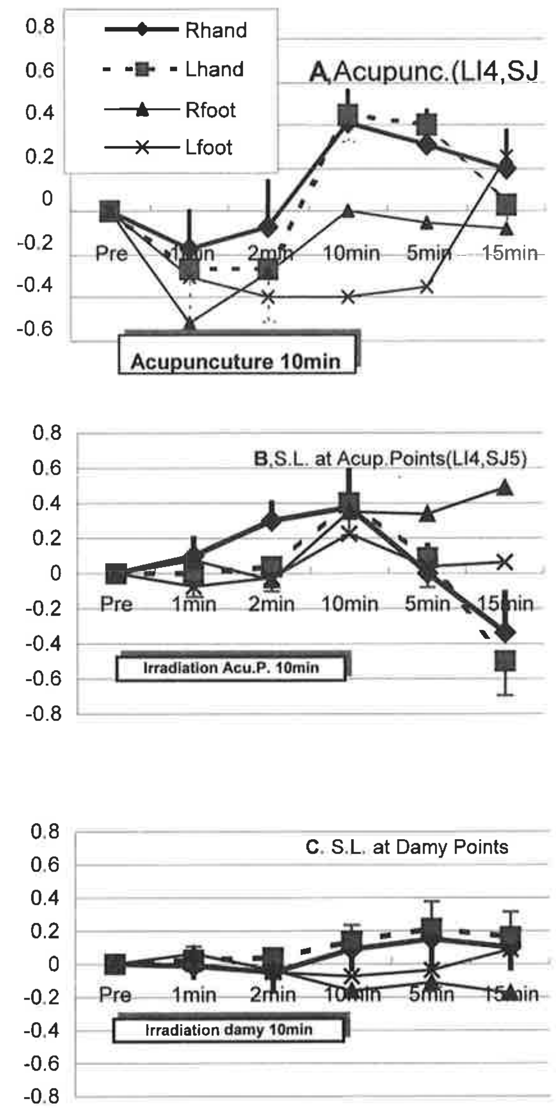


Figure 2. Effect of the polarized infra-red irradiation and needles at acupuncture points(LI4, SJ5) and damy (two) points..



Sunday, June 25

Pre-Congress

S-39

Central and Peripheral Origin of Involuntary Movement

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A group of conditions such as Parkinson's disease and dystonia feature abnormalities of motor control. These result from lesion of the basal ganglia, which consist of (1) the striatum, divided into the putamen and caudate nucleus, (2) internal and external globus pallidus, (3) pars reticulata and compacta of the substantia nigra, and (4) the subthalamic nucleus. The internal segment of the globus pallidus and the pars reticulata of the substantia nigra serve as the output nuclei, which inhibit the supplementary motor area via the ventro-lateral nucleus of the thalamus. The output nuclei receive inhibitory input from the whole of the cerebral cortex via the putamen (direct pathway). The external segment of the globus pallidus inhibits the subthalamic nucleus, which in turn facilitates the output nuclei (indirect pathway). In summary, the direct pathway, through cortical excitation of the striatum, will inhibit the output nuclei which, disinhibiting the thalamo-cortical loop, initiates movement. In contrast, the indirect pathway, via the external segment of the globus pallidus and the subthalamic nucleus, excites the output nuclei which, inhibiting the thalamo-cortical loop, reduces movement.

Apart from the classic movement disorders, muscles may stiffen pathologically with lesions involving the central nervous system, peripheral nerve trunk, axon terminal or muscle membrane. Myotonia, or delayed relaxation of voluntarily or reflexively contracted muscle occurs in a number of myogenic syndromes. Two groups of disorders have now emerged: (1) muscle sodium channel-associated diseases which include hyperkalemic periodic paralysis and its clinical variants, as well as paramyotonia congenita, and (2) muscle chloride channel-associated disorders which comprise both the dominant and recessive form of myotonia congenita. Involuntary muscle contraction also results from disorders of the peripheral nerve as in myokymia, the Schwartz-Jampel syndrome and neuromyotonia or continuous muscle fiber discharge. In still other sustained muscle contractions, spontaneous discharges originate centrally, as in the stiff-man syndrome. Other conditions with abnormal muscle activity include common cramp, contracture, tetanus, tetany, and hemifacial spasm. Some cramp syndromes display a distinctive pattern of abnormalities on electromyography. Others produced a normal interference pattern, although subject has no voluntary control

S-40

The theories and the techniques of modern motion analysis will be reviewed briefly and our recent kinematic and electrophysiological studies on posture and gait performed on a side-slope and a imitation frozen floor will be presented in the symposium.

1) Technology of posture and gait analysis

Knowledge of the mechanical and physiological mechanisms of walking and maintenance of posture has been advanced during the past decades. The internal and external forces acting on the body and the resulting movements can be expressed in mathematical terms for objective assessment. Gait and posture alnalysis need some instrumentation and devices to visualize and quantify the parameters that are used to describe the patterns of gait and posture. A basic understanding of the rationale for measuring each variables and the limitation of technology is essential for meaningful interpretation of the data. The historical and technological development of the methods used to analyze posture and gait will be reviewed briefly.

2) Change of posture and gait on a side-slope and a imitation frozen walk way

The maintenance of posture and body movements are controlled by exquisite peripheral and central neural systems with diverse sensors and feedback loops. EMG studies of muscles coupled with three-dimentional measurement of body movements has clarified the sequence of muscle recruitment necessary for regulation of postural change in various conditions. Enormous data have been accumulated in this field and provided for critical information to facilitate accurate decision and guide for therapeutic intervention. Since those studies have been performed mostly on a level and steady walk way, we could not apply the data on actual outdoor walking in various conditions such as on a sidewalk and a frozen road. The aim of our study was to clarify characteristics of gait kinematics and kinesiological EMG of lower limb muscles during walking on a unsteady walk way compared with on a level and steady walk way. The posture and gait analysis demonstrated abnormal kinetics and kinematics in all plane and the EMG analysis showed that the phasic action of lower limb muscles in walking on the imitation frozen walk way was similar to one of toddler's gait pattern. The effect of cold on maintenance of posture and regulation of gait will be also plesented.

S-41

"Movement Induced Interference upon Somatosensory Evoked Potentials"

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It is well recognized that the proprioceptive and cutaneous sensory feedback is important to execute appropriately balanced motions, and conversely the motor activity itself modifies the sensory processing. We earlier found that the recovery function of somatosensory evoked potentials (SSEP) measured by the paired stimuli demonstrated two phases of suppression; the 1st one occurred at the interstimulus intervals (ISI) of paired stimuli less than 10 msec and the 2nd one appeared at ISI of 30 to 50 msec. The 2nd phase suppression was greater in peroneal than in tibial nerve SSEP, and it was minimal in sural nerve SSEP. We then found that the 2nd phase suppression was the result of the movement induced interference associated with the mixed nerve stimulation. This was evidenced by the disappearance of 2nd phase suppression after the peroneal nerve block by local anesthesia at the knee, just distal to the stimulating electrodes, eliminating leg movements. The notion of movement induced interference was further supported by the evidence that the preceding sural nerve (pure sensory nerve) stimulation did not attenuate the tibial nerve SSEP. This also explained why the amplitude attenuation by the increased stimulus rate was greater in the mixed nerve than in the pure sensory nerve SSEP, and also was much greater when the mixed nerve causing greater movement was stimulated.

We also found that the movement triggered by one nerve stimulation affected the SSEP of other nerve; preceding peroneal nerve stimulation attenuated tibial nerve SSEP at two different phases, similar to those shown in recovery function in one paired nerve stimulations. Again, the 2nd phase suppression was abolished by the peroneal nerve block distal to the stimulation site eliminating leg movement. Similarly in upper extremity, the preceding ulnar nerve stimulation attenuated the median nerve SSEP at two different phases and the 2nd phase suppression was eliminated by local nerve block distal to the stimulation site paralyzing the finger motions. The attenuation affected mainly frontal P22 and N30 components. This is in line with the experimental studies showing active as well as passive finger movements attenuate frontal P22 and N30 selectively, leaving first cortical potential of parietal N20 intact.

All the above studies suggest that the movement-induced interferences upon SSEP are mediated through the centripetal "gating" mechanism. However, the innovative work by Cheron et al. have demonstrated that even "imaginary" movement attenuated frontal N30 selectively, implying the presence of centrifugal "gating" mechanism. These complicated interactions between sensory and muscle afferents and between sensory afferents and motor efferents, and also centripetal as well as centrifugal gating mechanisms are likely related to the intricate performance of purposeful behavioral task.

S-42

Pathophysiology of the Motor Unit

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INTRODUCTION

Human skeletal muscle is organized within fascicles as motor units. Function and metabolism of the muscle fibers are regulated by the motor neurons and classified as type 1, slow-oxidative, 2A, fast-glycolytic-oxidative and 2B, fast glycolytic. Diseases of the motor neuron, nerve fiber or junctions can result in pathophysiologic changes in muscle. Some of these disorders will be discussed and cases presented.

METHODS

Muscle biopsies obtained from consenting patients with a variety of neuromuscular disorders were stained with multiple histologic and histochemical reactions and examined on cross and longitudinal sections.

RESULTS

Pathological changes included muscle fiber degeneration, necrosis, regeneration, central nuclei, sarcolemmal changes, inflammation, abnormal organelles and inclusions, atrophy, hypertrophy, fiber splitting, denervation and reinnervation. Histochemistry revealed the 3 fiber types interspersed within the fascicles and abnormalities included change in size, shape and distribution.

DISCUSSION

Motor neuron diseases and neuropathies show neurogenic changes of angulated fiber atrophy, target fibers, fiber type grouping and atrophy. Duchenne muscular dystrophy shows fiber atrophy, necrosis, hyaline fibers, endomysial fibrosis, fat cells and complete absence of dystrophin in the sarcolemma. Mitochondrial cytopathies such as Kearns-Sayre syndrome are characterized by ragged red fibers. Congenital myopathies have structural abnormalities such as cores or rods, type 1 atrophy or type 2 preponderance. Metabolic myopathies may contain vacuoles with lipid such as carnitine deficiency or glycogen such as phosphorylase deficiency.

CONCLUSIONS

Changes in muscle structure and histochemistry may reflect change in function of motor neurons reflecting the interdependence and plasticity of the motor unit.

Monday, June 26

Free Paper

O-11

Cervical impulsation and posture- clinical and experimental studies

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INTRODUCTION

According to Fukishima et al. [4] both cervical and lumbar proprioceptive stimulation are ingaged in the maintaining the muscle tonus of the lower limbs. The change of this tension affects position of the center of gravity, inducing the body sway- easly measured during posturography [4], [6]. Stabilimeter, as a new type of dynamic posturograph, may be used to detect the posture disabilities and its additional special detector of the head movement is claimed to be useful in the diagnosis of cervical pathology. Although the role of cervical mechanism in the balance control seemed to be proved by Fukuda [3] but the question about the influence of the muscle or joint receptors and their proper localization is still actual. So the aim of the sudy was to estimate the cervical control of the balance (on the base of spino-vestibular reflexes) in the men suffered from cervical diseases and to analyse the cervical proprioception during the experimental impairments of the particular sensory organs in the pigeons *(Collumba domestica)*.

METHODS

106 patients (44 female and 40 male) suffered from cervical spondylosis or after cervical injures, who were classified to the operative or conservative stabilization of the cervical spine, were tested several times in the different periods of the disease. The following groups of patients were estimated: I: patients before the operation of the cervical stabilization; II: patients from group I, after operation; III: patients during 4 first days after operation; IV: patients who wear cervical collar; V: patients tested from 2 weeks till one year after opearation; VI: patients tested the year or longer after operation; VII: patients after cervical injures; VIII: patients with cervical spondylosis; IX: healthy cases.

In all cases the Freyss' stabilimeter with the head detector was used to appreciate: maximal and mean amplitude (A max, A mean) of the movable platform, the mean velocity (V platform) of it and the mean velicity of the head movement (V head). The measurements were done during 4 sequences of the test: when the platform was moved forward-backward and then right-left, firstly with eyes opened, then closed.

74 pigeons (average weight=300g) were chosen for experimental study. There were 9 groups of birds according to type of cervical impairment made for the purpose to distinquish between the various types of cervical proprioception: I-healthy subjects; II- pigeons after anaesthesia of bilateral cervical muscles; III-pigeons after anaesthesia of right cervical muscles; IV-pigeons after anaesthesia of left cervical muscles; V-pigeons after bilateral dividing of cervical muscles; VI- pigeons after dividing of right cervical muscles; VII-pigeons after dividing of left cervical muscles; VIII-pigeons with the cervical stabilization with collar; IX- pigeons after operation of cervical stabilization with the use of ironplates.

The pendulum was used to observe the spino-vestibular reflexes of the pigeons (pursuit swaing or loss of the balance=fall) and rotatory test was performed to notice the frequency of the head-nystagmus. The statistical comparison on the base of t-student test was introduced to reveal the significant differences between the groups of the people and the birds.

RESULTS

In Table I the significant differences in stabilimetry between the gropus of people are specified.

Table I

The significant differences between the values of the parametrs of stabilimetry during the movement: forward-backward (↕), right-left (↔) and with eyes closed (c) or opened (o)

Comparison bctwccn groups	Paramctrs of thc stabilimctry			
	A max	A mean	V platform	V head
I-II	c↕	O↕		
I-III	o↕, c↕, o↔	o↕, c↕	c↕	
I-V		O↕	o↔	
I-VI	o↕	o↕, c↕	c↕	
IV-IX	o↕, c↕	O↔	c↕, c↔	
I-IX	o↕		c↔	

In the pigeons the significant differences were noticed between:

1. anaesthesia a) right and bilateral on the base of behaviour on pendulum and in rotatory test, . b) right and left on penlulum and in rotatory test
2. healthy and subjects with collar on the base of rotatory test
3. healthy and cases after operation on the base of rotatory test
4. birds with collar and pigeons after oparation on the base of rotatory test

DISCUSSION

The results of stabilimetry were worse just after the operation then the improvement of the posture control was observed till one year after operation and the next expression of pathological findings was demonstrated after the year post operation. It was a real ifluence of the operative stabilization of the cervical spine because the comparison between the healthy people and these before operation was more similar than this after the operation. The collar did not allow the neck movements, suppressing the cervical proprioceptive impulsation clearly demonstrated during bad light which proved the previous observation by Fukushima et al.[4]. Endo et al.' s [2] suggestion about the localization of the propripocetive centers on the level C5-C6 seemed to be real because the majority of our patients suffered from cervical diseases demonstrated the significant pathological results of spino-vestibular reflexes comparing with healthy subjects and they had the disabilities of C5-C6.

The configuration of the data in pigeons postulates that the symmetry of cervical impulsation is the main necessity for proper balance, such as the isolated muscles did not play the essential role, similarly as in Hamann's [5] study. Independently of the type, the cervical stabilization modifies predominantly the head-nystagmus in the birds. From the other side, among the non-stabilizing procedures- anaesthesia disturbes the balance more deeply than dividing of the muscles, which was discovered ealier by Cohen et al. [1]

CONCLUSIONS

1. Proprioceptive impulsation modyfies the vestibular reactivity. Symmetry of proprioceptive stimulation seems to be the most important.
2. The cervical stabilization changes the proprioceptive impulsation. The negative influence of the collar was noted.
3. The operative cervical stabilization in birds impaired especially the frequency of head-nystagmus.
4. In men, the period of time after operation is of great importance: posture control –bed just after operation, improves during the period of 2 weeks till 1 year post stabilization and becomes again worse after 1 year.

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O-12

Gait Analysis in Ankle Arthrodesis

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INTRODUCTION

Ankle arthrodesis is the primary treatment for most disabling arthritic ankles that do not respond to conservative treatment. In spite of its popularity, there are disadvantages to arthrodesis, including prolonged immobilization, a high pseudoarthrosis rate, and the altered stresses on the neighboring joints of ankle. It is important to measure the limitation of motion of each joint after arthrodesis in order to understand its clinical implication. Therefore, the purpose of this study is to employ a computerized motion analysis system to identify the effect of ankle arthrodesis on three-dimensional kinematic behavior of the rear and fore foot and muscle activities of the lower extremity during level walking.

METHODS

A three-segment rigid body model was utilized to describe the motion of the foot and ankle. The segments consisted of the tibial/fibular, hindfoot/midfoot, and forefoot. Eleven spherical retroreflective markers, diameter 1.2 cm, were placed on the subject's affected-side foot and ankle. These were located on the lateral and medial tibial condyles and lateral and medial malleoli of the tibial/fibular segment, medial, rear and lateral calcaneus of the hindfoot/midfoot segment, and the base and head of the 1st and 5th metatarsals of forefoot segment, respectively.

Ten patients, seven males and three females, with single-side solid arthrodesis of the ankle performed due to trauma, degenerative osteoarthritis or rheumatic arthritis, were recruited for this study. The mean age was 39.6 years old (range, 13 to 64). The mean duration of follow-up after arthrodesis was 1.7 years (range, 0.5 to 4 years). Ten normal subjects, mean age 28.8 (range, 20 to 35), served as controls for comparison.

A Hi-Res ExpertVision™ system (Motion analysis Corp., Santa Rosa, CA) collected the trajectories of reflective markers sampled at 60 Hz. Three Kistler force plates and a MA-100 electromyography (EMG) system were synchronized with the ExpertVision™ system to measure ground reaction forces and phasic activities of muscles of the lower extremities. Surface EMG of five muscles, including rectus femoris, vastus lateralis, vastus medialis, tibialis anterior and soleus, and force-plate data were sampled at 1000Hz.

A Mann-Whitney test was used to compare patients' affected side gait parameters with those of normal subjects.

RESULTS

For the arthrodesis group, the hindfoot joint had 10.8° of dorsiflexion/plantarflexion, 10.8° of inversion/eversion and 13.8° of internal/external rotation (Table 1). The forefoot results were 18.8° in dorsiflexion/plantarflexion, 14.0° in valgus/varus and 12.6° in abduction/adduction. For normal subjects, these data were 16.3°, 7.1° and 10.6°, respectively, in the hindfoot joint and 13.4°, 11.1° and 6.9° in the forefoot joint. Sagittal plane motion in the hindfoot was significantly decreased in the patient group compared to normal subjects. The kinematic data explicitly indicated generalized stiffness of the hindfoot on the involved foot in the sagittal plane. In contrast, sagittal plane motion in the forefoot and transverse plane motion

in the hindfoot and forefoot demonstrated relatively larger values in patients than controls. This may be explained by the angle limitation of the hindfoot joint in the sagittal plane which has been compensated for by the forefoot and subtalar joint.

All patients had marked calf atrophy (average, 1.5 centimeters) on the fused side, indicating that calf muscles function was partially lost (Figure 1). In the patient group the phasic pattern of the soleus was abnormal in that this muscle was not active during loading response to terminal stance phase as in the normal subjects, but became active at the pre-swing phase, a time when these muscles are normally inactive.

DISCUSSION

The three-rigid-body description, which describes the specific motions of the ankle and adjacent joints, can improve our understanding of movement at these joints. While primarily positioned for plantar flexion, the soleus also has good inversion leverage at the subtalar joint. This becomes significant because of the muscle's size (five times the size of the tibialis posterior). Abnormalities in soleus action lead to its contribution to inversion. Therefore, weak and delayed soleus positions the foot into eversion and then maintains this undesirable posture throughout stance. The rearfoot patterns indicated eversion instead of inversion. These patients reported that the ankle had suboptimal stability. These results suggest a need for more emphasis on postoperative rehabilitation.

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ACKNOWLEDGMENTS

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Table 1: Comparison of the range of motion (mean ± standard deviation)

	Joint Movement	Range of motion (degrees) Affected side	Controls
Hindfoot	**Dorsiflexion/Plantarflexion	10.8 ±4.8	16.3 ± 3.7
	Inversion/Eversion	10.8 ± 4.6	7.1 ± 2.3
	* Internal/External rotation	13.8 ± 3.2	10.6 ± 3.8
Forefoot	**Dorsiflexion/Plantarflexion	18.8 ± 3.9	13.4± 3.8
	Valgus/Varus	14.0± 3.5	11.1 ± 2.1
	* Abduct/Adduct	12.6 ± 3.5	6.9 ± 3.9

*: $p<0.05$ (Mann-Whitney test); **: $p<0.01$

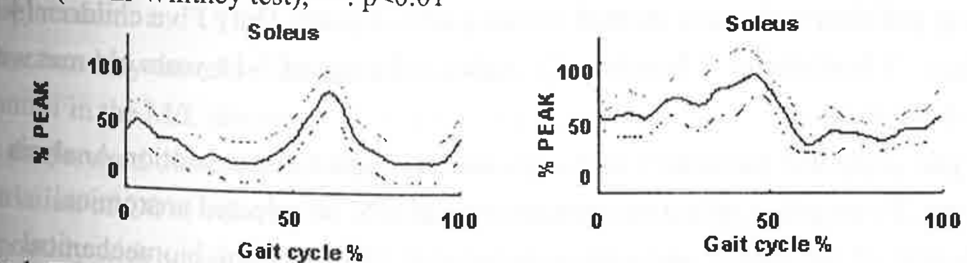

Figure 1: EMG envelops for the group of (a) ankle arthrodesis patient and (b) normal subject.

O-13

Measurement of the Trajectory of the Whole Body's Center of Mass to Evaluate the Surgical Outcome for Children with Spastic Cerebral Palsy

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INTRODUCTION

Although children with cerebral palsy (CP) have static brain lesions, their clinical symptoms, motor function and gait may deteriorate with time [1]. Since motor functions and gait are affected both by neural system and peripheral musculoskeletal system as well. Orthopedic surgeries are often needed to release tightened soft tissues, transfer muscles and de-rotate the bony structures to improve postural alignment and gait performance. Gait analysis is commonly performed to evaluate the efficacy of surgical interventions by measuring temporal-distance parameters, joint angles and joint moments. However, there is a lack of information demonstrating the efficacy of surgical interventions on the overall balance control of the patient. Therefore, the purpose of this study was to quantify the efficacy of orthopedic surgery on the overall dynamic balance control of children with spastic CP from the measurement of the trajectory of the whole body's center of mass (COM).

METHODS

Children were selected retrospectively based on the certain including criteria: spastic cerebral palsy, received orthopedic surgery, completed a pre-op and post-op gait laboratory study, walked independently without using assistive devices during gait data collection, studied within past two years. Only Five children (4 diplegic, 1 hemiplegic, 4 female and 1 male) at the age of 7-14 years old met with the above criteria.

The gait study was performed with a six-camera ExpertVision Motion Analysis System. Twenty-five reflective markers were placed on selected anatomical landmarks of the subject and were sampled at 60 Hz. A 13-link biomechanical model of human body was used to calculate the kinematics of the whole body's center of mass from the weighed sum of COM of each segment. The linear velocity of the COM was computed using the GCVSPL algorithm [2]. The temporal-distance parameters and the COM displacement and velocity in the forward and medial-lateral (M/L) directions were studied as potential outcome measures.

ESULTS

Post-operatively, the subjects demonstrated an average of increase of 23.8% in walking velocity (Fig. 1), which primarily resulted from an increase in stride length (29.7%). All subjects present an increase of the displacement and maximum velocity of the COM in the forward directions, while with one exception, demonstrating a decrease in step width (Fig. 2) and maximum velocity of COM in the M/L direction after surgery (Fig. 3). The range of velocity of COM in the M/L direction all demonstrated a decrease after surgery.

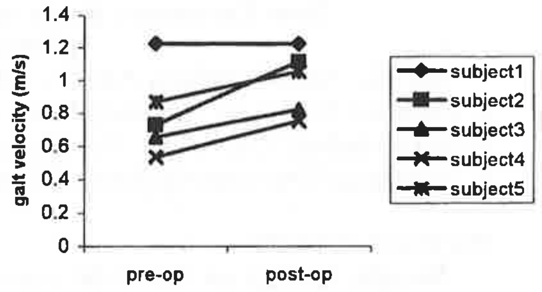

Fig. 1 Walking velocity

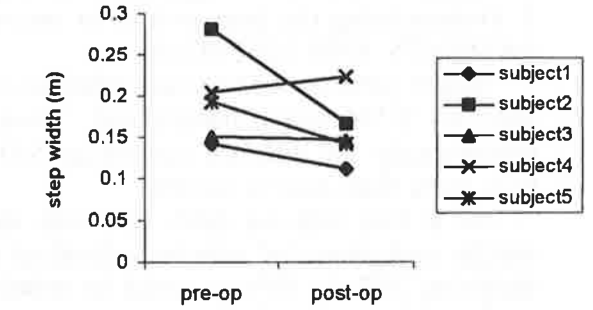

Fig. 2 Step width

DISCUSSION & CONCLUSION

Chou et al, showed that the COM velocity in the M/L direction during gait and during crossing obstacles was constrained in a small range to ensure the line of progression within the base of support [3]. Greater excursion and faster movement of the COM in the M/L direction during gait indicates poor balance control. After surgery, all subjects increased the displacement and velocity of COM in the forward direction, which agreed with the improvement observed in the temporal-spatial parameters. The reduced COM displacement and COM velocity in the M/L direction may decrease the demand of balance control in the M/L direction. This may contribute to an increase of COM velocity in the forward direction and then increase the overall gait velocity. The reduced variation of COM velocity in M/L direction indicates that the subjects walk more smoothly with better control.

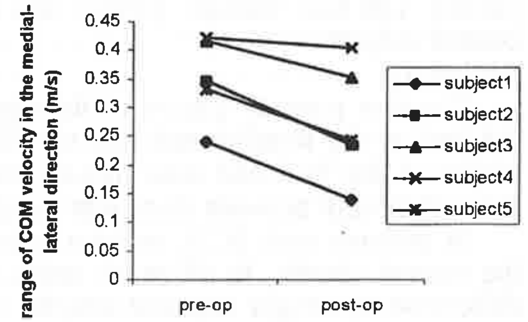

Fig. 3 Variation of COM velocity in the M/L direction

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O-14

New Corrective Shoes to Improve Ataxic Gait of Patients with Spinocerebellar Degeneration

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INTRODUCTION

Weight loading on the distal portion of the extremities has been recognized to improve ataxic movements since an early report by Holmes [1]. In particular, distal loading the lower extremities is known to ameliorate ataxic gait [2-5]. We developed new corrective shoe with an appropriate weight and sole shape for patients with cerebellar ataxia, using gait analysis to determine the best weight and sole shape for each patient.

1. Determining the best weight to improve ataxic gait

PATIENTS AND METHODS

Seven patients with spinocerebellar degeneration (SCD); five men and two women aged from 48 to 74 years, participated. While every patient had an ataxic gait, all could walk continuously for distance exceeding 500 m without assistance. Three patients experienced falls more than once a month.

As a first step we fabricated trial shoes for gait analysis to determine the appropriate weight and shape of sole in individual patients. On the insoles of the trial shoes, pieces weighing 250 to 1250 g could be attached or detached in 250-g increments. As the trial shoe itself weighed 300 g, the total weight could be adjusted from 550 to 1550 g. On the lateral portion of the sole, wedge boards could be attached to adjust thickness in 5-mm increments. An F-SCAN pressure sensor pad (Nitta, Osaka, Japan) was attached to the insole to analyze the foot pressure pattern during walking. We first determined the best weight for the shoes, and then decided the most appropriate sole shape for a particular patient. The foot pressure pattern was analyzed in a healthy 32-year-old man as a normal control subject.

RESULTS

The foot pressure pattern of the control subject showed peak pressure progressing from the heel to the forefoot and first toe. The trajectory of the center of pressure started at the center of the heel and then moved toward the forefoot in an arc with lateral convexity. Reproducibility between steps was good.

In patients with SCD, without correction, pressure of the forefoot was greater than in the normal control. In all seven cases, an additional 500 g weight load was best, with no difference in weight required despite varying patient height or weight. In three of seven cases, laterality of the foot pressure pattern was observed; on one side the trajectory of center of pressure deviated laterally. Attachment of 5-mm lateral wedge was required for that foot. In the other four cases, the center of pressure deviated laterally in both feet; attachment of 10-mm lateral wedges improved the foot pressure pattern bilaterally. We followed the patients in terms of gait for at least 3 months, and in all cases the improvement of gait was maintained and patients subjectively reported the corrective shoes to be helpful.

In the three patients fell frequently before using the corrective shoes, this tendency no longer was present, suggesting that the shoes could reduce the risk of falls in the patients with cerebellar ataxia.

2. Weight distribution of the shoe

At first we designed the corrective shoes with the 500-g of additional weight load affixed to the external aspect of the sole as a lead plate. While the shoes significantly improved the patients' ataxic gait, the sole was inflexible and patients sometimes complained of foot pain with long-term use. Also, in terms of production, affixing lead plates of individualized size was complicated. To address the problems above we decided to change the method of weight loading to insertion of a 500-g block into either the heel or the toe of the sole. We then needed to determine which location was preferable.

PATIENTS AND METHODS

The seven patients participating were the same as in part 1. We made trial shoes with urethane soles including a hole in the heel and another in the toe. Plugs consisting of 500 g of lead or a corresponding volume of urethane could be switched between these sites. The shoe itself weighed 300 g, so with the 500-g lead plug, each shoe weighed 800 g.

To determine optimal weight placement, we used two types of assessment as before. We first attached the F-SCAN pressure sensor pad to the insole of the trial shoes to assess the foot pressure pattern during walking. Next we simultaneously measured three-dimensional motion and ground reaction force to determine the moment of force at joints in the right lower limb during walking

RESULTS

In patients with SCD without weight loading, the trajectory of the center of pressure showed a lateral convex curve and excessive pressure on the forefoot. With weight loading at the heel, the foot pressure pattern tended to normalize. With the weight load at the toe, the foot pressure pattern deteriorated, resembling the pattern without weight loading. Observations were similar in all seven SCD cases.

With weight loading at the heel, step width was reduced, step length was expanded, adequate heel strike and push-off were attained, and patients' gait improved to resemble that of the normal subject. This was confirmed by investigation of the moment of force at lower extremity joints during walking.

Based on the results above, we designed corrective shoes. The weight of each corrective shoe was 800 g including a 500-g weight block in the heel. The top of the shoe extended over the ankle to maximize support around that joint. Closures for the shoes used Velcro tape to facilitate putting shoes on and taking them off.

DISCUSSION

The mechanism of improvement of ataxic gait by weight loading is thought to involve increased firing of impulses in the afferent nerve fiber from the muscle spindle, which can influence the central motor program involving the cerebellum.

In all seven cases presently studied, 800 g of shoe weight per foot was optimal for improving ataxic gait. When a lateral wedge was added to complement the effect of weight loading, optimal gait improvement resulted. Weighting the heel worked much better than weighting the toe.

So far, most gait analyses have been performed either to study gait phenomena or to assess treatments including orthoses. In this trial we used gait analysis to closely guide development of a treatment modality. Such approaches should lead to more effective design of orthoses to minimize disability.

CONCLUSION

The corrective shoes which we developed remarkably improved the ataxic gait of patients and eliminated a tendency toward frequent falls while walking.

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O-15

QUANTITATIVE MEASUREMENT OF SPASTICITY OF TRICEPS SURAE

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INTRODUCTION

Spasticity affects standing and walking. Quantitative evaluation of spasticity had been attempted by a various means[1]. But it is still difficult to assess spasticity of muscles quantitatively. Especially, under dynamic situations such as standing and walking, there have been less proper methods to evaluate spasticity of muscles. We propose the method using changes of postural alignments during standing on a platform which was gradually inclined for quantitative assessment of spasticity of the triceps surae.

METHODS

The alignments of standing posture on a platform, which was inclined gradually for 11 normal subjects and 10 subjects who were spastic, were measured by photographical analysis. The relationships between hip and knee joints, and knee and ankle joints were analyzed.

RESULTS AND DISCUSSION

Increasing inclination angle of the platform, the sudden knee flexion of the knee and the hip joints occurred(Fig.1). We defined this inclination angle as TT(Tensile Threshold). The TT was significantly smaller in CP than normal children. From the TT, a stretching reflex of the triceps surae would occur. As the triceps surae were plantar flexor muscles, contraction of the triceps surae due to stretching reflex would make the knee joints flex and body fall backward. In order to keep standing, pushing the body forward would be necessary. Therefore, from the TT, the hip joints started to be flexed suddenly(Fig.2). We can use the TT as a quantitative spasticity of triceps surae during standing.

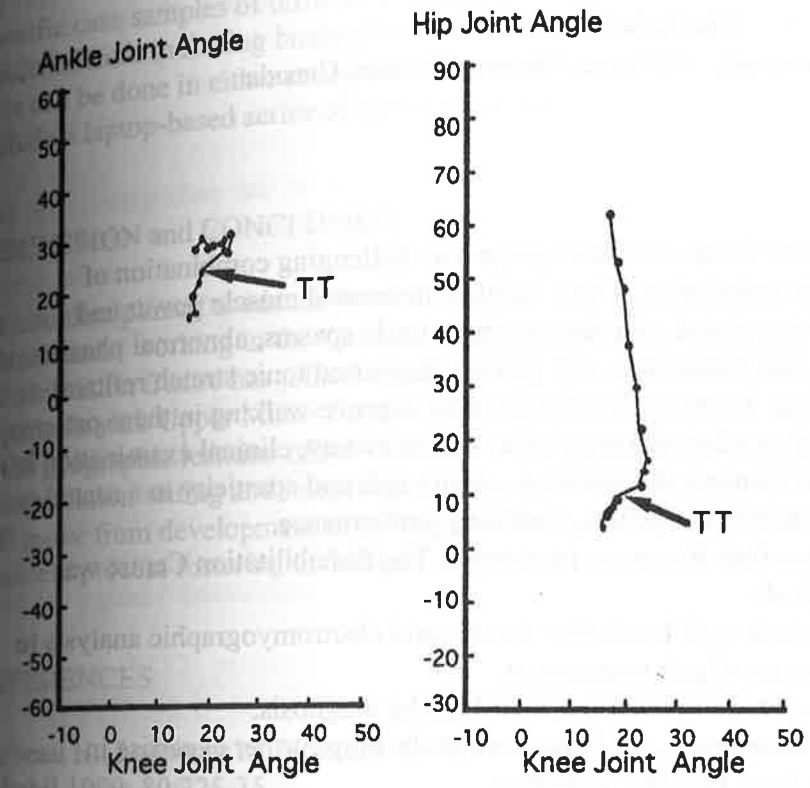

Fig.1

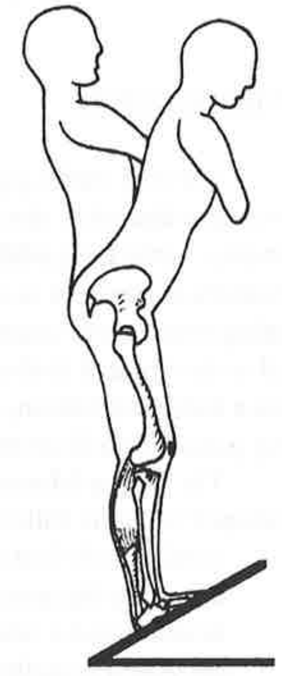

Fig.2

CONCLUSION

Standing on ascending inclined plane test described in this paper is the simple, harmless and reliable method to evaluate spasticity of triceps surae during standing.

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O-16

Upper Motor Neuron Gait Recovery
A Clinical and Research Collaboration

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INTRODUCTION

Patients with Upper Motor Neuron Injuries present a challenging combination of movement disorders that impair ambulation. These include: decreased muscle power and dexterity, early fatiguability, exaggerated reflexes causing muscle spasms, abnormal phasic activation of muscles in swing and stance stages of gait and increased tonic stretch reflexes causing muscle and joint stiffness. Interventions designed to improve walking in these patients need to be targeted to the specific underlying problems. Unfortunately, clinical examination is often a static evaluation, and assessment of parameters of strength and spasticity in a seated or lying patient bear little relationship to the patient's walking performance.

The Upper Motor Neuron Gait Recovery program at The Rehabilitation Centre was developed with the following goals:

- combine clinical assessment with kinematic, kinetic and electromyographic analysis to diagnose the specific causes of gait impairment
- develop and evaluate targeted interventions based on the diagnosis.
- provide a consultation and educational framework to develop further expertise in diagnosing and treating these patients' problems.

METHODS

This effort is being developed in three arms.

The clinical arm combines Physiatric, Physiotherapy and Gait Analysis to arrive at specific diagnosis of gait disorders. Particularly in cases where the clinician is trying determine whether specific therapy should be used to treat weakness, inappropriate activation or tone, the addition of dynamic electromyographic analysis will indicate which therapies to use.

The research arm, in collaboration with many other academic centres, evaluates therapeutic interventions targeted at weakness (specific exercise protocols, Laufband locomotion, 4 AP, FES), tone (antispasticity agents) or abnormal phasic activation of muscles (Laufband locomotion, biofeedback, noradrenergic agonists, NDT therapy).

Practising physiotherapists from the Neurologic Rehabilitation Service, physiotherapy student and physiatric residents rotate through the Gait and Motion Analysis Laboratory to learn these techniques, participate in various research projects and present new ideas for evaluation, thereby making the education arm of this effort.

RESULTS

Specific case samples of difficult patient problems and solutions will be presented. Research results of trials including biofeedback, Laufband locomotion and 4AP will be summarised. This can be done in either poster or platform presentation. The poster or platform format would include a laptop-based series of video gait analyses.

DISCUSSION and CONCLUSION

An interdisciplinary academic team including a physiatrist, physiotherapists, engineers and biomechanist working in the Gait and Motion Analysis Lab (GAMA) at the Ottawa Rehabilitation Centre has joined together to create a collaborative clinical and research approach to patients with Upper Motor Neuron gait disorders. Part of the success of this approach is related to the geographic location of the GAMA Lab to the treatment team, being within the Rehabilitation setting and integrated into the clinical and academic programs. New treatments will move from development to testing and through to clinical teaching and treatment in a seamless process fostering investigative spirit and evidence based practise.

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O-17

Use of a piezo-dynamometric platform to analyse the foot loading pattern in diabetic patients with peripheral neuropathy.

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INTRODUCTION

Abnormal plantar pressures are considered to play a major role in the pathogenesis of the neuropathic ulcers in the diabetic foot. Several authors have expressed the opinion that vertical stress alone is not the only determinant of tissue breakdown, and that shear stress should also be considered. We used a piezo-dynamometric integrated platform to simultaneously collect pressure distribution and the evolution of all the three components of the ground reaction force (GRF) under total foot and under specific selected foot subareas. The alterations of the shear components of the GRF, especially under the metatarsals, has been widely analysed and discussed [1]. Briefly, the detailed dynamic analysis of rearfoot, metatarsals and hallux allowed us to highlight the gait instability of the neuropathic patients, and to confirm the structural and functional alterations of the diabetic neuropathic foot. The different roles the heel, the metatarsals and the hallux have with respect to the corresponding areas of the normal foot, well demonstrate the effect of a substantial change in the deambulatory strategy from an ankle to a hip strategy.

In the present study we evaluate the excursion of the centre of pressure (COP) during the stance phase of a walking cycle to verify the above hypothesis in terms of its temporal and spatial evolution and spatial integrals.

MATERIALS AND METHODS

We used a 40 x 60 cm piezo-dynamometric platform obtained by superimposing a dedicated resistive pressure platform (spatial resolution 5mm, temporal resolution 10ms) onto a commercial force platform. The accuracy in the evaluation of the COP displacement was assured by the redundancy of information supplied by the two platforms [2]. The device was inserted at a level in the middle of a wooden walkway 8 m long, and patients were trained to centre it while walking barefoot at their preferred speed. Six footprints were collected for each foot of 31 diabetic patients and 11 healthy volunteers (class C). Patients were subdivided into three classes [1]: diabetics without neuropathy (class D, 10 patients), diabetics with neuropathy (class DN, 11 patients) and diabetics with previous neuropathic ulcer (class DPU, 10 patients). The two feet of the same patient were analysed separately. For DPU patients, only the previously ulcerated foot was included in the study. For a correct comparison of the COP evolutions, two 2D reference systems have been considered: the former solid with the bisecting line of the footprint and the line orthogonal to it passing through the most distal point of the rearfoot; the latter solid with the measurement device. Therefore, each curve was first rotated and translated in order to match the former reference system with the latter. Then it was temporally resampled over a fixed number of samples, greater enough to assure a good interpolation of the original COP positions (256 points, with the original sampling rate equal to 100 samples/s). Finally, it was normalised with respect to foot length and width. The curves have been averaged over the 6 experiments for each foot of each patient, and then averaged over each class. Curves related to left feet have been rotated of 180° with respect to the longitudinal axis. Among the possible parameters, we compared the curve patterns of the transversal versus the longitudinal axis, the maximum excursions along both axes, and the integrals along the longitudinal axis expressed as cm times % of the total foot length. The statistic significance of the differences was assessed by means of the ANOVA test and the Bonferroni correction.

RESULTS

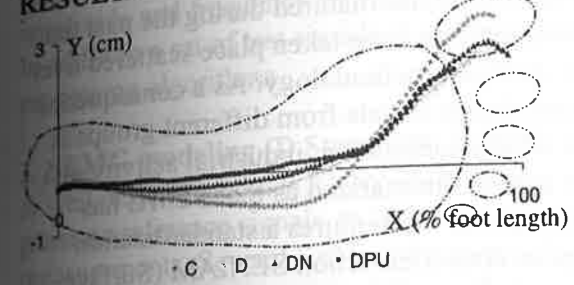

Fig. 1
COP curve patterns

Figure 1 shows the COP curve patterns. The excursion along the transversal axis Y clearly decreases from C to DPU class. COP for DPU patients also shows a significantly reduced excursion along the longitudinal axis X. It is also evident that the loading time of the central metatarsals increases according to the severity of the pathology. Mean values, standard deviations and statistically significant differences of the maximum excursions along both axes, of the integrals along the Y axis, and of the vibration perception threshold (VPT) are reported in Table 1. The clinical variable VPT accounts for the severity of the pathology.

Table 1
Mean values and standard deviations of COP maximum excursions along both axes and integrals, and of the Vibration Perception Threshold (VPT).

Class	X excursion (cm)	Y excursion (cm)	Y integral (cm · % length)	VPT (Volt)
C	26.5 ± 1	3.67 ± 0.1	78.65 ± 3	-
D	26.8 ± 1	2.79 ± 0.1 §	55.50 ± 2 §	14 ± 5
DN	27.1 ± 1	2.61 ± 0.1 §	57.31 ± 2 §	31 ± 7
DPU	24.2 ± 1 § ° ^	1.92 ± 0.1 § ° ^	27.43 ± 1 § ° ^	40 ± 5 ^

Legend for the statistically significant differences ($p < 0.05$): § = diff vs C; ° = diff vs D; ^ = diff vs DN.

DISCUSSION AND CONCLUSIONS

In neuropathic patients the COP excursion significantly decreases along both axes. This is the effect of a change in the loading pattern which entails a very poor loading of the hallux and a major involvement, for a longer time, of a specific part of the metatarsals area. This area just coincides with the most frequently ulcerated part of the foot sole.

We believe that COP is one of the most appropriate and easily collected biomechanic variables for revealing the tendency of distal neuropathic patients towards a flat-footed gait, which is typical of their hip strategy. While it is usually considered in qualitative terms, the accurate measurement system we used, with adequate temporal and spatial resolution, the normalisation criteria and the computation methodologies we applied, allowed us to exploit it as a reliable quantitative variable.

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O-21

Development of recommendations for recording and processing SEMG: The SENIAM project

HJ Hermens, B.Freriks, R.Merletti, C.Disselhorst-Klug, G.Hagg, D.Stegeman, G.Rau

INTRODUCTION

From the broad field of applications, involving neurology, rehabilitation, orthopedics, ergonomy and sports, one might conclude that surface EMG has matured during the past ten years. However, one has to recognize that most developments have taken place scattered over the world in specific scientific groups, using rather different methodology. As a consequence when one considers applications, exchange and compilation of data from different groups is difficult. Another consequence is that due to a lack of standardization, industrial activity at a European scale is missing. So the present situation can be summarized as that SEMG has developed and is developing rapidly but its real widespread use requires a standardization effort. This is one of the key reason why the European concerted action SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) was defined and carried out.
The objective of the European concerted action SENIAM (1997-2000) were:

A. To integrate basic and applied research on SEMG at an European level and to establish European cooperation and

B. To solve key items that presently prevent a useful exchange of data and clinical experience.

This concerned especially the development of recommendations for

1. Sensors (configuration of electrodes), and sensor placement procedures,
2. SEMG signal processing
3. SEMG modeling.

RESULTS

1. Sensors and sensor placement procedures (H.Hermens, C.Disselhorst-Klug, B.Freriks, G.Rau)

An extensive literature scan was performed on the methodology for SEMG recording. This resulted in information on sensor properties and sensor placement procedures from 144 papers. One of the main conclusions was that in general authors report very sloppy about the way SEMG is being recorded; in most publications the sensor properties and sensor placement procedure is not properly described to allow replication of the experiment. If we should address the most commonly used sensor configuration this is a circular Ag/AgCl sensor with a diameter of 10 mm, used in a bipolar configuration with an inter electrode distance of 20 mm. The skin is shaved, rubbed and cleaned before sensor placement.
In total 352 sensor locations were counted for 53 different muscles. In 4 cases neither the muscle(s) nor the sensor location was mentioned, whereas in 58 cases the sensor location on the muscle was not mentioned. The remaining 294 descriptions mentioned both the name of the muscle and described the sensor location or referred to literature.
The next activity was a state of the art concerning the effects of sensor properties and their placement on the muscle, on the SEMG signal characteristics and reproducibility of measurements. This was done by organising a topical workshop (SENIAM 5).
Based on the conclusions of the workshop and the inventory, initial recommendations were developed for the sensor properties. Also a general sensor placement procedure was developed and worked out in detail for 27 different muscles (SENIAM 5). This initial set of recommendations were sent to all SENIAM partners and SENIAM club members for review. Based on their comments the recommendations were changed in some details.

2. Signal processing (R.Merletti, D.Farina)

An inventory was made on the different signal processing techniques used in the European labs. In addition a topical workshop was devoted to a present state of the art and discussion on future aspects (SENIAM. It was concluded that in most practical applications rather simple techniques are being applied, while many new techniques are under development. It was chosen to develop recommendations for the techniques being used in practice involving amplitude and frequency estimators and the muscle fiber conduction velocity.
In addition a set of test signals was developed to enable testing of equipment and signal processing algorithms.

3. SEMG modeling (D.Stegeman, J. Blok)

A well defined model is a very useful tool in addressing issues in the other tasks by using it to generate reference signals, to test and compare algorithms and simulate situations and measurements. Several SENIAM partners developed models of myoelectric signal generation (SENIAM 6). These models differ with respect to their starting points, their input parameters, calculation methods and output. An inventory was made on the models developed and authors were also asked to make their model available to SENIAM. Initially, it was tried to develop a common model, but this appeared to be not feasible but also not efficient. In the end 4 models were made available to the SENIAM project. They were tested extensively, guidance was developed and published on the CD–Rom (SENIAM 9).

CONCLUSIONS

During the SENIAM project 4 general workshops and 3 topical workshops have been organized. On average about 40 people participated in each general and 15 in each topical workshop. The proceedings all have been published, resulting in 7 books.
The recommendations on SEMG recording and processing have been published in a separate book (SENIAM 8) as well as on a CD-ROM (SENIAM 9). A SENIAM club was made in order to facilitate dissemination and to enhance international exchange and cooperation. At this moment this club has over 100 members. So, with the SENIAM project a start has been made to combine the knowledge of different disciplines into recommendations for recording and processing of the SEMG. This has been done in a number of sequential steps, with the strong support of the management team and the continuous involvement of the SENIAM partners and members of the SENIAM club.

Literature

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O-22

FINE-WIRE EMG MEASUREMENT OF CERVICAL MUSCLES IN PATIENTS WITH LATE WHIPLASH SYNDROME PERFORMING ISOMETRIC AND DYNAMIC EXERCISE

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Introduction: Late Whiplash Syndrome appears with about 10-20% of all patients and represents an immense diagnostic, therapeutic and expertise problem. The main symptoms are pain and a decreased range of motion. Functional disorders of the muscles (atrophy, dyscoordination) are often blamed for that but can not be diagnosed by radiologic techniques. Up to now there is no information in literature about a reliable, objective procedure to evaluate muscular dysfunction of the cervical spine.

Aim of the study:

1. Developing an objective and reliable method to perform intramuscular fine-wire EMG of the cervical muscles.
2. Describing patterns of muscular disorders in patients with cervical spine injuries while performing isometric and dynamic exercise.

Methods/Materials: We developed guidelines by mathematical transformation of CT scan (n=20) detected data for the intramuscular application of fine-wire electrodes into cervical muscles. The technique has been validated by inserting wires in 10 human corps and by sonographical control of the needle location in 25 healthy volunteers. Subsequently we determined the average rectified amplitude, median frequency, power spectrum and linear envelopes while 25 controls and 40 patients with whiplash injuries performed isometric and dynamic exercises. These data have been correlated with the patients clinical outcome and individual pain scores.

Results: The objectivity (reproducibility) of intramuscular fine wire application was 0.94, while reliability was 0.92. Neither in corps nor in controls injuries to vessels or nerves occurred. Patients indicated reduced force levels, a loss of electric amplitudes up to 67% and a smaller frequency shift in the fatigue test (patient median 5%, controls median19%). The linear envelope curves of pain free controls showed all similar characteristics in each of the four movement phases. Compared to those, patients with pain exhibit several deviations depending on the movement phases like amplitude increases and decreases.

Conclusion: Using our new method it appears that intramuscular EMG measurement is an easy and precise diagnostic tool to investigate the function of the cervical muscles. Analysis of amplitudes and frequencies under isometric conditions do only show differences by comparing groups (minima, medians, maxima). However, the shape of linear envelopes under dynamic conditions is directly influenced by pain and therefore represents a reliable parameter for individual objective pain detection.

O-23

Fuzzy-Logic to Support the Assessment of the Muscular Co-ordination Pattern Detected by Surface-EMG

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INTRODUCTION

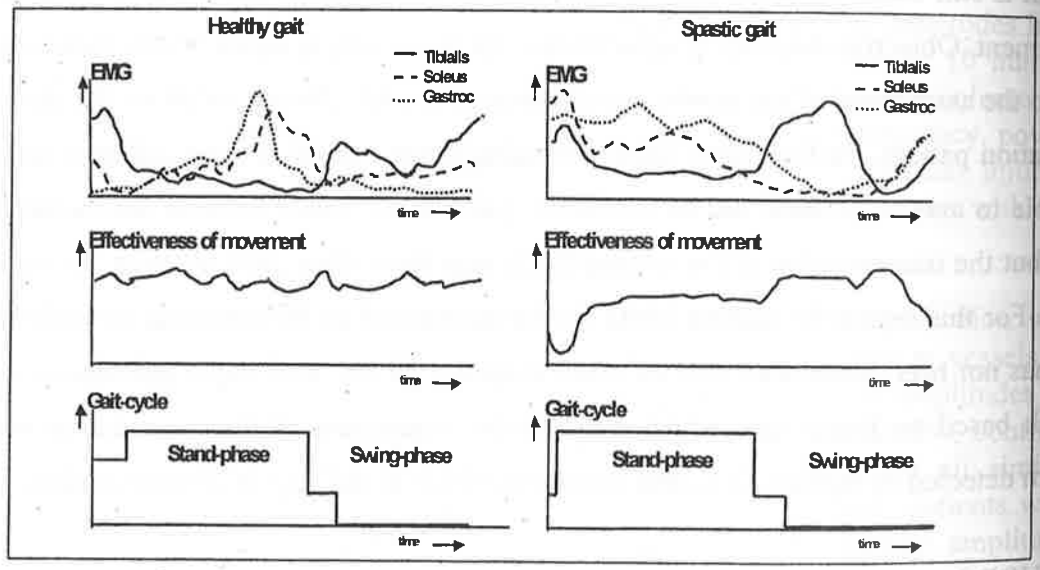
Damages of the central nervous system frequently result in serious impairments of the patients' functional movement capacity. Among others, the deficiencies are caused by an abnormal co-ordination pattern of different muscles which hinders the generation of an effective movement. Therapy is focused on the maintenance of patients' functional movement capacity. The difficulty herewith is to decide which therapy is the most efficient in treating the individual deficits of each patient. In clinical practice, the decision on the treatment of the individual patient is still based on subjective data like clinical examination and visual assessment of the movement. Objective data can be achieved by 3D movement analysis which, however, is limited to the assessment of the movement and does not yield information about the muscular co-ordination pattern. Surface-EMG signals simultaneously recorded from different muscles are suitable to assess the muscular co-ordination pattern and would provide additional information, but the interpretation of the surface-EMG signals is often difficult even for experienced users. For this reason the surface EMG for the assessment of the muscular co-ordination pattern has not been introduced into the clinical routine so far. This paper introduces a new approach based on fuzzy-logic which supports the assessment of the muscular co-ordination pattern detected by surface EMG and which contribute to utilise it in clinical routine.

METHODS

The effectiveness of the movement of the ankle joint has been investigated in children suffering from spasticity in gait. Conventional bipolar surface-EMG has been recorded simultaneously from the tibialis anterior, the soleus and the gastrocnemius medialis according to the recommendations of SENIAM. The EMG-data have been rectified and smoothed by a 10 Hz high-pass filter. For each muscle different EMG-sweeps have been synchronised to the gait cycle, averaged and normalised. The fuzzy-inference-method has been used to assess the resulting EMG signals with regard to their contribution to the effectiveness of the ankle joint motion. The fuzzy-inference has been based on 11 rules like e.g. *'If tibialis anterior and gastrocnemius are simultaneously active, then the movement of the ankle is not effective'*. Each rule has been weighted according to its relevance for the ankle movement. The resulting outcome measure 'effectiveness of movement' indicates to which extent and at what periods of time the muscular co-ordination pattern yields an effective movement of the ankle.

RESULTS

In the figure the averaged and normalised EMGs and the resulting effectiveness of the ankle movement of a healthy volunteer and a patient with spasticity in gait are compared. In contrast to the normal muscular co-ordination pattern, in the case of the spastic patient the effectiveness of the ankle movement is poor at the beginning of the stand-phase and gradually becomes more effective during the gait cycle until it is almost normal with the beginning of the swing-phase.



DISCUSSION AND CONCLUSION

The interpretation of the muscular co-ordination pattern detected by surface electrodes can be supported by the fuzzy-inference method. This is a prerequisite for the use of the information about the muscular co-ordination in clinical routine. The example of the relatively simple ankle movement initiated by three muscles clearly demonstrates the principle's feasibility. However, the methodology can be extended to more complex movements. This opens new information for the treatment of patients with movement disorders.

O-24

High Spatial Resolution EMG in Children with a Rupture of the N. Plexus Brachialis

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INTRODUCTION

Obstetric palsy of the plexus brachialis nerve occurs in about one of 2000 births. Since the plexus brachialis is a net of nerves supplying a variety of muscles of the arm, the hand and the fingers, frequently a multitude of muscles are affected by its lesions. About 10 % of the patients have severe functional and esthetical impairments in arm movement. Nerve repair or joint release operations are commonly performed to support the recovery. Thus, for the physician's diagnosis the information about the extend of nerve damage, the condition of the motor units (MUs) and the progress of the reinnervation processes is essential. Since the patients are children, the methodologies and procedures which are used to obtain the information about the muscles' condition should be non-invasive. Additionally, non-invasive procedures allow a follow-up of the patients, which would give insight in the development of the reinnervation. The High-Spatial-Resolution-EMG (HSR-EMG) may be a suitable tool to gain the required information about the single MUs in a non-invasive manner.

METHODS

The non-invasive HSR-EMG is based on the detection of the change of the spatial potential distribution over time generated on the skin surface by the excitation of the muscle fibres. The EMG is recorded monopolarly with 2dimensional electrode arrays. For the distinction of the excitation of single MUs located close to the skin surface a spatial filter is applied to the data. A 2dimensional Laplacian filter is applied to five channels arranged crosswisely. The activity of a single MU can be separated and identified as an isolated peak in the spatially filtered EMG signal (Rau and Disselhorst-Klug, 1997).

RESULTS

Investigations on three different muscles, m. abductor pollicis brevis, m. biceps brachii, m. infraspinatus, were performed on about 30 children with a rupture of the plexus brachii nerve. For example, Figure 1 shows the HSR-EMG signal from the abductor pollicis brevis muscle of three different patients. In the first case the signal shows a high activity of a large number of MUs, since the muscle is not affected by the lesion. In the second signal less activity can be found, which can be attributed to a loss of MUs. In the third tracing the muscle is affected strongly and only a few very isolated peaks can be seen.

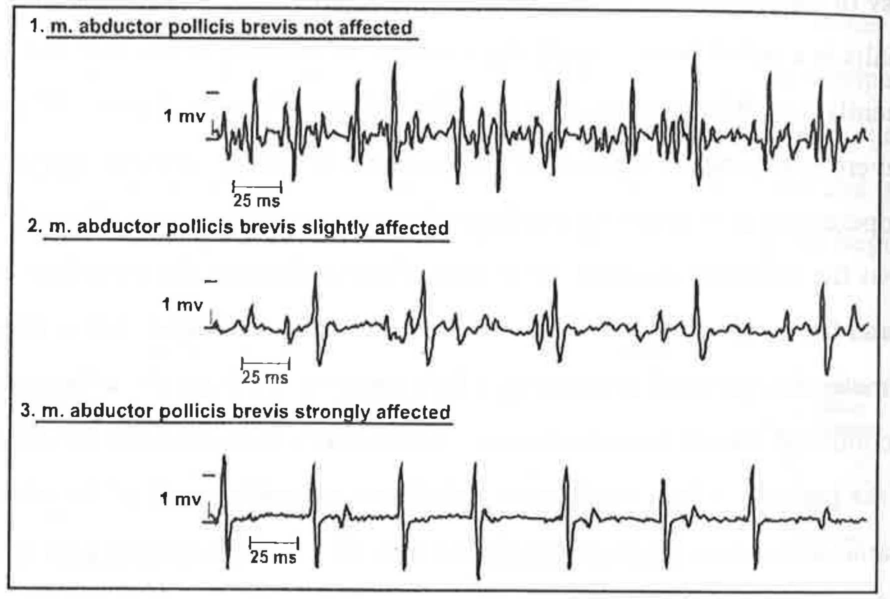

Figure 1: HSR-EMG signals of the m. abductor pollicis brevis from patients with different degrees of impairment

CONCLUSION

The HSR-EMG seems to be a suitable tool for the non-invasive assessment of muscular function in children with obstetric plexus lesion. The methodology allows the determination of the degree of impairment of the lesion on a specific muscle as well as the progress of the recovery.

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O-25

Myoelectric Recordings of Multiple Motor Units of the Human Larynx

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INTRODUCTION

Proper functioning of the larynx is essential for maintaining a patent airway, to facilitate swallowing, and to produce voice. These important physiologic functions require complex coordination of five intralaryngeal muscles innervated by two cranial nerves [1]. We utilize a quadrifilar electrode and the Precision Decomposition technique [2] to obtain recordings of multiple motor units of thyroarytenoid (recurrent laryngeal nerve) and cricothyroid (superior laryngeal nerve) muscles. The results provide specific information about how laryngeal muscle force is being controlled by the central nervous system (CNS), in terms of recruitment and firing rate of individual motor units. This study provides new information about neuromuscular physiology of the larynx—specifically, the recruitment patterns of multiple motor unit activations and the existence of a common neural drive—in normal and disease states.

METHODS

All recordings are undertaken in the Voice Research and Clinical Laboratory at New York Medical College in an electrically isolated and acoustically quiet room. Subjects include normals, without a history or indication of laryngeal or nervous system disorders, and patients with laryngeal dystonia, including laryngeal spasm and vocal fold paresis. Quadrifilar needle electrodes are inserted by an otolaryngologist into mid-regions of unanesthetized thyroarytenoid and unilateral cricothyroid muscle of unsedated subjects prior to being instructed to perform tasks of quiet and deep breathing, Valsalva maneuver, whispered /i:/, voiced modal /i:/, and high pitch /i:/ vowel tasks in stop-start fashion, permitting for adequate rest between multiple repetitions.

Recorded channels include three differencing signals and a composite signal for each electrode, amplified by four-channel isolation amplifiers, and the acoustic signal recorded by an electret microphone and preamplifier. Myoelectric composite signals are bandpass filtered from 33 to 1000 Hz and difference signals from 500 to 10,000 Hz using a new nonrecursive digital filter [3] and acoustic signals were lowpass filtered at 20,000 Hz prior to digitizing all signals at a rate of 25,000 samples per second (sps) by a 12-bit digitizer and personal computer. Post-recording processing of data included interpolating myoelectric data to 50,000 sps, and compressing segmented data files prior to applying the Precision Decomposition technique via minicomputers at the NeuroMuscular Research Center at Boston University.

RESULTS

Fig. 1 illustrates a mean firing rate (MFR) plot of five motor units (MU) of the thyroarytenoid muscle that have been determined by the procedure, along with the acoustic signal. Accompanying these is a signal derived from the attendant composite myoelectric signal, by extracting the rms value in each neighborhood of a 150 ms sliding window. The rms composite signal is offered here as an indicator of overall muscle activity because a direct measure of muscle force is not available for the larynx.

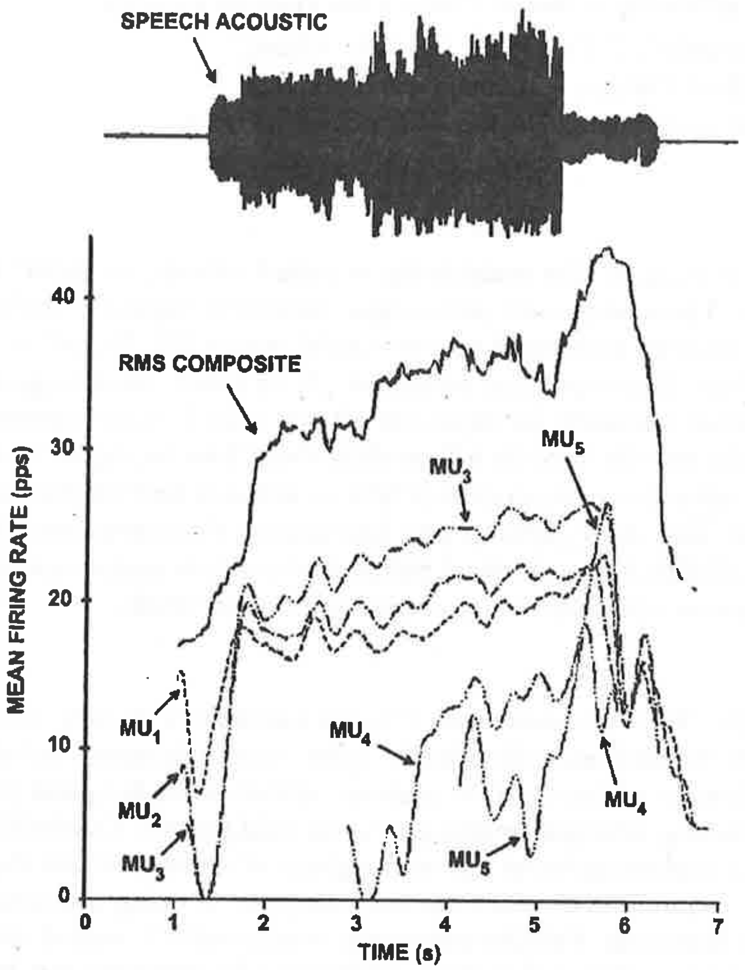

Figure 1: Mean firing rate of five motor units (MU) of thyroarytenoid muscle of the larynx during sustained high-pitch vowel /i:/ ("eee"). The acoustic sound pressure signal indicates the output production of the vocal motor system. The rms ("moving average") of the composite myoelectric signal indicates summed activity in the vicinity of the recording needle electrode. Subject is a 26-year old female with "normal" vocal physiology. (Five of ten motor units are shown, for lack of space.)

DISCUSSION and CONCLUSION

Transition from *modal* to *falsetto* register of the larynx occurred at approximately 5.3 s for this subject, resulting in increased tension of the thyroarytenoid muscle and reduced sound pressure intensity. Here, motor units 1, 2 and 3 appear early in the task, while motor units 4 and 5 begin to fire at 4.2 and 5.5 s into the task, respectively. The appearances of motor units 4 and 5 correspond to increasing activity of the thyroarytenoid muscle, corresponding to an increase in force demand, to offset stretching of the epithelium cover of the vocal folds by cricothyroid during falsetto register. This phenomenon shows recruitment and decruitment of individual motor units during periods of increasing and decreasing neuromuscular activity. It also demonstrates the presence of a neuromuscular "common drive" in control of the larynx by the CNS.

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O-26

Studies on characteristic of constant exercise around VT using spectral analysis of EMG and ECG-RR interval variability

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INTRODACTION

A study was performed to investigate characteristics of three constant exercise around ventilatory threshold(VT) using spectral analysis of EMG and ECG-RR interval variability.

METHODS

The subjects were 11 healthy male students (ranging in age from 20 to 25 years). Surface EMG from the knee extensor muscular(m. vastus medialis) and RR interval of ECG were recorded by bicycle ergometer during three constant exercise which were 20% less than VT level (-20% VT), VT level and 20% more than VT level (+20 VT). Power spectral analysis of EMG was performed to obtain power spectral dencity(PSD) of 4 bands (20-50Hz, 50-100Hz, 100-150Hz, 150-200Hz) for every 2 seconds by maximum entropy method(MEM). And, power spectral analysis of RR interval variability of ECG was performed for every 1 minute by MEM to obtain the low-frequency band (LFB, 0.04 to 0.15Hz) , and the high-frequency band (HFB, 0.15 to 0.4Hz) and the ratio of a LFB to HFB (L/H ratio).

RESULTS

Changes in Total PSD from 20Hz to 200Hz of EMG showed higher value at +20VT level than at VT level or -20VT level. The %PSD of EMG at the band of 100-150Hz and 150-200Hz increased in the work load at +20VT level more than VT level or -20VT level. HF component of RR interval variability showed a rapid decrease in proportion to load, whereas L/H ratio were not in a trend of 3 constant exercises.

DISCUSSION

The comparison of EMG parameters suggest a progressive recruitment of fast twitch fibres(type Ⅱ b) as time course. In each exercises, HF components of RR interval variability may be use as an indicator of parasympathetic nervous activities, but L/H ratio do not clealy show sympathetic nervous activities during constant exercise.

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O-27

Sural Nerve Reflex in the Back Muscles during Human Walking

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INTRODUCTION

Non-noxious electrical stimulation of cutaneous nerves like sural nerve during human locomotion produces phase dependent reflexes [1]. This phenomenon is explained in relation to postural adjustments to avoid stumbling or other events that hinder smooth locomotion. However, most of preceding studies focused exclusively on electromyographic and/or kinematic responses in the legs. In the analysis of the motor strategy underlying locomotion it is also important to consider the role of the trunk. Then we examined back muscle reflexes to sural nerve stimulation during locomotion and discussed the results in relation to postural adjustments to produce efficient and smooth locomotion.

METHODS

Young and healthy subjects with no neurological disorders participated in the experiments. While the subjects were walking on a treadmill at 3 km/h and at preferred cadence, non-noxious electrical stimulation (3.3×perception threshold on average) was applied to the sural nerve at the lateral aspect just posterior to the lateral malleolus. The stimuli consisted of a train of five rectangular pulses (duration=1 ms) given at 200 Hz. and were given at 8 different phases in the gait cycle. Surface electromyogram was recorded at bilateral erector spinae (ES) muscles, ipsilateral gastrocnemius medialis (GM), and tibialis anterior (TA) muscles. The EMG waveforms of responses were full wave rectified and were ensemble averaged (N=50). The effect of the electrical stimulation was estimated by subtracting the averaged waveform of the corresponding period in the gait cycle without a stimulus from the averaged response waveform.

RESULTS

The EMG response to the electrical stimulation was also observed in the ES muscles though it was not so distinct as in the GM and the TA muscles. The effect of the stimulus in the ES muscles was excitatory around the toe-off and the heel-contact of the ipsilateral foot in general (Fig. 1). No clear difference was observed between the right and the left muscles. In the GM and the TA muscles clear phase-dependent modulation of the reflex responses was observed (Fig. 1). The effect of the stimulation at the latency of ~100 ms after the onset of the stimulus was inhibitory for the MG muscle during stance phase and excitatory for the TA muscle during early swing phase. These results are in consistence with preceding studies. The activation patterns of the bilateral ES muscles during walking without electrical stimulation were somewhat different from those of a preceding study[2] in that no clear difference of amplitude between right and left muscles was observed in the present study. But this might be resulted from a methodological difference (intramuscular wire electrodes vs. surface electrodes).

DISCUSSION

The main finding of the present study was the excitatory effect of the stimulation to the ES activity around toe-off and heel-contact of the stimulated foot. This could be illustrated in relation to dynamic posture control during locomotion. At the toe-off phase, since the foot is located at the most rear position relative to the body, paresthaesia to the foot will be perceived as a dangerous obstacle like a creeper weed that might cause falling down. Around the heel-contact on the other hand, the paresthaesia might be perceived as the tactile sensation of the heel-contact. Since the forward moment of inertia of the body is at its maximum around this phase of the cycle, the ES muscles should be active just after the heel-contact to brake the body sway and actually they are[2]. Therefore the sensation of foot-contact or the paresthaesia might trigger the activation of the ES muscles. Thus the paresthaesia might trigger excitatory reflexes at these two phases in order to prevent the body from excessively bending forward and thus falling down.

CONCLUSION

The central pattern generator for locomotion is considered to contribute also to the control of the trunk muscles. The reflex responses at the ES muscles might be functionally meaningful in a context of dynamic postural control during locomotion.

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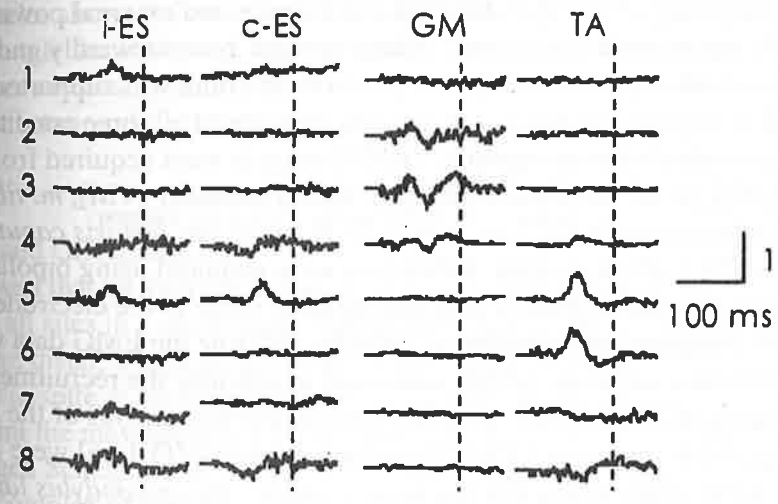

Figure 1. Interpersonal averages of the EMG responses to the sural nerve stimulation during walking. After subtracting control waveforms from response waveforms (see METHODS), the subtracted waveforms were averaged for 3 subjects (ES) and for 7 subjects (GM, TA). The ordinate value was normalized for the maximum EMG output during average gait cycle. The numbers at the left end indicate the phase in the gait cycle (e.g. 1:early stance, 2~4:stance, 5:late stance, 6~7:swing, 8:end swing). The vertical broken lines indicate 150 ms from the onset of the stimuli before which no voluntary effect is assumed.

O-31

ANGULAR DISPLACEMENT IN ONE JOINT AFFECTS THE COORDINATION AROUND OTHER MORE DISTAL JOINTS IN CYCLING

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INTRODUCTION

In cycling the external power is affect by the magnitude of the component of the force applied to the pedal that is perpendicular to the crank arm. This makes cycling a movement condition that requires the optimisation of both the direction and the magnitude of the external force. Van Ingen Schenau *et al.* [1992] showed that the direction and the magnitude of the externally applied force is governed by the mutual relation of forces generated by antagonistic mono- and biarticular muscles. They also showed that the activation of specific muscles is constrained by the joint moments that result from pedal reaction force and the desired joint angle changes. Thus a complex system exists in which the tuning on the one hand determines the direction of the external force and on the other hand is determined by it.

From this it can be derived that changes in the availability of muscles around one joint will affect the activation of all muscles in a limb, including those working solely over other joints. To test this hypothesis the hip joint angles of bicyclists were manipulated, affecting the length of the muscles spanning this joint.

METHODS

Six male subject [age 26-37years] participated in this study. They were asked to perform short, steady-state bicycling exercise at different trunk angle and external power [100 and 250W]. Three trunk angles were considered: sitting upright, bent forwardly and bent backward. In the forwardly and backward bent position the trunk was supported by a rest, the arms were not used to support the trunk. All subjects performed all three conditions.

During 15 seconds electromyographic [EMG] signals were acquired from the *m. gluteus maximus* [GM], *m. rectus femoris* [RF], *m. vastus medialis* [VM], *m. tibialis anterior* [TA], *m. gastrocnemius lateralis* [GL], *m. soleus* [SO], *m. biceps femoris caput longum* [BF] and *m. semitendinos* [ST] while cycling. EMG-data were acquired using bipolar surface electrodes. The signal was differentiated and preamplified close to the electrodes. Subsequently it was amplified and sampled at 1000Hz. Off-line the EMG data were rectified and filtered to assess linear envelops which were used to estimate the recruitment of muscles. During a 4 second interval in the EMG-sampling period, the movements of the limb segments were assessed using video-analysis [50Hz]. Therefore, spherical [Ø 1cm] were attached to the most lateral point on the *crista iliaca,* the *trochanter major*, the *epicondylus lateralis,* the *malleolus lateralis,* the heel and the centre of the rotation axis of the pedal. Using these markers trunk, hip, knee, and ankle joint angle were determined. Movement analysis and EMG-recording were synchronised.

To enable averaging of subsequent cycles and comparison between subjects, the EMG-envelops and the joint angle patterns for each cycle were normalised in the time domain. So far the data were not yet statistically analysed.

RESULTS

Relative to the upright position the subjects' trunks were found to be 25 degrees backward bent and about 40 degrees forwardly.

As an effect of trunk angle changes in the pattern of the ankle joint angle were found. In the backward bent condition in the latter half of the downward stroke the plantar flexion increased with about 15 to 25 degrees relative to the upright position [Fig 1]. Compared to the forwardly bent condition the increased plantar flexion is even more. The knee joint pattern appeared to be independent of the trunk angle. In the hip joint angle a gradual shift of the total angle joint pattern of 5 to 10 degrees to more flexion is seen concurring with the trunk angle being changed form a backward bent to a forwardly bent position.

The activity in the GM was found to increase considerably when the trunk was held in a more forwardly bent position. In the RF and VM [Fig.2] the opposite effect was seen: increased activity with backward bending of the trunk. Also the GL showed higher EMG-signals when the trunk was bent backward [Fig.3]. EMG-patterns of TA, SO, and both hamstrings muscles showed clear changes to variations in the hip joint angle, however to a large extend individual factors seemed to determine the instantaneous adaptations in activity.

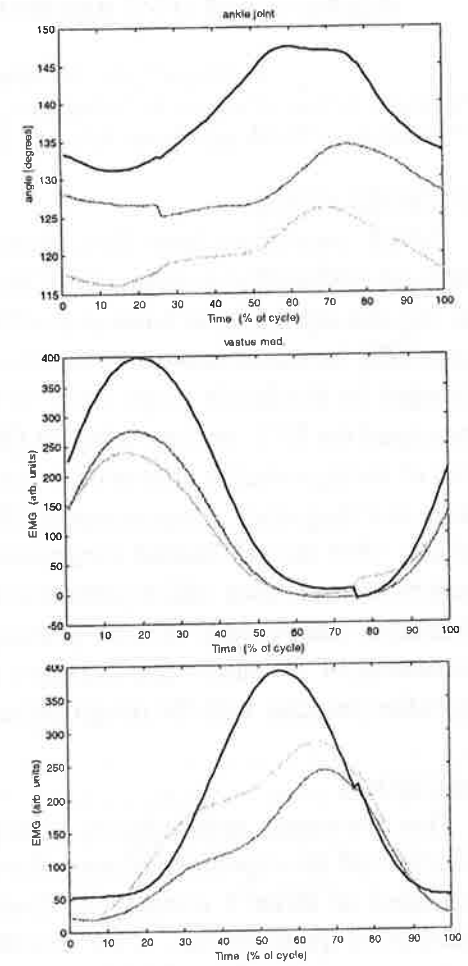

Figure 1,2 and 3 showing respectively ankle joint angle, VM and GL activity; dark lines represent backward bent, medium coloured lined upright position and lightest lines the forwardly bent position

DISCUSSION and CONCLUSION

This study showed that by varying the angle of the most proximal joint, the muscular coordination at all sites in a multi-body system will be affected. Also the activation of muscles far more distal, which do not span the manipulated joint, is influenced. Furthermore it was seen that in spite of unchanged begin- and endpoints of the kinematic chain distal to the manipulated joint the movements of the segments in this chain are adjusted. As was shown before [Van Ingen Schenau *et al.*, 1992] the mutually tuned activation of numerous muscles is governed by a complex of criteria. As the activation is changed also the efficiency will be affected. Thus it can be concluded that changes in trunk angle will not only affect the efficiency through changes in aerodynamics, but also by upsetting the mutual tuning between muscles. Furthermore, optimising the trunk angle to find an optimal tuning will be an option to improve cycling efficiency. Also in other movement tasks efficiency can be improved through optimising the coordination between muscles.

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Assessment of Functional Activities during Skiing Exercise

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INTRODUCTION

Many researchers have investigated physical responses while skiing in terms of muscular strength and aerobic endurance. Clarys and Cabri [1] studied ergonomic analysis of downhill skiing and reported that muscular activity varied with respect to the slope angle, while the heart rate (HR) increased at a constant rate. It should be kept in mind that the time-scales of those changes in biosignals range from several ten seconds to several hours. We simultaneously measured the ECG and myoelectric (ME) signals of two minutes at several phases during each trial of skiing over the course of a day. We used the continuous Wavelet analysis to clarify the dominant frequency components of HRV and compared them during skiing and during ski-lift riding. For the ME-related components, we evaluated conventional amplitude and frequency indices from surface ME signals during skiing. Observing the time-varying behavior of the dominant components in our primary results, we developed a tool for making snapshot evaluation of the interaction between cardiovascular and muscular activities during long-term repetitive exercise with the progression of fatigue [2].

METHODS

Five non-expert male subjects participated in our experiment on separate days after they were informed of the experimental procedures and risks associated with fatiguing efforts. Each trial consisted of about 3 minutes of downhill skiing, 10 minutes of ski-lift riding, and several minutes of preparation. Two minutes of R-R interval time-series was analyzed for the frequency ranging from 0.01 Hz to 1.25 Hz, by using the continuous Wavelet analysis. We tracked the peak frequency components within the range from 0.03 Hz to 0.17 Hz for sympathetic and parasympathetic activities and within the range from 0.3 Hz to 0.7 Hz for the parasympathetic activity in the time-frequency space. To compare the periodic time-varying behavior of the HRV during skiing and during ski-lift riding, we divided each 2-min interval into two 1-min segments. That is, we estimated the mean and standard deviation of α_{HF} and α_{LF}, as the amplitude of the dominant frequency components, for each segment as a function of trial. On the other hand, the parameters of muscular activity, the average rectified value (ARV) and the mean power frequency (MPF), were estimated from surface ME signals during skiing. Then, we calculated an averaged ratio, α_{LF}/α_{HF}, within every non-overlapping consecutive 10-sec segment (40 samples) and a correlation coefficient, $\gamma_{ARV\text{-}MPF}$, within the same interval. Finally, we proposed an α_{LF}/α_{HF} - $\gamma_{ARV\text{-}MPF}$ scatter graph for evaluating changes in functional activities, as a practical snapshot evaluation.

RESULTS

In each trial, the high and low frequency components of HRV increased during ski lift riding and decreased during skiing. **Figure 1** indicates scatter graphs of the relationship between the autonomic nervous activity related index, α_{LF}/α_{HF}, and the muscular fatigue related index, $\gamma_{ARV\text{-}MPF}$. This figure shows the results for the 1st, 4th (just after lunch), 10th, and 11th (final) trials during skiing. The $\gamma_{ARV\text{-}MPF}$ was negative from the beginning to the end of each trial for the non-dominant side (left) leg. A high α_{LF}/α_{HF} appeared during skiing around lunchtime. We did not distinguish the scatter graph at first trial from that at 11th trial. However, the means of α_{LF}/α_{HF} just before and just after skiing increased for the last trials, while the scatter graphs for the 1st and 11th trial are difficult to distinguish. A decrease in α_{LF}/α_{HF} and negative $\gamma_{ARV\text{-}MPF}$ were most likely a sign of the degeneration of functional activities due to exhaustion.

DISCUSSION

Regarding α_{LF}/α_{HF}, it became higher during skiing than during ski lift riding before lunchtime break probably for preventing from miss-control of the posture because of muscular fatigue. Due to stressful exercise after lunchtime break and strength exercise enhancing the postprandial changes in hemodynamic control possibly induced the peak in the α_{LF}/α_{HF}. Since there was no support for the lower legs during ski lift riding even at a resting phase, the feature might be caused by the sympathetic activity, which evidence was expressed by the Mayer wave. Uncomfortable fatiguing exercise could augment the sympathetic activity to maintain systemic blood pressure. Accordingly, the α_{LF}/α_{HF} - $\gamma_{ARV\text{-}MPF}$ scatter graph with α_{LF}/α_{HF} bars for the resting phases just before and after exercise is effective for evaluating functional activities during extended repetitive exercise. Classification of the differences in the α_{LF}/α_{HF} - $\gamma_{ARV\text{-}MPF}$ pattern are the next step in our research. The temporal features in the interactions between the ARV and R-R interval will also be studied more by using system identification.

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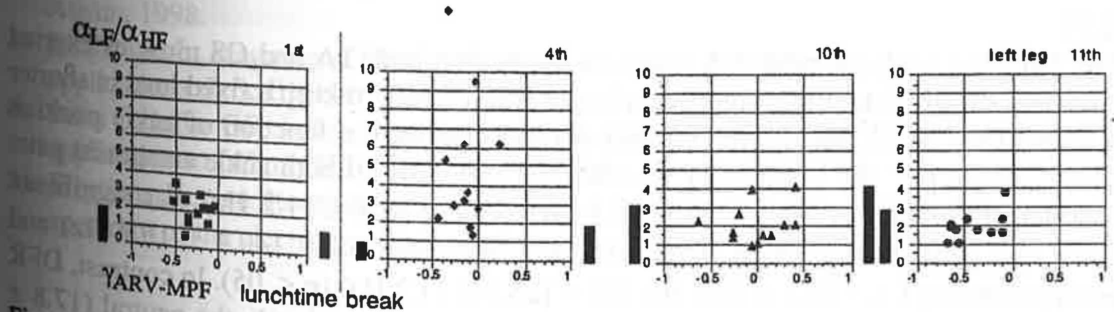

Fig. 1. Scatter graph between α_{LF}/α_{HF} and $\gamma_{ARV\text{-}MPF}$. The bars on both side are the means of α_{LF}/α_{HF} during the 1-min ski lift riding just before and after the present skiing.

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Control Strategy of Isometric Contraction in Different Muscle Lengths

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INTRODUCTION

It has major importance for research kinsiologists to investigate force regulation, considering the complicated torque-length relationship and corresponding neural regulation. With surface EMG quantitative analysis, the objective of this study was to investigate interaction of muscle length and neural regulation for maintaining a fixed load at various muscle lengths. In particular, the modulation of the motor unit recruitment, rate coding, and control stationarity of the prime movers of the ankle joint (tibial anterior (TA) and gastrocnemius (GS)) was addressed.

METHODS

Ten healthy subjects (7 male, 3 female) without previous neuromuscular diseases participated in this study. The subjects were instructed to perform three isometric contractions of a fixed load (40% MVC) against servo motor for 3 seconds in both dorsiflexion and plantarflexion directions in the position of plantarflexion 25 degrees, dorsiflexion 25 degrees and neutral position. A surface electrode unit was taped over right TA and GS to record muscle activities digitized at 1 KHz. Subsequent quantitative analyses included root mean square (RMS), median frequency (MF), dominant firing rate (DFR), time-varying median frequency across different experimental sessions to characterize motor pool excitability, recruitment, code rating, recruitment stationarity, respectively. DFR was estimated using autoregressive (AR) model (Paiss and Inbar 1987), and time-varying MF was determined by extracting MF of each time interval from the joint time frequency distribution (Hwang 1998). Repeated measures one way ANOVA were used to compare the differences of the RMS, MF and DFR of isometric contraction at various muscle lengths of the TA and GS. Recruitment strategy was considered stationary if MF in the time course was fitted with the first order polynomial whose slope did not significantly differed from zero. The hypothesis was tested by examining the pooled regression slope for all ankle positions using two-tailed t test. The level of significance for all statistical analyses was 0.05.

RESULTS

For EMG temporal analysis, ANOVA analyses shows that both TA and GS muscles exerted greater internal effort, in terms of significant larger EMG RMS, to keep a fixed load in shorter muscle length ($p < 0.05$). MF of the TA and GS muscles were a function of ankle position ($F_{TA}(2,18) = 20.63$, $p < .001$; $F_{GS}(2,18) = 14.68$, $p < .001$). MF of both ankle antagonist pairs in the shortened position (TA = 115.0 ± 16.5 Hz; GS = 150.8 ± 11.2 Hz) was significant larger than that in neutral position (TA = 100.5 ± 10.9 Hz; GS = 140.4 ± 16.7 Hz) and lengthened positions (TA = 93.5 ± 10.9 Hz; GS = 125.6 ± 11.2 Hz) ($p < .05$). In contrast, DFR in a shortened position (23.6 ± 7.8 Hz) was significant larger than that in the neutral (17.8 ± 3.9 Hz) and lengthened (16.2 ± 2.8 Hz) positions ($p < .05$). On the contrary, GS showed no significant difference in dominant firing rate in relation to ankle position ($F(2,18)=1.02$, p = 0.382). DFR of the GS muscle in the dorsiflexion, neutral, and plantarflexion were 22.6 ± 4.7 Hz, 23.4 ± 4.5 Hz, and 25.2 ± 6.8 Hz (mean ± SD), respectively. Stationarity of motor unit recruitment in different muscle lengths was estimated by fitting time-varying MF with the first order polynomials ($p < .05$). Statistics shows that that regression slope did not change with ankle position for both TA and GS muscles ($F_{TA}(2,18) = .35$, $F_{GS}(2,18) = .01$, $p > .05$), and the pooled slope did not show a significant increasing or decreasing trend during contraction period for various muscle length ($p > .05$).

DISCUSSION

Both increase in RMS and MF favored an increased voluntary drive via additional recruitment of larger motor units against predominate load, because increase in muscle fiber propagation velocity could conversely lead to decreased RMS in shorter muscle length according to Linstrom and Magnusson model for surface EMG electrodes (1977). This progressive recruitment could be a synergism for musculotendon mechanics and neural regulation in compensation for decrease in the number of cross-bridge attach-detach cycles and reduced tension of slack tendon in shorter muscle length. In spite of the change in recruitment pattern for effort-related isometric contraction, the other control strategy of motor units, code rating was less definite for the GS. There would be several possibilities for this inconsistent finding. First, code rating might be muscle dependent. Second, decrease in the firing rate of previously activated motor units as the firing rate of the newly activated motor unit increase (Lucas and Binder 1984). Third, potential limitation for the use of dominant firing rate in the estimation of code rating (Weytjens and Van Steenberghe 1984). In the dynamic spectral analysis, our results showed pooled regression slope of MF trace was neither dependent on muscle length. This fact was also support Bilodeau and his colleagues' research (1997) in which time-invariant mean and variance of the SEMG during isometric contraction was reported. However, in spite of stable recruitment, the process programmed by the CNS system could be a dynamic process which may involve balanced alternate recruitment and decruitment of many different motor units during the contraction period.

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Firing Frequencies of Single Motor Units in the M. Biceps Brachii During Elbow Flexion at Constant Angular Velocities

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INTRODUCTION

There are a few reports on the motor unit (MU) activities during voluntary dynamic contraction, though many reports during isometric contraction. Tax et al. (1989) and Bolhuis et al. (1997) have revealed that the MU activities are different in isometric v.s. isotonic muscle actions. They measured the MU activities in a relatively narrow range of elbow angle. Therefore, the relationship between MU activities and elbow angle has not been examined in detail. We measured firing frequencies of each identified MU action potentials in the m. biceps brachii at constant angular velocities during flexion movement, and investigated the relationship between elbow angle and the firing frequencies. Preliminary reports were published (Yoshida et al. 1996).

METHODS

Experiments were made on three normal subjects. The subjects sat on a chair, and were asked to hold the fully extended position (zero degree) of the forearm in the horizontal plane and then to flex the forearm at a constant velocity against a constant torque (10% MVC loads of maximum isometric force measured at elbow angle of 90 deg). Four kinds of constant angular velocities ranging 10-25 deg/sec were used.. The flexion angle was from zero to 120 deg. We measured the multi-channel surface EMG from the m. biceps brachii, where eight channel of bipolar electrode of stainless steel wire (1mmϕ) with 2.54mm spacing was used. In order to classify each MU from the EMGs, we identified action potentials of single MU interactively on a graphic monitor with template matching; we improved the decomposition algorithm of Mambrito and De Luca (1984) for our multi-channel surface EMGs. We calculated firing frequencies of individual single MUs, and investigated statistically the relationship between elbow angle and the firing frequency for all identified MUs.

RESULTS

One hundred and twelve MUs were identified from three subjects. Firing frequencies of each MUs were calculated successively during flexion movements. A regular trend of firing frequency was found, so that the relationship between angle and frequency was examined statistically. All identified MUs were compared by means of Student's T-test ($p<0.05$); whether or not the slope of the regression line of firing frequency against elbow angle is 'zero'. One hundred and three MUs showed no significant dependence of firing frequencies on elbow angle.

DISCUSSION

Our experiments were designed to study firing frequencies of MUs over a wide range during elbow flexion and with various angular velocities. Tax et al. (1989) and Bolhuis et al. (1997) designed their experiments to do with a small range of movement, because they aimed at identifying the differences of MU activities during isometric v.s. isotonic muscle actions. Bolhuis et al. (1997) also compared the MU activities during movement with those during isometric contraction. While Bolhuis et al. (1997) made experiments of sinusoidal movements, they have not fully investigated the relation between MU activities and elbow angle yet.

It can be said that firing frequencies of individual MUs would not change significantly with elbow angle during low-speed flexion movement against a constant torque in human motor control. Experimental conditions in other previous studies were different from ours, so that our results could not be compared to others at all.

CONCLUSION

In this study, there are some of advancements in comparison with previous studies. First, we could measure the firing frequencies of MU during elbow flexion with faster angular velocity and with a larger range of elbow angle than those of previous studies. Secondly, we showed that the firing frequencies of MUs have no tendency to depend on elbow angle during elbow flexion.

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Influence of motor unit synchronisation on force and EMG in skeletal muscles: A simulation study

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INTRODUCTION

Muscle vibrations and the shift of the EMG spectrum to lower frequencies are well known phenomena in local muscle fatigue (Basmajian & De Luca, 1985). Motor unit synchronisation and biochemical changes in the muscle fibres, (which decrease the muscle fibre conduction velocity), are mentioned as possible causes for the changes in the muscle force and EMG (De Luca, 1993). Although much is known about the effects of biochemical changes in the muscle, little is known about the possible influence of motor unit synchronisation on changes in force (Fuglevand et al., 1993) and EMG (Fuglevand et al., 1992).

METHODS

In this study a simulation technique was used to investigate the influence of motor unit synchronisation on force and EMG in skeletal muscles. The mathematical model of Fuglevand et al. (1992, 1993) was modified to investigate the influence of motor unit synchronisation and was implemented in *Matlab®*. The modifications related mainly to the input to the model. Instead of using an excitatory drive function representing the net synaptic input, the muscle was excitated by means of a pulse train. An original method was developed to build these pulse trains. A fixed number of pulses (representing the pulse train) were randomly distributed around a carrier frequency of 10 Hz (Td = 0.1 s). Stochastic pulse trains and synchronised pulse trains were differentiated: for the stochastic pulse trains, the pulses were distributed during a period of ½ Td (= 0.05 sec), whereas the pulses for the synchronised pulse trains were distributed during a period of only one tenth of ½ Td (= 0.005 s). Therefore, the time interval between two pulses for the synchronised pulse trains is much smaller than for the stochastic pulse trains. The inter stimulus interval was variable in all the simulations. The above mentioned pulse trains are extremes on a continuum, so a stochastic variable was introduced, varying between 1.0 (purely stochastic) and 0.1 (almost entirely synchronised) to manipulate the degree of synchronisation. The pulse trains resulted in a specific membrane potential which was then used as excitatory drive to the muscle.
Fuglevand's original mathematical model (Fuglevand et al. 1992, 1993) and our model have the same final output, namely Force and EMG-signal.

RESULTS AND DISCUSSION

The simulation showed that increasing synchronisation leads to an increase in muscle vibrations, a decrease in the average force production and a shift in the frequency spectrum to lower frequencies (decrease of the median frequency). The decrease in force production is chiefly related to the absolute refractory period (0.4 ms) of the α-motoneuron. In synchronised pulse trains, the pulses are more concentrated around fixed time intervals, so that the inter stimulus intervals are sometimes smaller than the absolute refractory period (0.4 ms), resulting in loss of response to the pulses.

CONCLUSIONS

The decrease of the median frequency, which is normally attributed to a decrease in the muscle fibre conduction velocity, only occurs here as a result of motor-unit synchronisation. It thus appears that apart from the influence of the biochemical changes in the muscle fibre, synchronisation could also be influential in decreasing the median frequency (shift to lower frequencies). This study progressed development of a working instrument that can be used for further research. Future research will address the combined influence of motor unit synchronisation and decrease in muscle fibre conduction velocity, (seen in clinical study as a result of muscular fatigue), on force and EMG.

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RELATIVE CONTRIBUTION OF RECRUITMENT AND RATE CODING IN FORCE INCREMENT

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I. Introduction

A muscle consists of a large number of motor units (MUs). At the mode of MU activities, there are two essential factors in regulating the muscle force [1]. One is to increase the total number of active MUs. This factor is referred to as "recruitment". The other is to increase the firing rates of MUs that are already active. This factor is referred to as "rate coding". Relative contribution of these factors were estimated by using the firing rate and twitch force of MUs[2,3] and by computer simulation[4,5].

We estimate the relative contribution of two factors in two kinds of muscles (the brachialis muscle and the extensor digitrum communis muscle) by actually obtaining the necessary data from human subjects on the basis of force generation model of a voluntary isometric contraction.

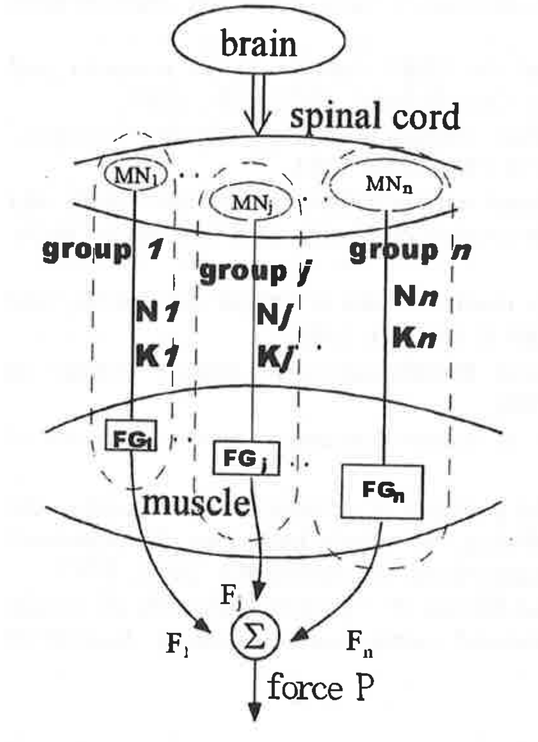

Fig. 1 A model of force generation

II. A model of force generation and estimation method

Figure 1 shows schematically a model of generation of the muscle force. For the convenience of modeling, the force range from zero to the maximum is divided equally into n segments, and the force of the muscle is denoted by P_i, (i=0,1,2...n). Segment j (SG_j) corresponds to the range from P_{j-1} to P_j. MUs recruited in SG_j are simply referred to as group j MUs. The force generated by the group j MUs is denoted by F_j; total force of the muscle is a sum of F_j, (j=1,2...n). The increment of muscle force ΔP_j (= P_j - P_{j-1}) at SG_j is the sum of the force increment by recruitment ΔP_{rj} and that by rate coding ΔP_{fj}.

$$\Delta P_j = \Delta P_{rj} + \Delta P_{fj} \qquad (1)$$

The number of MUs recruited in SG_j is denoted by N_j, and their averaged size is K_j. The firing rate of group j MUs is denoted by $f_j(P_i)$ at the force level of P_i. Therefore, ΔP_{rj} is given by

$$\Delta P_{rj} = N_j K_j S\{f_j(P_j)\} \qquad (2)$$

where $S\{f_j(P_j)\}$ ranging from 0 to 1 is the normalized force generated by a single MU of group j MUs at the firing rate of $f_j(P_j)$. As the force changes from P_{j-1} to P_j, the firing rate of group m MUs (m<j) ascends from $f_m(P_{j-1})$ to $f_m(P_j)$. So the force increment by these MUs is $K_m S\{f_m(P_{j-1})\}$ - $K_m S\{f_m(P_j)\}$. Consequently, the force increment ΔP_{fj} by the change in firing rate of all MUs is given by following equation.

$$\Delta P_{fj} = \sum_{m=1}^{j-1} N_m K_m [S\{f_m(P_j)\} - S\{f_m(P_{j-1})\}] \qquad (3)$$

As shown in equation (2) and (3), ΔP_{rj} and ΔP_{fj} could be calculated by the number N_j, the size K_j, the firing rate $f_j(P)$ and the force-firing rate relation $S\{f\}$.

III. Results

The number of MUs and their size were estimated by statistical processing of mass EMG [6]. Results obtained from the brachialis muscle is shown as a function of force P in Fig.2. The broken lines in Fig.3 show firing rate-force (f-P) curves measured from the brachialis muscle [7] and the solid lines show the approximated curves used for estimation. The f-Fj relation S{f} was obtained by applying the electrical stimulation of the brachialis muscle. With these data of the brachialis muscle, we estimated the force increments by ΔP_{rj} and ΔP_{fj} at each segment. The results were shown with thin line in Fig.4 that was the average of the results for two subjects. We made similar estimations to the extensor digitrum communis muscle (EDC). The result was shown with thick line in Fig.4. The contribution of the recruitment is 35.6 % in EDC at 60% of MVC, though it is 59.5 % in the brachialis muscle.

IV. Conclusion

Our estimation results show that the brachialis muscle utilizes the recruitment more dominantly and EDC the rate coding in regulating the muscle force. This may be reasonable, by considering different functions of these two muscles. The recruitment changes the force stepwise while the rate coding can change the force continuously. As the muscle of finger needs a minute control of force, the rate coding is more important than the recruitment.

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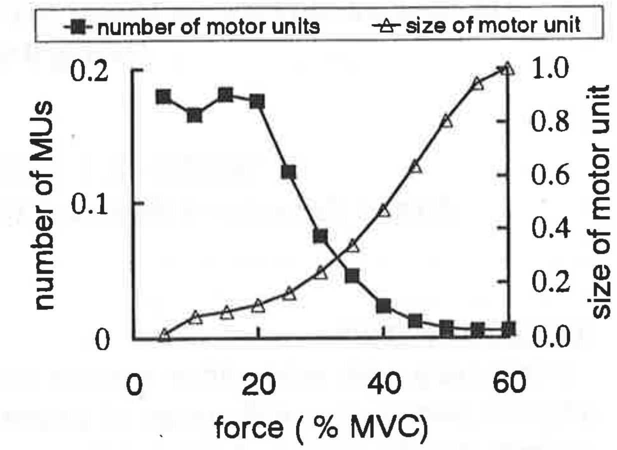

Fig. 2 Number and size of MUs for each segment

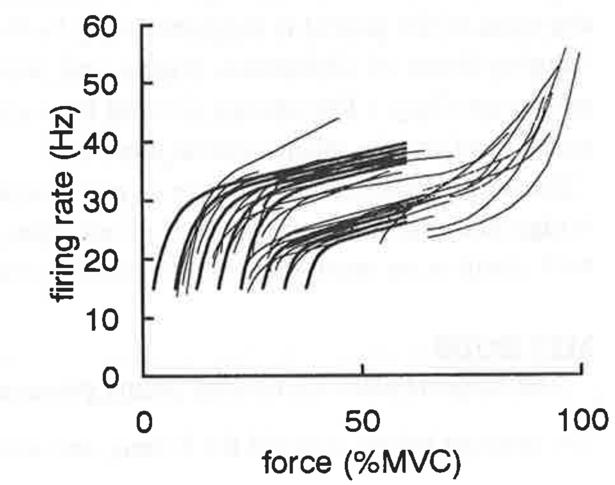

Fig. 3 Firing rate of MU

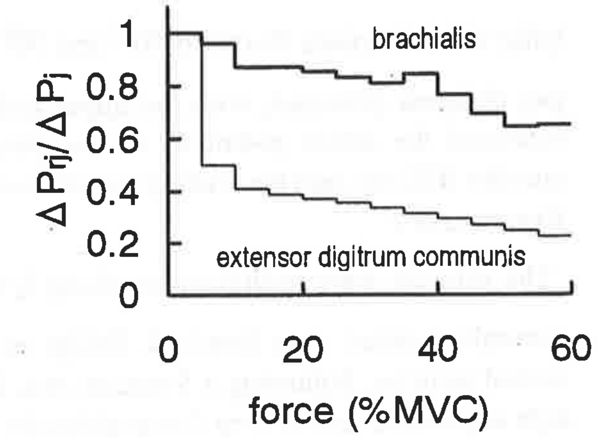

Fig. 4 Relative contribution of recruitment

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The Relationship between Muscle Activity and R-R Interval Variations in ECG During Bridge Exercise

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INTRODUCTION

Crook lying with pelvis lifted exercise (so called bridge exercise) is often applied for physical therapy in a wide range of patients including the elderly, bedridden and stroke patients. It is the purpose of this exercise to reinforce erector spinae muscles, hamstrings and gluteus maximus muscle in the elderly and to prevent the development of bedsores and improve the excretion activity in the bedridden. Nevertheless, during the bridging exercise, the trunk of the patient is supported only by the head and bilateral soles, which may cause the hanging-down of abdominal organs and some changes in the respiratory and circulatory responses. Only a few studies showed the various forms of the muscular actions, the load on soles, head and the atlanto-dental interval.

The purposes of this study were to examine:1) the influence of different starting postures of bridge motion on action potential of muscles in the lower limbs, 2) the effect of changes in neck position on respiratory and circulatory responses during bridge exercise.

METHODS

The subjects were ten healthy young persons (four males, six females, average age 21.8). The average height was 164.8±8.2cm, and average weight 56.6±7.5kg. None of the subjects had a known history of heart, neurotic or respiratory diseases.

Experiment 1

The subjects were asked to assume two different starting postures; crooking lying with the knees flexed to 50° and 70° . Every two postures were further divided into two different positions, with the upper limbs raised and attached to the side of body. We measured the action potentials of the gluteus maximus muscle (GM), the erector spinae muscles (ES) etc. and the loading pressures of the bilateral soles during bridge motion.

Experiment 2

The subjects were positioned crooking lying with the knees flexed to 70° and the upper extremities raised on a firm bed. Bridge exercise was made with the neck flexed and in a neutral position. Following a 5-minute rest, the subjects were asked to raise their buttocks as high as possible and to keep that position for 10 seconds. This exercise was repeated 30 times immediately one after another without discontinuance. Measurements were made before and after the exercise and also every one minute during the exercise. We took electrocardiographs, and the respiration depth and respiratory rate were recorded by electronic spirometer. A statistical analysis was performed by the analysis of variance (ANOVA).

RESULTS

Experiment I

In starting posture with the upper limbs attached to the side of the body, the action potential of GM and hamstrings showed an increase with a knee angle of 70 degrees, and an increase in the electric discharge of the Latissimus dorsi muscle was observed with both knees angled. In starting posture with the upper limbs raised, the action potentials of ES and GM increased, being not influenced by the knee angle. The loading pressure of the sole was approximately 12% of body weigh in both starting postures.

Experiment II

1) The R-R interval (irrespective of neck position) became significantly shorter one minute after the initiation of the exercise, and the level was kept through the experimental period. The R-R interval during the exercise was shorter with the neck flexed than with the neck in a neutral position. 2) The resting respiration rate was slightly higher with the neck flexed than with the neck in a neutral position, and the respiratory rate during the exercise showed a similar change. 3) Respiration depth was increased by about 50% with the neck in a neutral position and about 10% with the neck flexed one minute after the initiation of the exercise.

CONCLUSION

These results indicate that bridge exercise from a posture with the neck flexed induces tachycardia, suggesting that the exercise may be contraindicated in patients who have a circulatory disorder.

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O-41

Adaptive FES Switching Control for Hemiplegics Using EMG Signal

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INTORODUCTION

FES is an effective method to restore function for paraplegic patients and makes it possible to realize some ADL. However a switch signal is necessary to denote the onset of stimulation, whereas, in most of the current FES technology, patients have to make a superfluous action. We are developing another type of switch for FES control for hemiplegic patients, based on the consideration that, lower limbs' actions, for example, standing-up and ambulation, need the synchronization of both limbs. So that, in the case of lower limb hemiplegics, it is possible to recognize the action that the patients intend to do, from some kind of physiological signal detected from their normal side. In this research, EMG is employed as the signal. EMG is physiological signal with individual disparity, which inevitably results in classification difficulty. To overcome this problem, we use an ANN based on-line classifier method. This paper will present such an automatic switch system and show the possibility.

METHODS

The purpose of experiment is to recognize two action patterns (standing-up and start of the swing phase of ambulation) and to send operation command to FES stimulator at right moment. One male subject(47) participated in the experiment. The subject is hemiplegic patient, whose left limbs are paralyzed while right limbs are normal.

The change of joint angles are measured by optical 3D-position (MA6250,ANIMA). EMG sensor is surface EMG differential electrode (Model DE-02.3H, DELSYS). FES stimulation device is CE1230 (NEC) and implanted electrode is NEC. Sampled temporal EMG data was recorded and used as teaching data and recognition data. The on-line learning of the switching is realized by BPNN (Back Propagation Neural Network) on PC and goes on until the learning of the network is converged. When action intention is recognized, the corresponding control signal is sent to FES controller.

RESULTS

Fig. 1. shows the temporal mean value of EMG, when FES is on and off, respectively. In mean EMG graph, each of 6 channels stands for the integrated EMG detected on the surface of quadriceps, hamstrings (normal side), rectus abdominis, erector spine muscle, quadriceps, hamstrings (paralyzed side), respectively. The vertical line represents the timing of teaching (when FES is off) and recognition (when FES is on). The most left vertical line denotes the timing of standing-up and the other two lines denote those of ambulation (the moment of toe off). The x-axis stands for time elapsed and the y-axis represents the mean value of EMG. Ovals denote the ideal stimulation timing.

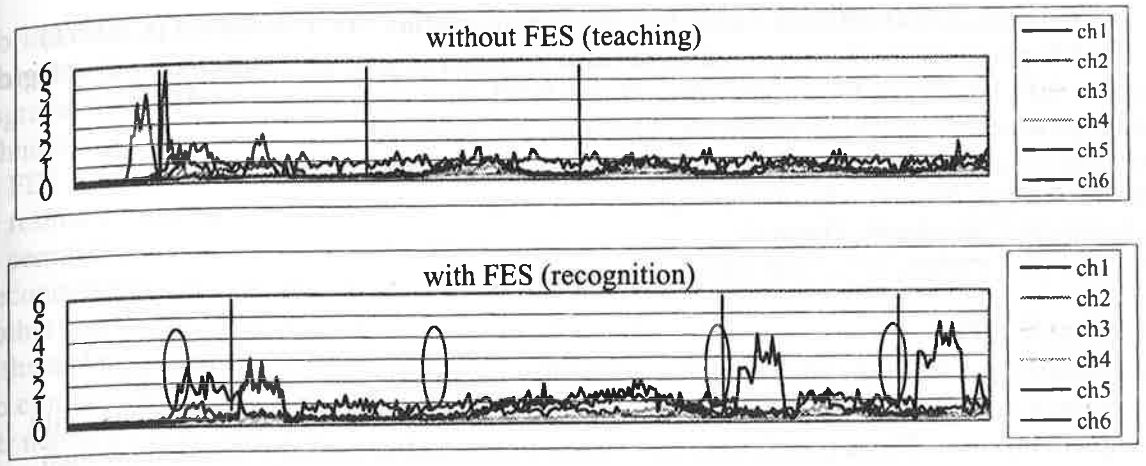

Fig. 1. Mean EMG of teaching (a), and mean EMG of recognition(b). x-axis is time (15 seconds).

DISCUSSION

For standing-up, as can be seen in Fig. 1, recognized timing is later than timing taught. This delay is probably the consequence of large noise presented in the teaching signal of ch2 (normal hamstring). The system learned the recognition rule through the noisy data. But as shown by the graph in Fig 1, for the other channels except ch2, there is little difference between the mean EMG of teaching and that of recognition. Therefore, it is almost certain that the standing-up action can be recognized this system.

For ambulation, the first step couldn't be recognized. It may be due to the delay caused by the stimulation of standing-up. On the other hand, the timing of second and third step was correctly recognized. That is, the recognized timing fits the timing taught very well. This graph shows only three steps data. But the fact is that, the subject could walk continuously until one operator turned off the controller.

CONCLUSION

This paper proposes EMG automatic switch for FES and shows the possibility of this system. Owing to this system, paralyzed patient can stand up and ambulate without superfluous activities.

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O-42

Clinical Rehabilitation using Electrical Stimulation via Telematics (CREST) An EU programme for restoration of improvement of gait of incomplete paraplegics

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INTRODUCTION

Most research in FES restoration of gait in patients with spinal cord injury (SCI) has concentrated on complete lesions; but there is a large and growing number of patients with incomplete injuries. These people may have some motor and/or sensory functions, which enhance the improvements they may expect to gain from FES. It has been shown that they may benefit from an individualised FES system for home use [1]. These programmes have also shown a number of therapeutic benefits including an increase in voluntary control, an increase in muscle bulk and a reduction in spasticity [2]. Since the gait deficit is this group is highly variable, it is necessary to produce an individualised FES gait strategy for each subject. This requires the use of programmable multichannel stimulators.

A main obstacle to the deployment of FES in rehabilitation of incomplete SCI at spinal injuries units is the lack of sufficient knowledge to tackle the often complex problem of optimising the equipment for individual patients. The knowledge is present in a small number of groups scattered over Europe and the world and the target population is spread around a large number of clinical sites. There is therefore a need to bring the expert knowledge of the users (engineers and clinicians) and the latest techniques in programmable stimulators and control software to the rehabilitation institutions where it is needed.

The main aim of the European CREST project was to demonstrate that FES systems can be delivered by local non-expert professional users supported by interactive teleconsultation with a remote expert, enabling incomplete SCI individuals throughout Europe to increase their mobility.

METHODS

The CREST project (1997-2000) consisted of the following phases:

1. An inventory of user needs among the incomplete SCI subjects
2. Development of tools for clinical decision-making including multimedia gait analysis tool, standardised patient assessment, visual programming tool, telematic links between the sites.
3. Demonstration and evaluation of the system at expert clinical sites (Rehabilitation Centre Het Roessingh, Enschede; Southern General Hospital, Glasgow; Northern General Hospital, Sheffield) and with 2 clinical non-expert sites (Righospitalet, Copenhagen; Hospital Juan Canalejo, La Coruña).

RESULTS

1. The survey

The survey was held amongst the Scottish, Dutch and British Spinal Cord Injury Associations. In total 5500 inquiries were sent out of which 1500 were returned. The results clearly indicated three major mobility functions to be addressed by the CREST FES treatment:

a) improvement of the quality of gait
b) provide strategies for the negotiation of different level ground surfaces
c) provide strategies for the negotiation of curbs, ramps and flights of steps

2. Development of tools

A PC-based multimedia system called the CREST user interface was developed. This allows the conduct of tests combining video, foot-contact, EMG, goniometer, time and distance information. The results of these tests together with standard assessments (manual muscle, Ashworth, joint range-of-motion, 6 minute walk, FIM) are stored in a database. A visual programming interface (VPI) was developed to enable programming the stimulator by a non-technician. So, the results of the FES intervention can be reviewed using the multimedia tests and the FES strategy can then be modified in an iterative manner. When the clinician is satisfied with the results the strategy is downloaded to the stimulator for use outside the laboratory.

To permit the transfer of expertise between different sites the CREST user interface provides a teleconsultation function in which the results (including video) from one site can be examined by another and the FES strategy can be remotely modified via the VPI. The system was developed by the technical partners in conjunction with their local clinical sites. It was then delivered to the two clinical sites without local technical support. Advice was exchanged amongst the clinical-user network via teleconsultation.

3. Demonstration phase

Two types of assessments were carried out during a typical patient treatment programme. Assessments for the evaluation of a patient's clinical and functional status, typically to be performed prior to the treatment phase ('initial evaluation') and after completion of this phase ('final evaluation'). This type of assessment provides background material for decision making during the treatment phase, and allows an evaluation of indirect effects of the treatment programme, i.e. effects not related directly to the application of FES.

After an evaluation for inclusion, an extensive initial assessment was performed including ASIA and FIM scoring, manual muscle testing, modified Ashworth scale, ROM, proprioception, upright motor control, walking endurance, and Observational Gait Analysis (OGA). Based on the initial assessment, goals for treatment were laid down, and a FES strategy developed. The FES was used at home and adjustments were carried out in the centre before an extensive final assessment including most of the tests from the initial assessment.

During the verification phase, 72 patients came for initial evaluation. So far, 34 patients have come for the final assessment. Of these, 31 had the wish to continue the use of FES after termination of the study. For those participants who wished to use the FES after the study period: 37% used one channel, 58% two channels, and 5% three channels for stimulation. 89% used unilateral, and 11% bilateral stimulation. In 52% were the Flexor Withdrawal Reflex (FWR) used, in 30% stimulation of the quadriceps, in 15% stimulation of the dorsiflexors, in 3% stimulation of medial gluteal muscle.

Apart from the subjective assessments decisive for the continuation of FES usage, no significant difference was found for the walking endurance, but the gait was evaluated to be better by the OGA.

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Acknowledgements

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O-43

DIFFERENCES IN CERVICAL MUSCLE DYSFUNCTION IN SUBGROUPS OF NECK PAIN PATIENTS

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INTRODUCTION

In the Whiplash Associated Disorder (WAD), WAD grade II is characterised by neck pain and neck stiffness or tenderness (1). In our line of research the use of surface EMG is investigated to improve the diagnostic procedure. Earlier we performed a study in which we were able to discriminate WAD-II patients from healthy controls using sEMG measurements (2). It appeared that both groups differed in muscle reactivity of the upper trapezius muscle in response to a physical exercise. For diagnostic purposes however, it is important to be able to discriminate between WAD patients and other neck pain patients. Therefore, the goal of the present study was to analyse differences in muscle reactivity (strength and time course) between WAD patients and aspecific neck pain patients.

METHODS

Subjects: A group of 19 chronic WAD-patients, 13 aspecific neck pain patients and a control group of 18 healthy volunteers participated in the study.

Experimental design:

1. Before starting the experiment a normalisation procedure was carried out in order to be able to express the SRE-level of the trapezius in relation to a reference value (3).
2. The first part of the experiment consisted of 4 baseline measurements.
3. Then a unilateral manual exercise was performed: the subject sat at a table and was then asked to continuously move the dominant arm/hand between three target areas by putting marks with a pencil in circles with a diameter of 70 mm. During this task the non-dominant arm rested on the table without moving. The pace of 88 marks/min. was kept constant using a metronome. This activity was carried out for around 2 minutes.
4. After the exercise, 6 return to baseline measurements were performed.

Each measurement consisted of recording the EMG-signal during 15 seconds. This was processed to produce a Smooth Rectified Electromyography (SRE). Between each assessment there was a pause of 1 minute.The averaged SRE-value was expressed as a percentage of a reference voluntary electrical activation (%RVE).

Analysis: we used 2 parameters to study the reactivity of the upper trapezius muscles:

1. Time dependent muscle behaviour: a best fit regression analysis was performed of the 6 return to baseline measurements. Differences in course were analysed by comparing the regression coefficients of the three groups using 95% Confidence Intervals (95% CI).
2. Strenghth of reactivity: We averaged the 4 baseline measurements and the 6 return to baseline measurements. The strength of the muscle reactivity was calculated by subtracting the mean baseline value from the mean return to baseline value. Differences in were analysed using 95% CI's.

RESULTS

Figure 1a and 1b show that both the WAD-group and the aspecific neck pain group showed a similar rise in EMG amplitude. The healthy group however showed a small decline in amplitude. This was true for both active and passive side. No clear time dependent behaviour

Figure 1a : Difference in course of upper trapezius muscle reactivity in WAD, aspecific neck pain and healthy (active side)

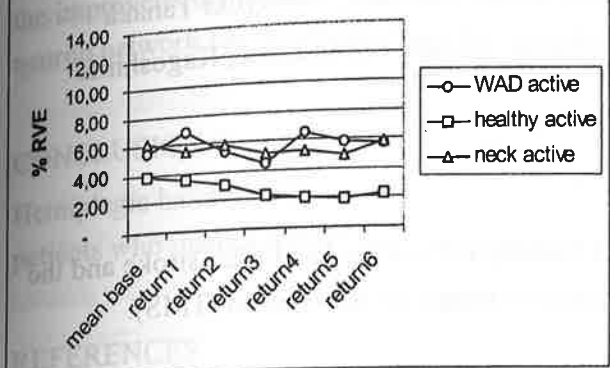
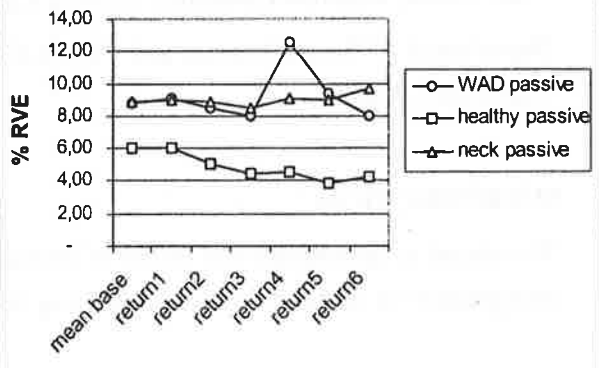
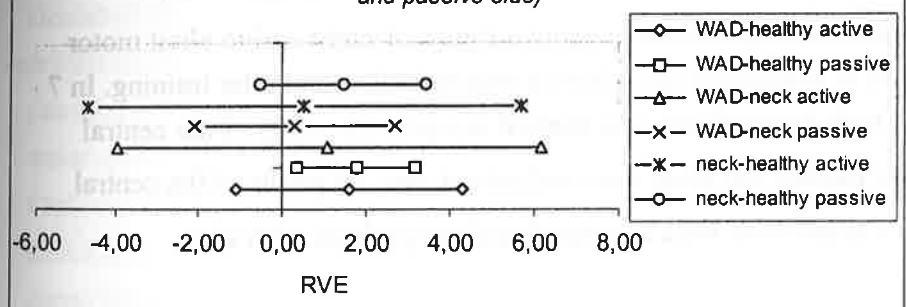


Figure 1b: Difference in course of upper trapezius muscle reactivity in WAD, aspecific neck pain and healthy (passive side)



of muscle activity was found at group level, probably due to large interindividual differences in time course. In fig. 2 the differences in strenght of reactivity is expressed in the 95% CI's. It appears that there are no differences between the two neckpain groups. Both groups however show a stronger reactivity than the healthy controls. This was most pronounced in the passive side, the arm that was inactive during the unilateral manual exercise.

Figure 2 : 95 % CI's of the differences in upper trapezius muscle reactivity between WAD, aspecific neck pain and healthy (active and passive side)



DISCUSSION AND CONCLUSION

Both WAD patients and aspecific neck pain patients show an inability to relax the trapezius muscles after physical exercise. However the extend of this inability to relax is not related to the origin of the paincomplaints, i.e. the whiplash trauma or the aspecific onset.

So, from this study, it appears that the muscle reactivity of the upper trapezius muscles does not seem to be suitable for differential diagnostic purpose in the chronic whiplash associated disorder.

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O-44

Functional Recovery of a Hemiplegic Hand by Intensive Training and Motor Cortical Mapping by Transcranial Magnetic Stimulation

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INTRODUCTION

We aimed to investigate the effect of intensive training (IT) of the hand after stroke and the reorganization of hand motor maps using transcranial magnetic stimulation (TMS).

METHODS

The subjects were 23 patients with hemiplegia due to stroke (57.0±10.9 years old, 16.7±4.8 weeks after onset). They received 2 to 6 week long IT focussing on hemiplegic upper limbs, in addition to the basic casual training (CT) for hemiplegia. CT included ROM exercise, sanding, peg board. IT included several kinds of assisted or voluntary movements of upper limbs and fingers being coordinated and free from synergy. Voluntary movements were repeated more than 500 times a day, under strict attention to his or her movements.

TMS was given in 8 patients during relaxation using a figure-of-eight coil to elicit motor evoked potentials (MEPs) in abductor pollicis brevis muscle before and after training. In 7 patients, the scalp of the both hemispheres was marked out over 10 points of the central area in a 2cm grid. In one patient, the scalp was marked out over 20 points of the central area in a 1cm grid. MEPs amplitudes were measured peak-to-peak on each site.

RESULTS

After 2 weeks of IT, Ueda's grade and Brunnstrom stage were significantly improved compared with those measured after an initial 2 weeks of CT.

MEPs of both hemispheres could be recorded in 6 patients. Sum of all response amplitudes (larger than 0.05mV) of the affected side in relation to the unaffected side was 1.60±1.96 (before training) and 1.33±1.47 (after training). Number of effective stimulation sites (response amplitude >0.05mV) of the affected side in relation to the unaffected side was 1.09±0.59 (before training) and 1.21±0.97 (after training). Amplitude ratio was decreased in 2 patients who made a good recovery of hand function (Simple Test for Evaluating hand Function: STEF score were 85-95). Amplitude ratio was not changed in 4 patients who did not make a good recovery of hand function (STEF score were 0-49).

DISCUSSION

Results suggests that the functional recoveries after training are considered not simply due to the improvements of brain edema and muscle strength, but the improvement of some central neuron network i.e., brain plasticity and the cortical excitability.

CONCLUSION

Hemiplegic hand function was improved after IT. MEP amplitude ratio was decreased in 2 patients who made a good recovery of hand function.

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O－45

I-wave Networks in Human Motor Cortex

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INTRODUCTION

Double magnetic stimulation technique has provided a great insight into motor cortical function as well as other higher brain functions. Some of these functions are probably derived from interactions among I-wave networks. In our previous study, I-1 and I-3 are crucial for cortical inhibition or excitation. These cortical modulations, however, have still remained debated. Here we studied 10 normal subjects in order to verify how the interactions of I-waves are brought about, by using double magnetic stimulation technique.

METHODS

10 normal subjects participated in the study, who gave written informed consent. They were seated in a reclining chair and also were asked to contract their first dorsal interosseus muscles (FDIs) sustainingly. The contralateral hand motor cortex was stimulated through figure-of-eight coils placed over it with the conditioning-test manner. The intensities of both shocks are equal, and adjusted just enough to evoke around 300 uV of motor responses in peak-to-peak amplitude in mildly contracted muscles (10-20% of maximum contraction). I-waves were recorded from the activated FDIs muscles. I-1 is preferentially evoked in the posterior-anterior direction (PA) of the induced current and I-3 in the opposite direction (AP). To demonstrate the interaction among I-1 and I-3 waves, double magnetic shocks were delivered with one or two separate figure-of-eight coils placed over the motor cortex. In each session, conditioning-test intervals (CTIs) were varied from -7 to +20 ms. The subtraction method was applied for the evaluation of effects of conditioning stimuli.

RESULTS

When double shocks for I-1 or I-3 alone were applied, I-1 or I-3 inhibition lasting over 10 ms was followed by excitation. In contrast, when the conditioning shocks for I-1 preceded the test ones for I-3, the slight excitation occurred first, which was followed by the similar prolonged inhibitions. When I-3 was exchanged for I-1, however, the behavior of the

modulation of MEPs completely disappeared ($p < 0.05$). The effect remained virtually unchanged or even showed a little excitation with CTIs ranged from -1 to -4 ms. In addition, at +1.5 to +3.5 ms of CTIs, I-2 components were brought about, for which anodal stimulation responses by the conditioning or test shocks failed to show any modulation. Furthermore, when contraction levels of the FDIs were gradually increased from resting state to about 50% of the maximum, conditioning shocks with intensity under motor threshold evoked great inhibition of I-2 components around +2 ms of CTIs at rest, whereas this was gradually changed into excitation along with increase in force level. The difference between resting and 50% of the maximum was statistically significant ($p < 0.01$).

DISCUSSION

Magnetic stimulation over motor cortex can induce multiple descending volleys. Double magnetic stimulation technique is probably of great use for the evaluation of cortical excitability. Given that I-waves are of different origins, the cortical excitation would be due to some interactions among these I-waves or the responsible interneurons. The discrepancy between results by the studies using one and two separate coils probably suggests that I-1 and I-3 waves are of different cortical origins. Again, the interaction between I-1 and I-3 around at +2 ms can produce I-2 wave, which suggests that cortical networks among I-1 and I-3 have other connections to induce I-2 wave. These networks are also subject to the effect of motor cortical output such as a task force.

CONCLUSION

Cortical excitability by using double magnetic stimulation technique is probably based on some interactions among different I-waves. I-2 wave can be brought about through the specific networks between I-1 and I-3, which is influenced under a task force as well.

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O-46

Localization Error Pattern of Stroke Patients to Binaural Sound

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INTRODUCTION

Although visual hemispatial neglect in stroke patients has been well studied, there is little information on the auditory space of stroke patients (1-3). Patients with right brain lesion were shown to have a systematic rightward error of sound localization (1,2). On the other hand, Ruff, et al. (3) could not detect the existence of a systematic error in stroke patients even after stratification of the patients by the location of the lesion. To solve this discrepancy, we analyzed the errors of sound localization in stroke patients using the sound space processor, RSS-10, and headphones.

METHODS

The subjects included 15 healthy subjects and 46 patients with supratentorial stroke (left brain lesion: L-group, 17 patients; right brain lesion: R-group, 29 patients) who did not have hearing difficulty. Twenty-five of the 46 patients had cerebral infarction and 21 patients had cerebral hemorrhage.

The RSS-10 Sound Space Processor (Roland Co., Tokyo, Japan) was used to produce sounds that had directional character in realtime. White noise was presented from 7 directions at intervals of 30 degrees in the 180-degree frontal area of the subject, and the subject indicated the direction from which he/she thought the sound was coming by mentioning the corresponding hour hand on a clockface. A cross-table between the presented direction and answered direction was made for each subject. Each subject's response pattern to left/right auditory presentation was classified into one of four patterns: "deviated to the left", "deviated to the right", "bilaterally fluctuated", or "deviated a little".

RESULTS

Table 1 summarizes the number of subjects in each group who have each pattern of deviation of sound localization. As to left auditory field presentation, the majority of subjects in the Healthy Group and L-group had the "deviated little" response; in the R-group, although over 50% had a "deviated little" response pattern, an approximately equal number of the remaining subjects was "deviated-left", "deviated-right", or

"bilaterally deviated".

DISCUSSION

The deviation pattern in left auditory field presentation to the R-group was not unidirectional. Such heterogeneity of the response to sound localization was described by Vallar, et al. (4). The difference in the severity of sound localization error between patients with damage to the left or right cerebral hemisphere, may be explained by one of the hypotheses of visual hemispatial neglect, i.e., the inattention theory.

CONCLUSION

An error of sound localization was seen in stroke patients. The error of sound localization in patients with right brain lesion may represent hemispatial neglect syndrome.

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Table 1. Patients' response patterns

Healthy group		Left auditory presentation				
		Left	Right	Bilateral	Little	Total
Right auditory presentation	Left	0	0	0	0	0
	Right	0	0	0	7	7
	Bilateral	0	0	0	0	0
	Little	1	0	0	7	8
	Total	1	0	0	14	15

L-group		Left auditory presentation				
		Left	Right	Bilateral	Little	Total
Right auditory presentation	Left	0	0	0	0	0
	Right	0	0	0	3	3
	Bilateral	0	0	0	3	3
	Little	1	0	0	10	11
	Total	1	0	0	16	17

R-group		Left auditory presentation				
		Left	Right	Bilateral	Little	Total
Right auditory presentation	Left	0	0	0	0	0
	Right	1	2	1	2	6
	Bilateral	0	0	0	1	1
	Little	3	3	2	14	22
	Total	4	5	3	17	29

O－47

Suppression of the hand motor area by painful stimuli on chin

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INTRODUCTION

We have reported that a loud auditory stimulus suppresses the excitability of the hand motor area at short intervals (30 - 60 ms) and demonstrated its physiological similarities to an audiogenic startle response [3]. We speculated that our effect is induced by the polysynaptic pathway such as that inducing audiogenic startle responses. In order to see whether the same suppression is elicited by another kind of noxious stimuli, we studied effects of a pain on the hand motor area in the present communication. We compared its effect with the effect of a loud sound.

METHODS

Five normal volunteers participated in this experiment. Electrtomyographic (EMG) responses were recorded from the first dorsal interosseous muscle (FDI). Transcranial magnetic stimulation (TMS) was given in all the subjects. In one of them, the ulnar nerve was stimulated at the wrist to elicit their H-reflexes [electrical stimulus (ES)]. We studied the effect of conditioning stimuli on these responses using a randomized conditioning-test paradigm. The conditioning stimulus (CS) was a loud auditory stimulus or a painful stimulus. The former was a sound of 110 dB intensity presented through binaural headphones. The latter was an electrical stimulus given to the chin, the intensity of which was 5 times the sensory threshold. The test stimulus (TS) was either of TMS or ulnar nerve stimulation. Therefore, six different conditions were randomly intermixed. In control trials, TMS or ES was given alone. In conditioned trials, a painful stimulus or a loud sound was given prior to TMS or ES at different interstimulus intervals (ISIs: 10 to 100 ms). The intertrial intervals were carefully set to avoid the habituation. We compared the sizes between the control and conditioned responses. We calculated the average of the size ratios over the range of ISIs of 30 to 50 ms (averaged size ratio [30 - 50 ms]) for each conditioning stimulus, since the main effect was observed at these ISIs.

RESULTS

Both a loud sound and a painful stimulus similarly decreased the size of responses to TMS at ISIs of 30 - 50 ms. Neither the sound nor the painful stimulus affected H-reflexes. The mean averaged size ratio (30 - 50 ms) from all the subjects for the painful stimulus (0.52) was almost the same as that for a loud sound (0.55).

DISCUSSION

We have shown that a pain on the chin reduced the size of responses to TMS without any effects on H-reflexes, which suggests the cortical suppression. The time course and the degree of this suppression were much the same as those of the effect of a loud sound. Recently, two other reports also showed transient suppression of the hand motor area by a painful heat [1] or trigeminal sensory stimulus [2]. These all suggest that several kinds of noxious stimuli which usually evoke startle responses transiently suppress the hand motor area in humans. We suppose that these inputs activate some brainstem structures which send ascending inhibitory influence on the motor cortex through a polysynaptic pathway. It is interesting to speculate why activation of the startle system might simultaneously activate spinal motoneurons (to produce the visible startle reaction) and suppress the motor cortex. Perhaps this is a mechanism that prevents unwanted interference between the two systems. At a time of emergency, the startle system takes prominence, giving the voluntary, cortical system, especially that for hand muscles, time to reanalyze the best course of action after an important novel input.

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P-101

Power Spectrum Changes in Surface EMG during Sustained Isometric Contractions

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INTRODUCTION

The characteristics of muscle fatigue are complex and it has not been clearly recognized yet. Many efforts have been developed to investigate the fundamental mechanisms of it and many electrophysiological studies also attempted to define the changes of characteristics of EMG discharges during contractions. In this study, power spectrum analysis of the surface EMG signals during sustained isometric contractions was performed to determine the changes of electrophysiological properties of fatiguing muscles.

METHODS

Subjects were healthy 8 volunteers who were informed the aim of this study before the experiments. The muscle selected for this study was the first dorsal interosseus (FDI). The isometric contraction was sustained for 90 seconds at the maximum level. The discharges were acquired with surface bipolar electrodes and subjected to the interference pattern analysis program. The original waveforms were analyzed by Fast Fourier transform, and a power spectrum distribution was achieved. Then, the peak power frequencies(PPF) determined and the power % at each peak was also calculated. Segments of time which represented 2-second contractions were selected for every 10 seconds to determine the changes of the spectrum distributions.

RESULTS

All subjects were exhausted at the end of the 90 seconds contractions. Initial PPFs were ranged almost from 60Hz to 200Hz. High ranged PPFs (over 100Hz) diminished clearly during

contractions and it came to be disappeared at the end of contractions. Furthermore, low ranged PPFs (below 100Hz) were became lower and finally low peak at around 40Hz was obviously recognized.

DISCUSSION

It is widely assumed that there are two types of muscle figers, namely slow twitch (type I) fiber and fast twitch (type II) fiber. The property of type I fiber is fatigue resistant and type II is not, so that type II fibers would not evoke any discharges during sustained maximum contractions. It is probably the reason of the diminution and final disappearance of high ranged PPFs. Low ranged PPFs were remained at the final term of contractions but they became lower than the initial PPFs. It suggests that the inefficiency of ion transportation through muscle fiber membranes was increasing and the mechanism which elicit the action potentials was affected not to develop the rapid electrophysiological activity.

CONCLUSION

Power spectrum analysis of surface EMG signals during sustaining maximum voluntary contraction has been performed to investigate the electrophysiological property of muscle fatigue. High ranged PPFs were evidently diminished and low ranged PPFs were shifted to lower frequencies. It suggests that electrophysiological properties may be changed even in fatigue resistant muscle fibers.

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P-102

Evaluation of Muscle Fatigue for Field Assessment

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INTRODUCTION

We have studied a method to evaluate muscle fatigue using superimposed M wave (SM wave) and background activity at the several submaximum voluntary sustained contractions [1]. The SM wave is an electrically elicited M wave superimposed on a voluntary contraction. A fatigue index is a correlation coefficient between the instantaneous frequency (IF) of the SM wave and the mean power frequency (MPF) of the preceding background activity. We applied our method to the evaluation of "*fatigue*" after treadmill running [2]. As a result, the contraction level of 30% of maximum voluntaly contraction (MVC) was suitable for demonstrating the differences in an MPF-IF scatter graph (MPF-IF pattern) depending on fatigue level.

METHODS

We first of all studied what contraction level is applicable for a practical evaluation of "*fatigue*". Twelve healthy male volunteers (aged 21-22 yrs) participated for an experiment. Each subject was seated in a chair and attached a force transducer to the instep of the foot. We fixed a pair of stimulation pads on the motor point area and adjusted the stimulation levels to obtain the highest amplitude of the SM wave. We measured the heart rate, a force output, and myoelectric (ME) signals from the tibialis anterior muscle. We asked subjects to maintain the force output at 20%,30%,40%,50%,70%MVC within an endurance period on separate days.

Two healthy male subjects (22 yrs) from twelve volunteers executed running exercise on the treadmill for three consecutive days. The running speed was 7.5km/h. The inclinations were 0, 4.5, and 9 degrees on the first, the second, and the third day, respectably. We measured 5-min of biosignals at 30%MVC within the endurance period before and after running exercise.

RESULTS

The MPF and IFs were uncorrelated or sometimes showed a negative correlation during the low level contractions (20% and 30%MVC). However, at the high level contractions (59% and 70%MVC), the MPF and IFs were initially closely correlated and then became uncorrelated as muscular fatigue progressed. Regarding treadmill running, the MPF-IF pattern of the first day was the same as that at the 30%MVC. On the ohter hand, it showed a sign of muscle fatigue like those at the 50%MVC on the third day. We classified (mpf, if) samples into two groups, G1 and G2, depending on the features of the MPF-IF pattern at two different contraction phases: muscle force sustaining phase and the

degeneration phase. On the first day, the correlation coefficient of the G1 was greater than that of the G2. However, the correlation coefficient of the G1 was lower than that of the G2 on the third day. Furthermore, the spectrum analysis of heart rate variability showed the augmentation of autonomic nervous activities on the third day: increase in the frequencies and decrease in the amplitudes of the low- and high-frequency components.

DISCUSSION

The features in the MPF-IF patterns were probably correlated with the accumulation of muscular fatigue and agreed with subjective reports. The MPF-IF pattern of the third day of treadmill running showed like that at the high level contractions, even at 30%MVC. This change seemed a sign of "*fatigue*" after fatiguing exercise, refering to RPE and Mets [3]. We considered there was some correlation between muscle fatigue and "*fatigue*" because those features occured at the same time.

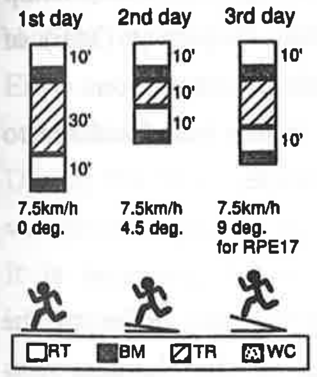
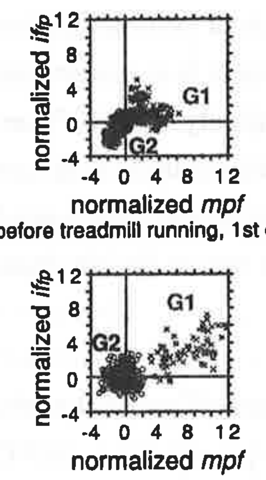


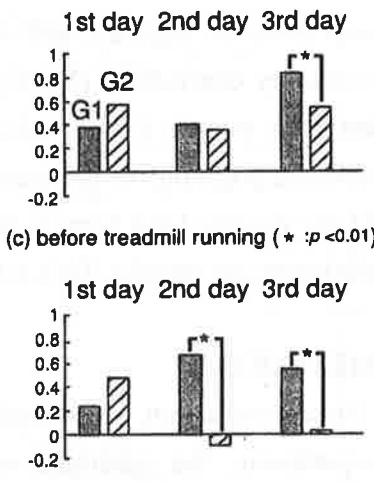
Fig.1. Protocol of readmill running.



(a) before treadmill running, 1st day.

(b) after treadmill running, 3rd day.

Fig.2. MPF-IF patterns.



(c) before treadmill running (* :p<0.01).

(d) after treadmill running (* :p<0.01).

Fig.3. Correlation coefficient between MPF and IFs.

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Changes in surface EMG during static fatiguing contractions in the upper trapezius muscle

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INTRODUCTION

In the study of mascular fatigue, the analysis of electromyographic signal has been employed extensively. Many investigators have reported the shift of frequency with fatigue, but also an increase in amplitude of EMG signals recorded with surface electrode. Recently, it has become easy to measure muscle fiber conduction velocity (MFCV) using surface electrode array, which enables us to examine the relationship between MFCV and the power spectrum. Many investigators have shown that the frequency shift is closely related to the decreasing of MFCV during static prolonged contraction.

However, many previous studies were performed on the muscle of leg and arm which was easier to measure, and were made at contraction levels higher than 30% maximum voluntary contraction (MVC). This study was undertaken to investigate the relationship between muscle fiber conduction velocity (MFCV) and median frequency (MF) of electromyography of the human shoulder muscle at different levels of contractions. Many reports have been published on shoulder pain syndromes which were localized to the trapezius muscle. This is the main reason for our choice of muscle.

METHODS

Four contraction levels were performed on 10 healthy male subjects. Prior to the experiment, the maximum voluntary contraction (MVC) force of the shoulder was determined using force instrumentation with few trials. Voluntary isometric contractions of shoulder were performed at 5% (30min.), 15% (10min.), 30% (5min.) and 50% (1min.) MVC, respectively. Electromyographic signals were detected with an active electrode array from the right trapezius. The electrode array consisted of 4 contacts 1mm thick, 10mm wide and spaced at 10mm intervals. The amplified gain was 500 over a frequency range of 5-1000 Hz.

After the experiment, the recorded signals were digitized with A/D converter at a rate of 5kHz with a 12bit resolution. MFCV was calculated by the cross-correlation method. The cross-correlation was applied to two EMG signals recorded positions 10 mm apart. MF has been used as an index of the EMG power spectrum. EMG amplitude was calculated as the root mean square value of the signal.

MFCV, MF and EMG amplitude were normalized by values obtained at initial values, because the absolute level of each parameter differed among the subjects.

RESULTS

Fig.1 shows the results of mean MFCV, mean MF and mean EMP amplitude of 10 subjects in 4 intensities of contractions, respectively. MFCV decreased about 20% from the initial value toward the end of the contraction. MF decreased 10-20% from initial value. EF in the 5%MVC decreased about 10% occurred mainly in the first few minutes of contraction. Afterwards a near steady level of MF was reached. EMG amplitude in 50% MVC increased from the beginning to the end of experiment. However, EMG amplitude varied indefinitely in other intensities of contractions.

DISCUSSION

The results show that MFCV and MF decreased during static contractions. These results agreed with the previous investigations. It was found that the same changes in MFCV and MF of surface EMG occurred during low levels of contractions and in the shoulder muscle. During 5% MVC, a decrease of MFCV was no corresponded to a decrease of MF. It is necessary to perform the further investigations for making clear this difference.

EMG amplitude did not increase during sustained static low contraction in shoulder muscle. It was suggested that the recruitment of new motor units did not occur with fatigue.

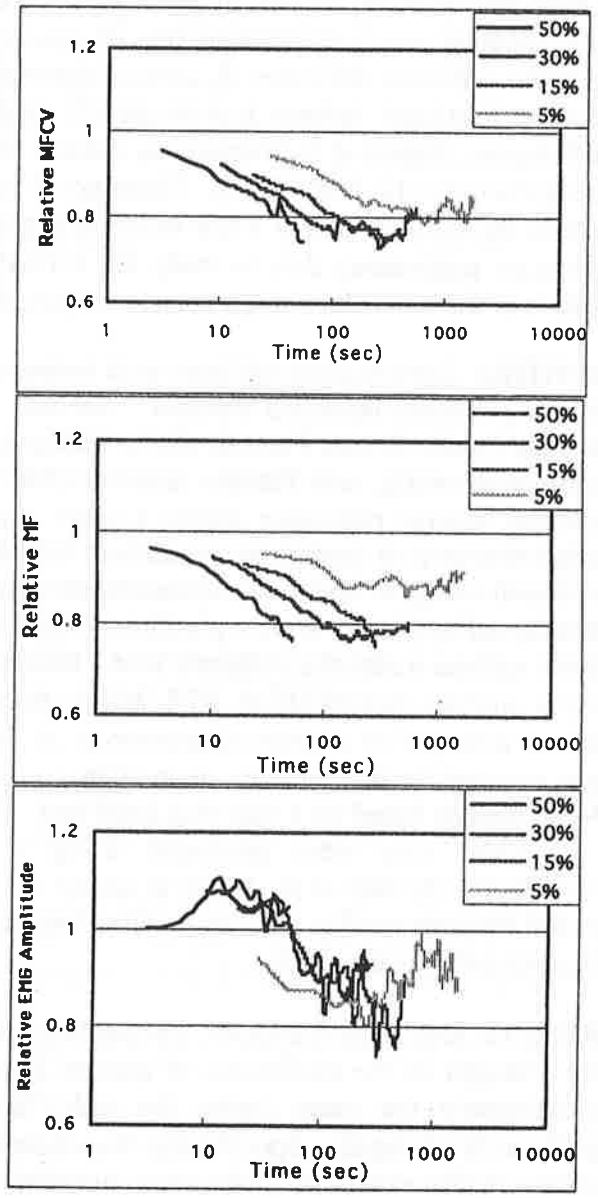

Fig.1 Changes in the relative value of MFCV, MF and EMG amplitude during 4 intensities of static contractions. Those indices are normalized by the initial values.

P-104

Effects of Fatigue on the Biomechanics of a Repetitive Knee Exercise in Patients with ACL Injury

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INTRODUCTION Rehabilitation management of patients with Anterior Cruciate Ligament (ACL) reconstruction is an important challenge for health care practitioners. Disruption of the ACL results in abnormal kinematics of the tibio-femoral joint and recurrent "giving way" or subluxation of the tibia. Safe and effective forms of exercise are crucial to guaranteeing the success of surgical interventions to reconstruct the torn ACL. A variety of strengthening exercises are in use, however, it is unknown whether excessive fatigue of the thigh muscles must be avoided when prescribing such exercises. Fatigue may alter the supportive capability of knee musculature, as well as modify joint kinematics and kinetics. The extent to which such changes may compromise the structural integrity of the reconstructed ligament is unknown. Recent advances in surface electromyography (EMG) now make it possible to estimate localized fatigue non-invasively during dynamic exercise [Roy et al. 1998]. Furthermore, improved biomechanical models are available to estimate joint loads in the knee during exercise [Lu et al. 1998]. These novel methods are being combined in this project to address the issue of safety when exercising patients with ACL reconstruction. This paper reports on preliminary data to study the normal changes that occur in joint kinematics and kinetics of the knee when thigh muscle fatigue, during a repeated squat exercise.

METHOD Eight healthy subjects with no previous history of ACL injury were tested after obtaining written informed consent. Surface EMG data were acquired from the Vastus Medialis (VM), Rectus Femoris (RF), Vastus Lateralis (VL), Biceps Femoris (BF), Medial Gastrocnemius (G), and Tibialis Anterior (TA) muscles during repetitive knee flexion and extension against resistance during a squat exercise. The squat exercise was selected for study because it is commonly prescribed following ACL reconstruction. The exercise was performed using an isokinetic dynamometer (*Ariel Dynamics, Trabuco Canyon, CA*) which was adapted by placing a force platform (*Kistler Instruments AG, Winterthur, Switzerland*) on a level surface under the subject's foot. Kinematic data were acquired using a two-camera motion analysis system (*Elite, BTS, Milan, Italy*) to identify body segments using reflective markers arranged in clusters [Cappozzo et al. 1995]. Subjects were instructed to repeat the squat exercise for five minutes, at an approximate rate of 12 squats/min., with a load between 75-100 pounds based on a maximal squat test.

EMG data were processed using a technique based on Cohen-Posch Class distributions [Bonato et al. 1999] to derive the *instantaneous median frequency* (IMDF), a spectral estimate used to monitor localized muscle fatigue during repetitive, cyclical exercises [Knaflitz and Bonato 1999].

RESULTS AND DISCUSSION The analysis of the kinematics of the squat exercise showed clear changes in the mechanics of motion during the task. While the cycle duration was approximately the same during the task, the relative phases of flexion and extension significantly changed. Specifically, we observed a decrease in the flexion phase and an increase in the extension phase time duration. The joint angular displacement at the hip, knee, and ankle also showed significant changes in range of motion and the peak of maximum flexion/extension. An example from one of the subjects recruited in this study is shown in *Figure 1* where a comparison between the hip, knee, ankle flexion/extension angular displacements at the beginning and end of the task is demonstrated. A large increase in hip flexion is shown from the comparison of the curves at the beginning and end of the squat exercise. Also, a decrease in knee flexion is indicated as well as a slight increase in ankle flexion.

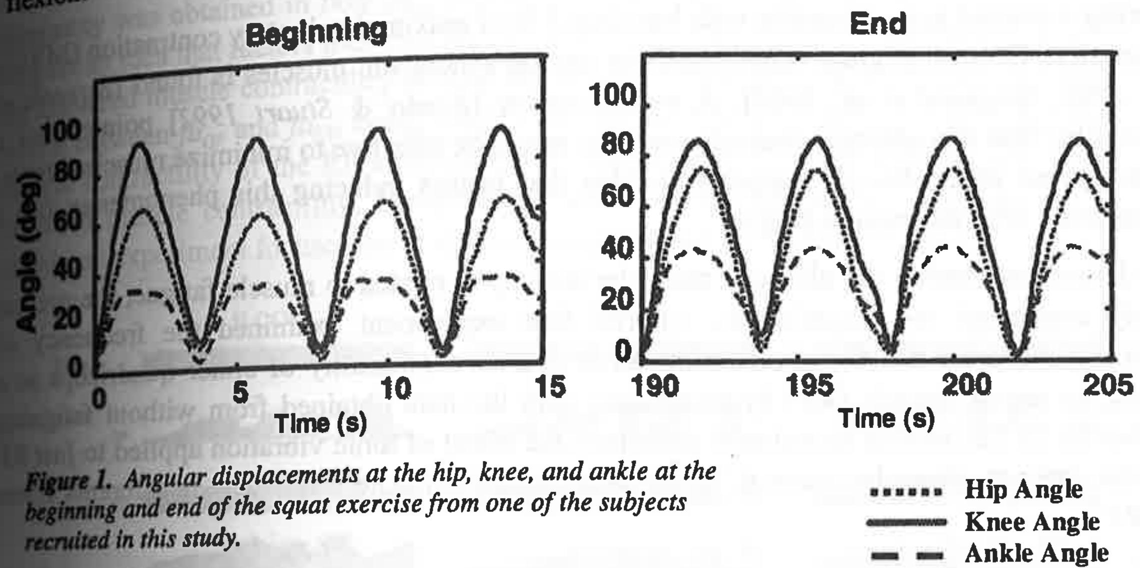

Figure 1. Angular displacements at the hip, knee, and ankle at the beginning and end of the squat exercise from one of the subjects recruited in this study.

Time-frequency analysis of the EMG data indicated an overall decrease of the IMDF toward the lower frequencies particularly for the Rectus Femoris muscle. Also, alternating phases of IMDF decrease and increase were observed in addition to the overall trend of IMDF decrease thus suggesting a possible mechanism of load sharing among muscles during the exercise.

CONCLUSIONS Preliminary results obtained in this study indicate that the mechanics of repetitive squat exercise changes while fatigue progresses as indicated by time-frequency analysis of the EMG data. Further analysis and experimental work is underway to assess possible changes in the load applied to the ACL during fatiguing repetitive tasks using a mechanical model of the knee designed for this purpose [Lu et al. 1998].

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P-105

Effects of Muscle Fatigue on Alternate Muscular Activity in Synergistic Muscles during Low-level Sustained Contraction

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Introduction

During sustained knee extension with less than 5 % of maximal voluntary contraction (MVC), alternative electromyogram (EMG) activity among synergistic muscles is found [*Kouzaki et al. 1999*; *Sjøgaard et al. 1986*]. A recent review [*Enoka & Stuart 1992*] pointed out a possibility that this alternate muscular activity would be effective to minimize muscle fatigue, although no study directly supports an idea that factors inducing this phenomenon has a connection with the muscle fatigue.

To determine whether the alternate muscular activity is related to muscle fatigue, the present study conducted two experiments. 1) The first experiment examined the frequency of alternate muscular activity after the impaired muscle contractility of either quadriceps as a whole or rectus femoris (RF) by comparing with the data obtained from without fatiguing activities. 2) The second experiment examined the effect of tonic vibration applied to just RF on the alternate muscular activity. This treatment can stimulate selectively Ia afferents fibers of RF.

Method

Ten subjects (23-30 yrs) maintained unilateral static knee extension contraction at 2.5 % of subjects' MVC for 60 min (CONT).

Experiment 1 (*n=10*) consisted of 3 different protocols, which is 1) CONT after 50 repeated MVCs of static knee extension for 3 sec with 3 sec rest in between each trial to induce the impaired muscle contractility of quadriceps muscle as a whole in advance (fa_{QF}), 2) CONT after 50 repeated MVC of static hip flexion for 3 sec with 3 sec rest in between each trial to reduce the muscle contractility of RF in advance (fa_{RF}), and 3) CONT without fatiguing activities.

Experiment 2 (*n=5*) consisted of 2 different protocols, which is 1) CONT after tonic muscle vibration applying to proximal portion of RF at 30 Hz for 30 min to induce the impairment of Ia afferents activity of RF in advance (tv_{RF}), and 2) CONT without treatment.

Surface EMGs recorded from RF, vastus lateralis (VL) and vastus medialis (VM) were digitized and sampled at 1,000 Hz, and these signals were full-wave rectified and integrated over every 1 sec period to yield integrated EMG (iEMG) sequences. The frequency of emergence of alternate muscular activity among heads of quadriceps muscle was calculated on the basis of differentiating iEMG sequences.

Results & Discussion

In both experiment conditions, the alternate muscular activity has never been observed between VL and VM. While, it could be found between RF and both VL and VM at several times.

Experiment 1: Cumulative frequency of alternate muscular activity in all the protocols exponentially increased with time course. However, significantly higher cumulative frequency was obtained in both fa_{QF} and fa_{RF} as compared to that in Cont. This result could support an idea that factors inducing the alternate muscular activity in quadriceps is related to the impaired muscle contractility of working muscles. Moreover, no difference in number of events between fa_{QF} and fa_{RF}, could imply that this event has a close relation to the impaired muscle contractility of the RF alone rather than that of whole quadriceps muscle. Since the impaired muscle contractility, however, includes both extrafusal- and intrafusal-fibers, an additional experiment focused on Ia afferents originating from intrafusal-fibers.

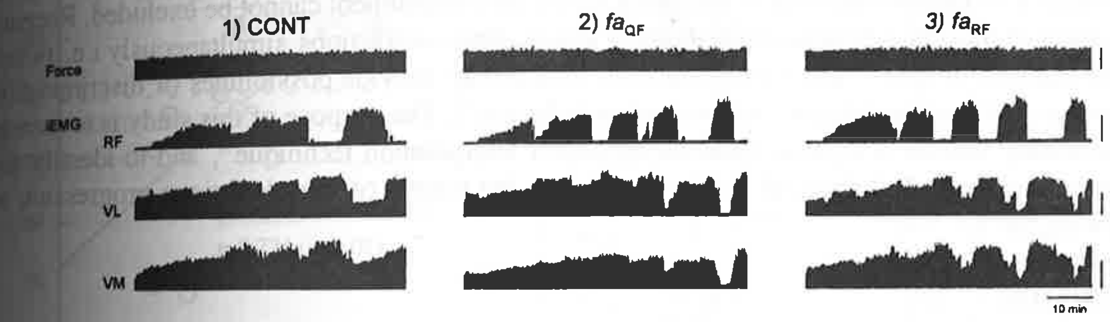

Fig1: Typical examples of force, iEMG sequences from RF, VL, and VM during sustained knee extension for 60 min in different protocols. It seems that frequency of emergence of alternate muscular activity is higher in fa_{QF} (middle panels) and fa_{RF} (right panels) than CONT (left panels).

Experiment 2: Cumulative frequency of alternate muscular activity was significantly higher in tv_{RF} than CONT throughout the sustained contraction. This result suggests that one of the emergent factors for the alternate muscular activity in quadriceps muscle is an impaired function of Ia afferents originating from RF.

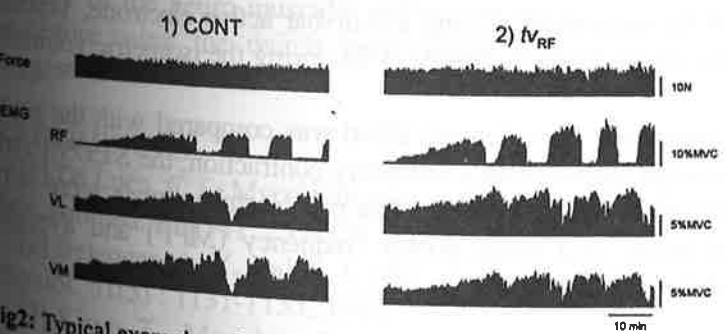

Fig2: Typical examples of force, iEMG sequences from RF, VL, and VM during sustained knee extension for 60 min in different protocols. It seems that frequency of emergence of alternate muscular activity is higher in tv_{RF} (right panels) than CONT (left panels).

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P-106

Voluntary Muscle Activation Estimated with Twitch Interpolation and Endurance Capacity in Fatiguing Isometric Contractions

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INTRODUCTION

Surface electromyography has been used extensively as a measure to evaluate muscle fatigue noninvasively. It has been well known that the power spectrum shifts towards lower frequencies and IEMG increases with progression of muscle fatigue[1]. Although the reduction in the muscle fiber conduction velocity has been reported to explain the frequency shift as a peripheral factor, involvement of central mechanism including motor unit recruitment cannot be excluded. Recently, evaluation of muscle fatigue using voluntary and evoked contractions simultaneously i.e. twitch interpolation technique[2] has been proposed, which may provide possibilities of discrimination between central and peripheral factors in muscle fatigue[3]. The purpose of this study is to measure the voluntary muscle activation (VA) using twitch interpolation technique[4], and to identify the endurance capacity in individual subjects based on the pattern of muscle fatigue progression as depending on the VA.

METHODS

In 14 young male subject (10 regular exercisers and 4 sedentary), force and EMG measurements were made by using an isokinetic training machine (Cybex II). Subjects exerted isometric knee extensions of 20, 40, 60, 80, 100% maximum voluntary contraction (MVC) for 5s. Simultaneously with the voluntary contractions, the quadriceps femoris muscles were stimulated percutaneously and supramaximally through two 6×6 cm dampened electrodes bandaged to the anterolateral thigh[5]. Square-wave pulses of 140-300V with 0.1msec duration were used. 8 train of stimuli at 100Hz was delivered at intervals of 5sec. The voluntary isometric torque (VT) and superimposed tetanic torque (STT) were measured at the ankle with strain gauge transducer. After thirty minutes rest, subjects exerted isometric knee extensions of 60% MVC (short-duration fatigue task; SDF task) and 20% MVC (long-duration fatigue task; LDF task) until the target force could no longer be maintained. Using a four-bar active electrode, bipolar surface EMGs were obtained from the vastus lateralis muscle (VL) during the isometric voluntary contractions.

The magnitude of the mean force generated by voluntary effort was compared with the peak force generated by electric stimulation superimposed on a voluntary contraction; the STT/VT ratio indicating a reserve of voluntary activation was calculated. The myoelectric signals were A/D converted with 2kHz sampling frequency, and mean power frequency (MPF) and average rectified value (ARV) were calculated.

RESULTS AND DISCUSSION

Subjects were divided into high voluntary activation group (HVA group) and low voluntary activation group (LVA group). Four sedentary subjects were included in the latter group, indicating that the VA adapts to exercise (Fig. 1). Maximum voluntary torque (MVT) was significantly lager in the HVA group than in the LVA group, and significant positive correlation (r=0.72) was found between MVT and VA.

The endurance time (ET) was 98±40 s for SDF task, and 1032±555 s for LDF task. A significant negative correlation (r=-0.71) was found between MVT and ET for the LDF task. The ET was significantly longer in the LVA group than in the HVA group. The MPF of voluntary EMG decreased consistently while the ARV increased during the contraction in both tasks (p<0.01), indicating the development of fatigue in the muscle. The final change of MPF relative to the initial value was significantly greater in the SDF task than in the LDF task (Fig. 2). A significant correlation (r=-0.83) was seen between the relative change in MPF and ARV in the SDF task. For the SDF task, the final change of MPF and ARV relative to the initial value was significantly greater in the LVA group than in the HVA group (Fig. 2). It is considered that these results are caused by the differences in the relative contribution of central and peripheral factors.

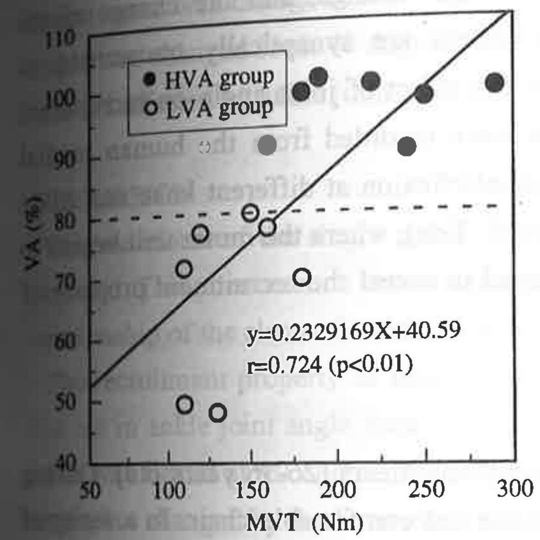

Fig.1 Correlation across subjects between MVT and VA.

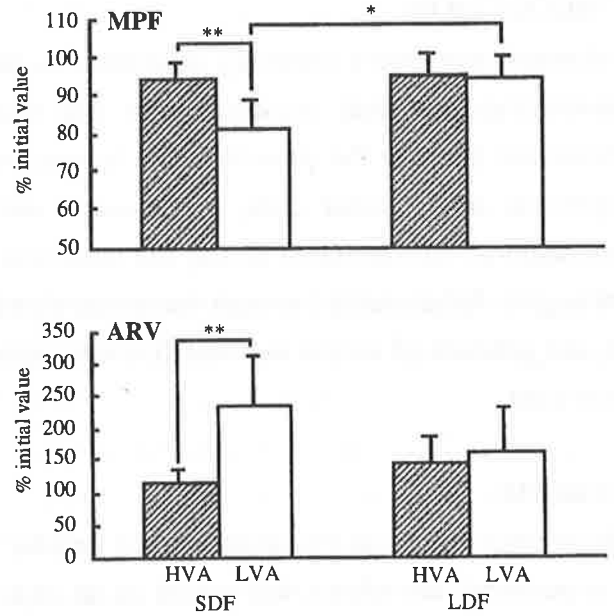

Fig.2 Final change of MPF and ARV relative to their initial values. Comparisons are made between HVA and LVA groups and between SDF and LDF tasks. Values are mean± SD. * p<0.05, ** p<0.01

CONCLUSION

Our results indicate that individual tolerance for local muscle fatigue, usually evaluated as maximum endurance time, may depend on the differences in VA, the VA, in turn, depending on the adaptation to exercise in individuals, and that there appears to exist a corresponding adaptative strategy of the neuro-muscular system working in fatiguing contractions. Usefulness of our procedure using the twitch interpolation technique in evaluating muscle fatigue was also suggested.

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P-107

Effect of joint angle on recruitment property of single motor unit in human gastrocnermius muscle

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INTRODUCTION

Voluntary movement generally accompanies joint angle change, and the change elicits afferent impulses from muscles, joint and skin, which are synaptically transmitted to motoneuron pool. In the present study, to examine the effect of joint angle on recruitment property of single motor units, single motor units were recorded from the human medial gastrocnemius muscle (GM) during the isometric planterflexion at different knee and ankle joint angles. Relationship between the torque-threshold (T-th), where the motor unit begins to fire, and gradient of torque increase (G) was examined to reveal the recruitment property of motor units.

METHODS

The present study was performed on six healthy male volunteers (26-36 years old). During the experiment, the subject was seated on an adjustable and comfortable chair. In a series of experiment, the ankle joint angle was fixed at 0 degree, while the knee joint angle was adjusted at 40, 65 and 90 degree flexion position. In another series of experiment, the knee joint angle was fixed at 90 degree (knee flexion), while the ankle joint angle was adjusted at planterflexion (25 degree), 0 degree and dorsiflexion (25 degree).

Measurements of maximum voluntary isometric contraction (MVIC) torque of the ankle planterflexion was determined prior to each experimental condition. Single motor unit discharges were recorded with a bipolar electrode of coiled type inserted into GM.

The subjects was asked to perform voluntary planterflexion at torque ramp speeds of 1, 2, 5, and 10 %MVIC/sec by showing their current torque to them as well as the command trace displayed on an oscilloscope. T-th were normalized to the previously measured MVIC of planterflexion at each joint angle, and expressed in terms of percentage.

RESULTS

The waveform of single motor unit potentials did not changed, but their amplitude changed gradually as the joint angle was changed.

The T-ths of all the motor units examined were increased as the ankle joint angle was changed form planterflexion to dorsiflexion, when the knee joint angle was fixed at 90 degree in each G. The T-ths of all the motor units examined were increased as the knee joint position was changed form 40 degree to 90 degree, when ankle position was fixed at 0 degree in each G.

The recruitment property of motor units is suggested to be determined by relationship between the T-th and G of torque increase. The proposed relationship was T-th = ρG^{λ}, where ρ is a proportional constant. The motor unit with a positive or negative value of λ is suggested to be static or phasic, respectively (Kurata, 1974). The recruitment property of motor units was changed from negative (phasic) to positive (static) one, as the knee joint angle was changed form 40 degree to 90 degree. But the recruitment property of motor units was not affected by ankle joint angles.

DISCUSSION

The waveform of the single motor unit potential changed gradually as the joint angle was changed. This phenomenon was considered to be principally due to a change in the geometric relationship of the electrode with the muscle fibers at various joint angles.

The recruitment property of single motor unit was affected by changes in knee joint angle, but not in ankle joint angle ones. This result seems to coincide with the report that when the knee was flexed at 90 degree, the muscle length of GM was not changed by the ankle joint angle, but changed by the knee joint angle (Kawakami et al. 1998).

The T-ths of all the motor units examined were increased, either as the ankle joint angle was changed toward dorsiflexion, or as the knee joint position was changed toward flexion. The GM muscle is a two-joint muscle crossing both the knee and ankle joints, whereas the soleus muscle is a single-joint planter flexor. Therefore, it was considered that in case of the ankle joint angle change, T-th depends on the length-tension relation of the soleus muscle because the muscle length of GM remains unchanged, and that in case of the knee joint angle change, T-th depends on the length-tension relation of the GM muscle.

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P-108

Rate Cording and Recruitment of Motor Units for Maintaining Sustained Contraction

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INTRODUCTION

Recently, we reported that motor units (MUs) from m. vastus medialis elongated their spike interval at initial stage of the submaximal isometric constant force contraction (1990). The elongation considered to be one of the strategies to maintain the target force because the elongation was observed in different muscles. In the present study, we made the detailed analysis on the single MUs behavior, including recruitment at the initial elongation phase. And we also compared to the MUs activity among synergistic muscles of knee extension.

METHODS

Action potentials of single MUs were recorded from m. quadriceps femoris, except m. vastus interned., simultaneously using the wire electrodes (ϕ 100mm).. In some experiments, we used surface electrode (Morimoto et al., 1980) to investigate the identified single MUs activities under the different target torque.

The subjects were seated on a high stool and fixed their knee joints at 90deg. The isometric knee extension force was recorded at the ankle with a strap connected to a strain gauge. The subjects requested to increase the force gradually to 5%MVC and to keep the target force for 5min. The developed force and the target force were displayed on the screen of an oscilloscope placed in front of the subject Electrical and mechanical signals were simultaneously stored on FM tape and were subsequently digitized for later analysis.

Identification of MU action potential was performed basically by visual inspection of waveform shape and amplitude in digital and analog recorded data. Spike intervals of identified MUs were measured from the recorded train MU action potentials using .computer soft wear program.

RESULTS

Spike interval elongated continuously for 3-5min of the contraction. And it found two phases in the elongation by the difference in extent. Within 30s, MUs showed the steep elongation in the spike interval, and successively the gentle elongation. The decruitment of MU following the elongation was also observed.

In both of the elongation phases new motor units recruited. To investigate the behavior of new MUs recruitment while the spike intervals are elongating we observed the recruitment time of the identical single MU recorded by surface electrode during the contraction at various target torques less than recruitment threshold of the MU. The identical single MU recruited in the both of elongation phases.

These were no significant difference in the elongation of spike interval and the time appeared the newly recruitment MUs among synergistic muscles

CONCLUSION

In the initial stage of the low level sustained contraction the elongation of spike interval and the recruitment of new MUs occurred to maintain the constant force regardless of the activating muscles.

It is possible to propose that the time course of the spike interval change is not monotonic but biphase or more, included the several factors on the elongation.

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P-109

UNUSUAL GAIT DISORDERS CAUSED BY TETHERED SPINAL CORD SYNDROME

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INTRODUCTION

Tethered cord syndrome is a developmental anomaly of an already dysraphic spine, known as spina bifida. It is an entity occurring during developmental period in childhood as the result of congenital anomaly of the spinal cord and its meninges. It is interesting that the anomaly may occur in previously operated anomaly (spina bifida aperta) and in closed forms (spina bifida occulta). Etiopathogenetic factors involve presence of lumbosacral spina bifida with traction of the spinal cord due to a discrepancy in the growth of skeletal and neural elements in the developmental period of the child.

METHODS

In the period of 1990 to 1999 year, at the University Children's Hospital of Belgrade, there were 38 children with atypical gait predominantly, aged 4 to 15 years, healthy in advance.

RESULTS

Anamnestic data include presence of different clinical signs, as a number of various orthopedic and urological disturbance, but primarily neurological disorders and abnormalities, starting with disordered gait with foot deformities of cavus or equinus type, pain of the back and legs and as well as different disorders of continence. Disorder of sensitivity, lowered or increased reflexes, trophic ulcus and bizarre foot osteomyelitis may be present. The diagnostic protocol involves a detailed clinical examination, neurological status, neuroradiological evaluation of the lumbosacral region (X-ray, CT, NMR) and neurophysiological examination (EMG, ENG., EP). Treatment is surgical, involving both spine and feet and rehabilitation, IN 28 cases with excellent results. In the other 10 cases operation hadn't beeing done and the deformity of the feet agravated.

CONCLUSION

The aim of the paper is to stress the significance of early diagnosis and adequate treatment, as the basis of preventing further progression of irreversible neurological deficit, which result in permanent sequel of the locomotor system and gait disturbance. Recognition of the syndrome is of great importance in clinical practice and to prevent unnecessary circulation of small patients from pediatricians to orthopedicians, physiatricians, urologists and pediatric surgeons, when precious time may be lost to adequate treatment. The surgery and rehabilitation are a choice of treatment.

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P-110

Effect of Plasmapheresis to Changes in Single Fiber EMG in Patients with Chronic Inflammatory Polyradiculoneuropathy

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INTRODUCTION

Plasmapheresis (IAPP) has been reported to be effective in CIDP[1]). In order to investigate the early changes of improvement in chronic inflammatory polyradiculoneuropathy(CIDP) after plasmapheresis , we studied the conventional EMG and single fiber EMG (jitter and fiber density) in patients with CIDP.

METHODS

Immunoadsorption plasmapheresis (IAPP) was applied in 17 patients (42-63Y. O) with CIDP. Each patient underwent 6 to 9 IAPP sessions.The electrophysiological examination (maximun conduction velocity, distal latency, F-wave latency of CMAPs, conduction block) was tried before and after IAPP .In order to study the early changes of improvement of nerve conduction in patients with CIDP, single fiber EMG (jitter and fiber density) was also performed .

RESULTS

Trial of IAPP was effective in 9 patients(the responders) , and noneffective in 8 patients. The electrophysiological examination disclosed the improvement of maximun conduction velocity and conduction block in six weeks after beginning of IAPP in the responders. We also examinened the single fiber EMG (jitter and fiber density) in order to investigate the early changes of improvement of nerve conduction in CIDP after beginning of IAPP .
As the results, the mean jitter was 65. 1±18. 4μsec(n=57) and the percentage of blocking of single fiber action potentials was 40.4% (23 units) in the responders before IAPP. Since the values of jitter of single fiber action potentials elicited by repetitive stimulation did not correlated with the changes of stimulus frequencies from 3Hz to 10Hz, it was considered that the increase of jitter did not reflect the disturbance of neuromuscular

junction, but rather reflect the disturbance of nerve conduction[2]. Furthermore, these increased jitter values improved to 43.1±12.1 μsec(n=37), and the percentage of blocking was also decreased to 18.9% (7 units) 7 days after beginning of IAPP.

On the other hand, in non effective patients, the mean fiber density was 64.9±17.8 μsec(n=49) before IAPP, and 65.8±17.5 μsec(n=27) 7 days after beginning of IAPP. These values were not significantly different before and after IAPP. The fiber densities were also investigated, but it was not significantly different before and after IAPP even in the responders.

DISCUSSION

The conventional EMG and single fiber EMG(fiber density) disclosed the improvement of nerve conduction and conduction block in patients with CIDP(responders) after IAPP. Since the increase in the jitter values was not changed by the repetitive stimulation, it was suggested the increased jitter values reflect ed the disturbance of nerve conduction in the CIDP patients. Furthermore, since the jitter values showed the improvement preceded to the improvement of conventional EMG findings and clinical symptoms, it was considered that the examination of jitter was beneficial for evaluating the subclinical improvement of nerve conductions in the responders to IAPP and the efficacy of IAPP.

CONCLUSION

Trial of IAPP was effective in 9 patients , and noneffective in 8 patients. The conventional EMG disclosed the improvement of maximun conduction velocity and conduction block after beginning of IAPP in the responders. Single fiber EMG also suggested that the improvement of the increased jitters preceded to the improvement of conventional EMG findings and clinical symptoms, and was beneficial for evaluating the efficacy of IAPP.

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P-111

Effects of Electric Stimulation on Intramuscular Energy Metabolism of Disuse Atrophied Muscle. A ^{31}P-MRS Study

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INTRODUCTION

Various countermeasures (1, 2, 3) to prevent disuse atrophy of skeletal muscle have been well studied; especially, electric stimulation and muscle stretching among them can be applied for patients during bed rest or in case of joint immobilization after surgery or injury (2, 3). However, most of researches done to evaluate the countermeasures have been based on *in vitro* measurement. Intramuscular energy metabolism in working muscles is one of the important indicators of skeletal muscle function, and it can be monitored *in vivo* and in real time using phosphorus-31 magnetic resonance spectroscopy (^{31}P-MRS). The purpose of this study was to evaluate the effects of electric stimulation as a countermeasure to prevent disuse atrophy of skeletal muscles by assessing energy metabolism in the working muscle by ^{31}P-MRS.

METHODS

Eighteen Sprague-Dawley rats were used and divided into three groups: control (C), hindlimb suspended (HS) for 7 days (5), the HS plus percutaneous electric stimulation for 7 days (ES). The electric stimulation for training of the gastrocnemius-plantaris-soleus (GPS) muscles was attained at 1Hz for 1hour a day. For ^{31}P-MRS measurements, contraction of the GPS muscles was induced by electrical stimulation of the sciatic nerve at 0.25Hz for 10 min following a 2-min rest, then the frequency was increased to 0.5 and 1.0Hz every 10 min. During the stimulation, twitch forces were recorded by a strain gauge, and simultaneously ^{31}P-MR spectra were also recorded. On each spectrum, the peaks of phosphocreatine (PCr), and inorganic phosphate (Pi) were measured. The ratio of the area of both peaks (PCr/(Pi+PCr)) and intracellular pH, which was determined by the chemical shift between both peaks, were calculated as indicators of energy metabolism. The PCr/(Pi+PCr) ratio and force were measured at a steady-state in each frequency, and the relationship between the PCr/(Pi+PCr) ratio and peak twitch force times rate (F*R) was examined to evaluate muscle oxidative capacity (4). Maximum tension (MT) was measured at the muscle contraction induced by 0.25Hz; the wet weight of the whole GPS muscles was also measured.

RESULTS

Muscle weight As shown in Figure 1, the weight of the whole GPS muscle, decreased significantly ($p<0.05$) in the HS and ES groups (2.65, 2.38, and 2.16 (g) in C, HS, and ES, respectively).

Maximum tension MT was 519, 450, and 516 (g) for C, HS, and ES, respectively. MT in HS was significantly smaller than MT in C ($p<0.05$), while MT in ES was not different from MT in the C.

MRS Spectrometry Intracellular pH did not decrease below 7.0 during muscle contractions, indicating the muscle exercise was aerobic. Significant ($p<0.05$) linear relationships between PCr/(Pi+PCr) ratio and F*R were found in all groups during muscle contraction. The slope in C group was gentler than that in HS ($p<0.05$), but no difference was observed between C and ES (Fig. 2). During aerobic exercise the slope indicates muscle oxidative capacity (4). Therefore, the oxidative capacity of muscles was shown to be maintained for seven days when electric stimulation was applied to the suspended limb.

DISCUSSION

Electric stimulation for training could not prevent disuse atrophy; however, based on the results of maximum tension and muscle oxidative capacity, we found that it prevented functional and energy metabolic deterioration during one week.

In suspended limbs, protein degradation increases while protein synthesis decreases, which reduces weight of GPS muscles (3). Therefore, to prevent muscle atrophy, protein synthesis must be increased by applying some countermeasures. The electric stimulation for training conducted in this study induced twitch contraction, therefore it might not have been enough to induce an increase of the protein synthesis in atrophied muscles due to disuse.

On the other hand, it prevented the deterioration of the intramuscular oxidative capacity. The training in this study was considered as endurance training, because the stimulation was low load and training was performed for one hour a day. Thus, the results of showed that the oxidative capacity might be maintained by such training. Moreover, these data indicated that to prevent disuse atrophy and functional deterioration, additional countermeasures such as tetanic contraction induced by electric stimulation and stretching (1, 3), which is considered to prevent atrophy, should be combined with twitch electric stimulation.

CONCLUSION

Electric stimulation in this study prevented deterioration of muscles function and energy metabolism, but did not prevent muscle atrophy.

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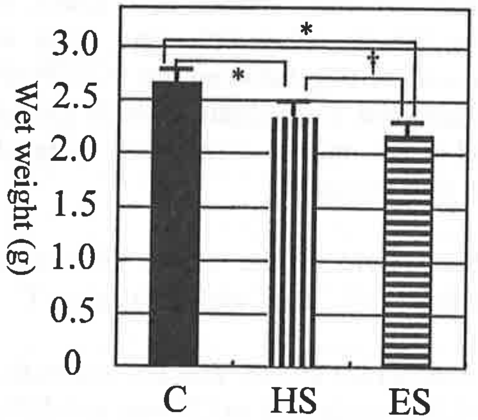

Fig. 1 Wet weight of the whole GPS muscles (g)
The bar indicates S. E. * p<0.05, compared with C group. † p<0.05, compared with HS.

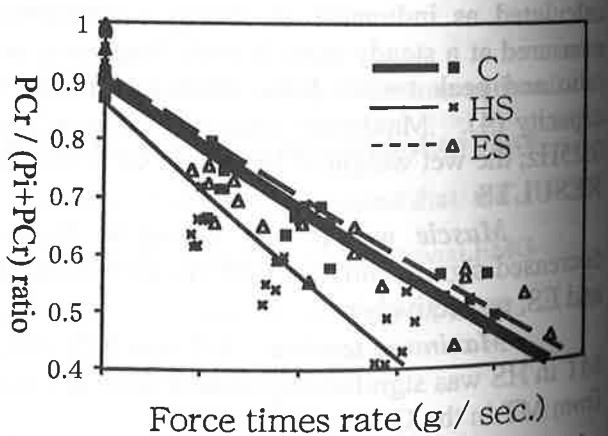

Fig. 2 Relationship between PCr / (Pi+PCr) ratio and force times rate.

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The effect of forearm endurance training on muscle activity during submaximal handgrip exercise

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INTRODUCTION

The effect of endurance training in the localized muscle groups on circulatory or sympathetic responses had been well reported, while the effect of endurance training in the localized muscle groups on muscle activation level during exercise had not been elucidated. The purpose of this study was to investigate the effect of unilateral forearm endurance training on the muscle activity during submaximal handgrip exercise.

METHODS

Subjects were six healthy female college students (mean age =18.6 yrs). Subjects were trained their nondominant forearm five times a week for the entire 6 weeks and dominant arm served as the control. They were asked to perform rhythmic handgrip exercise (30*1s contractions/min at 20% maximal voluntary contraction) until exhaustion in every training session. Before and after the six weeks training, we measured maximal voluntary handgrip force. The same submaximal rhythmic handgrip exercise as the training session were also performed before and after the six weeks training. During both maximal voluntary contraction and submaximal exercise, surface EMG was recorded from flexor capri ulnaris muscle and flexor capri radialis muscle. The EMG signals were full-wave rectified and integrated. The mean EMG activity was calculated and normalized by the values during maximal voluntary contraction. The muscle activity during handgip exercise was evaluated by the summation of the values for two measured muscles.

RESULTS

Before six weeks training, dominant arm showed significantly greater muscle activity during last 10 seconds of rhythmic submaximal handgrip exercise. However, maximal voluntary force and maximum work time to exhaustion did not differ between dominant and nondominant arm. After six weeks training, maximum work time significantly increased for the trained arm, while there was no significant change in the untrained arm. Six weeks training did not significantly affect the maximal voluntary force during handgrip exercise for both the trained and untrained arm. Only for the trained arm, mean EMG activity was significantly increased during last 10 seconds of the submaximal rhythmic exercise than that recorded before the training period (Fig.1).

DISCUSSION

Six weeks forearm endurance training did affect maximum work time to exhaustion during submaximal rhythmic exercise, since the EMG activity significantly increased as the exercise approached to the exhaustion. This results would be contributed by the changes in motor unit firing patterns occurred during the training period.

CONCLUSION

It is concluded that forearm endurance training would affect the muscle activity level during submaximal exercise especially near the exhaustion. Endurance capacity of the localized muscle groups would be enhanced not only by the changes in the circulatory or sympathetic responses but also by the neural adaptation during training.

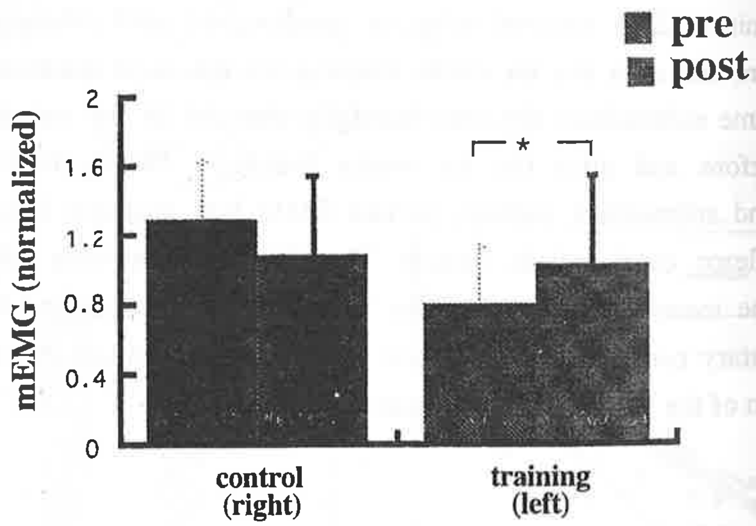

Fig.1 The changes of mean EMG activity during last 10 seconds of submaximal rhythmic handgrip exercise during training.

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Differences in Sensitivity of Short- and Long-Latency Stretch Reflexes in Human Elbow Flexor and Extensor Muscles

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INTRODUCTION

This study attempts to compare stretch reflex sensitivities among different muscles in vivo. The purpose of this study is to examine the relation of the short- (M1) and long- (M2, M3) latency stretch reflexes to the stimulus intensity which is estimated from in-vivo measurement of mechanical muscle stretches by using the ultrasound system, and to compare sensitivity of the stretch reflexes among elbow flexor and extensor muscles.

METHODS

Nine healthy male subjects aged 24 - 36 years participated in this study. Mechanical stretch stimuli were given to the elbow flexor muscles, brachioradialis (BRD), the long- and short-heads of biceps brachii (BBL, BBS), and the elbow extensor muscles, long-, medial- and lateral-heads of triceps brachii (TBLG, TBM, TBLT) by torque generation apparatus during weak isometric contraction ranging from 0 % to 9% of maximal voluntary contraction (MVC). The stretch stimuli were applied to the subject's wrist in extension or flexion direction 20 times at velocities in a range of about 50 - 250 deg/s. The total number of stretch stimuli was 160 (4 BGA levels x 2 directions x 20 times). The stimulus intensities of each muscle were measured by B-mode ultrasound system with 7.5 MHz linear-array transducer. The passive muscle stretching was applied to each muscle at low velocity to ensure immobilization of the probe. The actual change of muscle fiber length was possible to calculate from a planimetric model. Sensitivity of each reflex response was evaluated by the multiple linear regression analysis with two independent variables, muscular stretching velocity (MSV) and background EMG activity (BGA). The partial regression coefficient was defined as a reflex gain of each independent variable, and the intercept for an axis in each independent variable (X-intercept) was defined as a reflex threshold of each independent variable.

RESULTS and DISCUSSION

Fig 1 shows a typical example of the 3D graph with the multiple linear regression analysis for elbow flexor and extensor muscles. In both elbow extensor and flexor muscles, the sensitivities of long-latency stretch reflexes were larger than that of short-latency stretch reflex. On the other hand, in elbow extensors, the MSV gains of long-latency reflexes were significantly higher and the MSV thresholds of short- and long-latency reflexes were significantly lower than those of elbow flexors (Fig 2). These results indicated that the long-latency stretch reflex pathways of the elbow flexor and extensor muscles are dominant as compared to the short-latency stretch reflex pathway, and the sensitivities of long-latency stretch reflexes are greater in elbow extensor muscles than in elbow flexor muscles. This suggests that the high sensitivity of long-latency pathway in triceps brachii is more effective to generate the required torque, and compensates smaller mechanical advantages in those muscles.

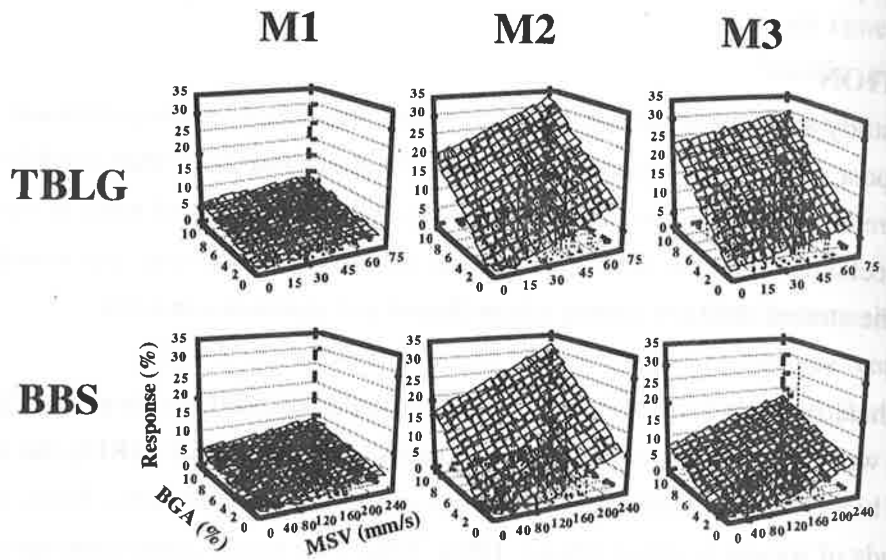

Fig 1 A typical example of 3D graph of each component in TBLG and BBS in one subject. It notes that there is a difference between TBLG and BBSin X_1 axis scale (MSV).

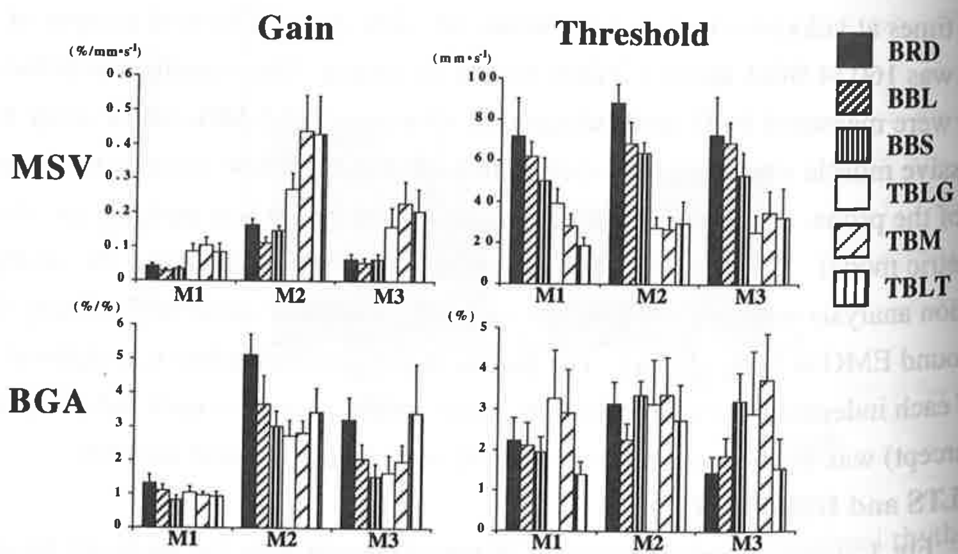

Fig 2 Mean and SEs of the partial regression coefficient (gain) and X-intercept (threshold) for each independent variable (MSV and BGA) of multiple linear regression analysis.

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Effect of Long-term Bed Rest on activation of the Human Soleus Muscles During Walking

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INTRODUCTION

It has been demonstrated that after the long-term bed rest (BR) the maximum H-reflex (Hmax) in the soleus muscle during upright standing is largely suppressed, whereas the size of motor evoked potential (MEP) by transcranial magnetic stimulation, normalized with the Hmax (MEP / Hmax) is increased (Yamanaka et al. 1999). These results suggest that relatively greater contribution of the higher center is required after the BR to compensate reduced neuromuscular function. If this is the case during walking, activation pattern of the soleus might change after the BR. The purpose of this study, therefore, was to elucidate if the activation level of the soleus during walking is changed after the BR in association with change in the maximum M-response.

METHODS

The experiment was performed on four healthy men (age = 29 +/- 6.8years; height = 177.8 +/- 8.6cm; weight = 68.5 +/- 15.0kg) with no known history of neurological disorder. All the subjects gave fully informed consent to the experimental procedures, which were approved by the local ethics committee. All subjects were confined to 6 degrees head-down BR for 20 days. We investigated the electromyographic (EMG) responses from the right SOL muscle and ground reaction forces (GRF; 9281C,KISTLER) during free walking before and after BR. The maximum M-response (Mmax) was elicited in the SOL by electrical stimulation delivered to the tibial nerve in the popliteal fossa. Ag-AgCl surface electrodes (4 mm in diameter) were applied over the SOL muscle. EMG and GRF signals were measured and stored using a personal computer for off-line analysis. At the beginning of the each experiment, the size of the Mmax was recorded and the size of SOL activity was expressed as a percentage of this.

RESULTS

After the 20-days BR, the stance time as the measure of walking velocity was prolonged from 981.2 +/- 119.2 ms to 1146.6 +/- 168.2 ms, indicating the slower walking velocity after the BR. The level of activation normalized by the Mmax in the SOL, however, was increased after the BR. This was observed for all subjects and was statistically significant ($P < 0.05$).

DISCUSSION

The results of this study indicated that the Mmax in the SOL was decreased due to the long-term reduced activity, while the relative activation level during walking was increased even though the walking speed was lowered after the BR. Together with the reduced Mmax after the BR, it is suggested that the relatively greater facilitation probably from the higher center is required to compensate the altered neuromuscular function after the long-term bed rest.

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ACKNOWLEDGMENT

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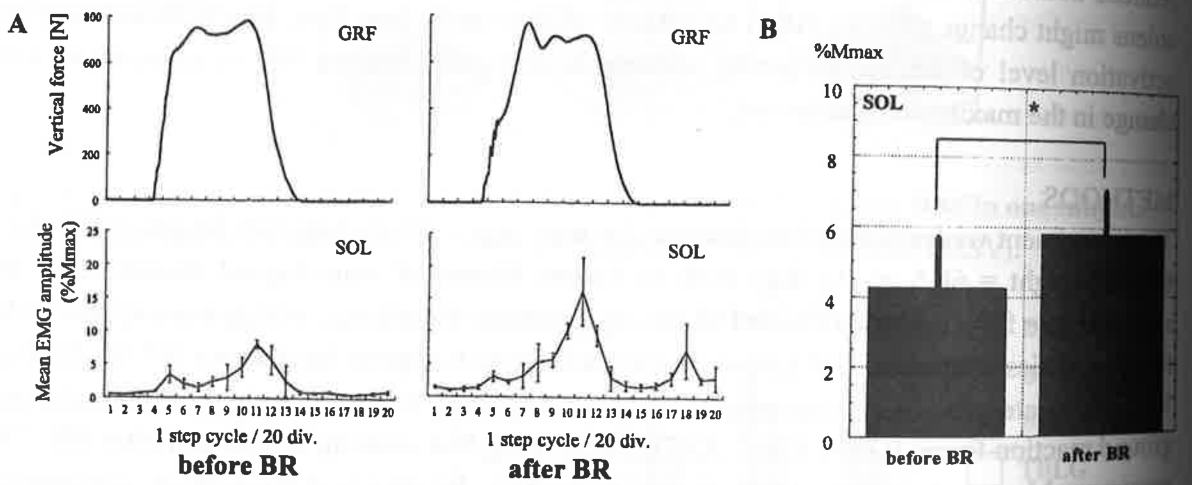

Fig.1. (A) A typical example of mean EMG and GRF profiles / cycle before and after the BR in one subject. The abscissa shows an one-step-cycle / 20 division. (B) The mean EMG (+/- S.D.) of SOL muscle during stance phase before and after BR for all subjects. *Significant difference at $P < 0.05$.

P-115

Assessment of muscle sound properties from intramuscular microstimulations

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INTRODUCTION

Soundmyogram (SMG) could represent muscle sound produced by the lateral expansion of the activated fibers that generated a pressure wave detectable at muscle surface, and therefore reflected the intrinsic mechanical activity of muscle contractions [2,4].

Our previous study [4] has demonstrated that SMG amplitude significantly increased with increasing force output during voluntary isometric muscle actions in the "fast" gastrocnemius muscle. However, in the "slow" synergist soleus muscle, these values decreased at 80% MVC. We have suggested that these different SMG characteristics were largely due to the differences of muscle fiber compositions, in other words, muscle contraction speed. The aim of this study is to actually explore the relationship between muscle sound properties and muscle contraction speed by means of intramuscular microstimulation.

METHODS

Eight motor units were studied in the medial gastrocnemius (MG) muscle of 4 healthy male subjects. The microphone sensor for SMG recordings was fixed to the center of the belly of MG. Motor units were isolated by the method of controlled intramuscular microstimulation [1]. A bipolar stimulating electrode was inserted into MG at the place just under the microphone sensor. At first, we employed single twitch stimulation to measure the mechanical properties, which included twitch contraction time (CT) and half relaxation time ($RT_{1/2}$). Then, each identified MU was stimulated at different frequencies (5, 10, 15, 20 Hz) for 8 second to observe the effects of stimulation frequency on the SMG characteristics. The DC component and linear trend of force signals were completely eliminated by digital filtering in order to investigate the relationship between force variability and SMG amplitude.

RESULTS

There is a highly significant positive correlation between the CT+$RT_{1/2}$ and SMG duration ($r = 0.91$, $p < 0.001$). Figure 1 shows typical sets of computer outputs showing SMG and DC component-removed force

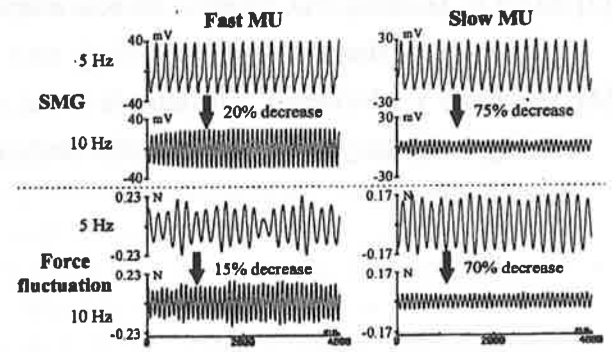

Fig.1. Typical data of computer outputs showing the oscillation of SMG (top) and force (bottom) in fast twitch (left) and slow twitch (right) fibers during 5 and 10 Hz stimulations.

curves at 5 and 10Hz stimulations. It can be noted that as stimulation rate increases, amplitude of the force and SMG oscillation decreases in parallel, and the magnitude of decline rate appears to be greater in the slow- than fast-twitch fibers.

DISCUSSION

Our experimental design allowed us to investigate the effect of the various MU types identified from contraction speed upon the SMG characteristics. From our data, it seems that the muscle sound are mainly caused by the force fluctuations. The existence of SMG oscillation in slow-twitch fiber could result in the fusion-like contractile state in which dimensional changes of activated muscle fibers may be greatly reduced. Thus, the diminution of muscle sound could easily take place in slow- compared to fast-twitch fibers. Based upon these notions, our previous observations [4], that SMG amplitude for SOL increased up to 60% MVC but decreased at 80% MVC, is due to the fact that the SOL is generally composed of 70-100% slow twitch fibers [3].

CONCLUSION

In conclusion, it appears that the SMG amplitude strongly reflects mechanical properties of contraction (contraction and half relaxation times). As a consequence the SMG can be considered as a reliable and non-invasive tool to investigate the MU contractile properties and firing rate in physiological and clinical studies.

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P-116

The Quantitative Control of The Athletic Training Intensity

Subtract

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1. Main use

Quantitatively control over the whole athletic training process is the critical sign of scientific athletic training and its key factor is to control the training intensity. Qualitative control was once practiced in China including professional sports teams. The trainers detemined only by their experience the extent to which trainees were instructed to do running, broad jump or high jump; Conversely, the intensity was defined while the percentage couldn't be set. The following research has solved this problem for the trainer both theoretically and practically.

2. theoretical Principles:

(1)Curve illustration is widely employed in producing its corresponding formula and chart of intensity control on the basis of training practice accumulation data an load intesiry control data. For example, to work out the running speed load intensity, P is designated as intensity percentage (namely energy consumption), and T the best record in training, t the formula, thus we have the following functional calculation: $P=(\frac{T}{t})^k \times 100\%$. (k=1,2,3···n). When k=1, the function is a linear one; when k=2,3···, that means respectively the second power function and the third power function. Thus the following formula can be inferred: $t=TP^{\frac{1}{k}}$. In the same way the formula for distance training conrtrol intensity progresses to be $L=LP^{-\frac{1}{k}}$; that for height $h=HP^{-\frac{1}{k}}$ (2)Provided that the power index from formulal-3 is changed to K', and formula is transformed to $K'=-\frac{1}{k}$, formula 2 or3 to $K'=\frac{1}{k}$, M is the best record an athlete sets up during a specific training period, C stands for the control intensity index, then the load intensity of any sports item can be worked out as long as there is a change in the training amount and an approproate value is assigned to K'.

3. Practical effects:

(1)In China, only Mr. Cai Guojun has reached 3/4 of the running speed and 1/2 of the intensity classification control in the formula and the chart. Martwiyerf, Soviet Union, merely attained the research of secondary control; The calculating training method created by James Gattna USA, also lacks quantitative control ofintensity. Our research, the first one to be created in China, has developed the secondary control into none-level, but is adapetd to sports items of any intensity and athletes with varying personality. (2)The formula, a combination of theory and practice, has been tested by experimentation and is flemible in its application. The calculation can not only be carried out rhrough the formula,but also be shorn by a right angle coordinate. It is for a trainer to make a quich view, too. This method can be very useful in teaching and training for both sports trainers and P. E. teachers in colleges and high schools.

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Strength training-induced changes in muscle fiber size and isometric specific strength

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INTRODUCTION

Several investigators have found a significantly greater maximal force per unit cross-sectional area (CSA) for the knee extensors in elite athletes having a long (several years) and intensive high-resistance strength training background than in normal males that have not undergone training (1,2). These studies imply that an increase in maximal strength may be due, in part, to an increased neural activation of the trained muscle. In addition, the mean fiber area of skeletal muscle is known to be related to the cross-sectional area of this muscle. Isometric force production capacity is dependent on the cross-sectional "size" of skeletal muscle. However, an increase in the maximal isometric strength per unit CSA (specific strength) of the quadriceps femoris due to short-term heavy strength training has not been clearly established. The purpose of the present study was to investigate the effect on isometric specific strength of muscle fiber size and increased neural activation during short-term strength training.

METHODS

Seven male strength athletes (MSA), nine physically active males (MPA), and ten physically active females (FPA) volunteered as subjects for the present study. All subjects were in good physical condition with no neuromuscular impairment. Seven MSA were elite body builders and power lifters who had a competitive and training background of 5-10 years in one particular sports. MPA and FPA were not athletes in any specific sports event, but rather they engaged in some form of physical training, such as jogging or weight training, approximately 1-3 times a week. An electro-mechanical dynamometer was used to measure the maximal bilateral isometric strength (MIS) of the leg extensor muscles. Electromyographic activity (EMG) during the maximal isometric testing contractions was recorded from the vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF) muscles of the right leg. Bipolar (20 mm interelectrode distance) surface EMG recording (Beckman miniature-sized skin electrodes) was employed. EMG was integrated using a separate computer system for each muscle for the maximal force phase of the isometric contraction and was expressed for 1 sec. The positions of the electrodes were marked on the skin by small ink tattoos (3). The cross-sectional areas (CSAs) of the VL and QF muscles were calculated from the picture using an ultrasound device (2). Muscle biopsy samples were taken from the VL of the right thigh both before and after training for 10 weeks using the needle biopsy technique (4). The strength training of the subjects was programmed for two separate leg exercises: 1) back squat with a loaded barbell and 2) bilateral knee extension in a sitting position using a knee extension training device. The number of repetitions in a single set varied from 1 to 12 repetitions (REPs). The loads used for both exercises varied from 70 to 100% of the one-repetition maximum. The average number of total REPs for each exercise was approximately 30 REPs per day. The exercises were performed 3 - 4 times per week.

RESULTS

The percent change in MIS was 7.8 (SE 2.4), 13.4 (SE 2.6) and 18.0 (SE 3.9)% in MSA, MPA and FPA, respectively, at week 10 of strength training. In addition, the CSA of QF in MSA, MPA and FPA increased 8.2 (SE 2.8), 13.6 (SE 3.0) and 11.8 (SE 2.0)%, respectively, after training. No statistically significant changes occurred in the averaged maximum integrated EMG (VL+ VM+ RF / 3) of all groups after training. A slight, although statistically insignificant, increase was observed in the averaged maximum integrated EMG of FPA (17.4 (SE 6.8) %) after training. The mean fiber area in MSA, MPA and FPA increased 3.3 (SE 5.6), 23.8 (SE 5.6) and 29.1 (SE 3.8), respectively, after training. The specific strength in all groups was not improved by strength training. The specific strength in MSA remained approximately 23% greater than that in MPA ($p < 0.05$) after training, but no significant differences were observed between MPA and FPA. The specific strength was significantly related to the mean fiber area of VL muscle before training ($r = 0.57$, $p < 0.01$) and after training ($r = 0.44$, $p < 0.05$). Furthermore, specific strength was significantly related to FTa fiber area in VL muscle before training ($r = 0.51$, $p < 0.01$) and after training ($r = 0.50$, $p < 0.01$).

DISCUSSION

These results indicate that 1) isometric specific strength does not change significantly during short-term strength training, 2) that there exists a pre-training status difference in isometric specific strength, but not a sex-related difference, and that 3) the size of the change in mean fiber area differs significantly between MSA and MPA ($p < 0.05$), but not between the sexes. Bottinelli et al. reported that specific strength was significantly lower in ST fibers than in FTa or FTb fibers. Therefore, the present results suggest that a pre-training status difference in isometric specific strength may be explained by differences in FTa fiber size following long-term specific strength training.

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P-118

The Effect of Initial Graft Tension On Mechanical Behaviors of the Femur-Graft-Tibia Complex During Submaximal Cyclic Loading is Different Between Bone-Tendon-Bone and Flexor Tendon Grafts.

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Introduction

The graft after anterior cruciate ligament (ACL) reconstruction is inevitably exposed to submaximal repetitive loads in the early rehabilitation phase. Our pervious studies have demonstrated that submaximal cyclic loading significantly changes biomechanical properties of the femur- graft- tibia (FGT) complex after ACL reconstruction under a constant initial graft tension
. However, orthopaedic surgeons commonly apply various degrees of initial graft tension during ACL reconstruction. Therefore, we should clarify the effect of the initial graft tension on mechanical characteristics of the FGT complexes during and after cyclic submaximal loading. No studies, however, have dealt with this issue. The purpose of this study is to compare the effect of initial graft tension on biomechanical behavior of the FGT complex with ACL reconstruction during and after submaximal cyclic loading between the bone- patella tendon- bone (BTB) and doubled flexor tendon (FT) grafts.

Materials and Methods:

Based on our previous biomechanical study, a porcine ACL reconstruction model was used in this study. In this model, the BTB and flexor digitorum profundus tendon grafts harvested from the fully matured LWD pigs were used as substitutes for the human BTB and hamstring tendon grafts, respectively. A pair of flexor tendons was trimmed so that the cross-sectional area became 14 and 7 mm^2, respectively. Twenty porcine knees were randomly divided into four groups of five specimens each. For each group, after the ACL was resected, ACL reconstruction was performed with one of two procedures. The femoral and tibial tunnels were drilled through the anatomical insertions of the ACL. The diameter of the tunnels was matched to the graft diameter in each knee. In the first and second groups (Groups B20 and B80), each end of the BTB graft (10 mm wide) was secured without any graft tension using an interference screw (Kurosaka screw, Depuy Inc.) having a diameter of 9 mm and a length of 25 mm. In the third and fourth groups (Groups F20 and F80), a pair of the flexor tendons was doubled and each end of the tendons was tethered without any initial graft tension using 4 Tevdek sutures (#2) to a plastic button. The FGT complex was attached to a tensile tester at 45 degrees of knee flexion so that the femur and the tibia were positioned to allow tensile loading aligned with the long axis of the bone tunnel. Then, a tensile load of 20 N was applied to the graft for 2 minutes as an initial graft tension in Groups B20 and F20, while a tensile load of 80 N was applied to the graft for 2 minutes in Groups B80 and F80. After preconditioning, submaximal cyclic tensile loads of 5000 cycles were applied to the FGT complex at the same speed (0.2 Hz) so that the graft was stretched by 2 mm. Tensile loads during cyclic testing were recorded throughout the experiment. Then, tensile failure tests of FGT complexes were performed at a cross-head speed of 50 mm/min. Statistical comparison was made using the two-way ANOVA with the Bonferroni test for post-hoc multiple comparisons.

Results:

1) For the BTB graft fixed with interference screws, an increase of initial graft tension from 20 N to 80 N increased the average peak load from 135 N to 278 N and the average valley load from 9 N to 42 N at the 1st cycle. For the FT graft fixed with sutures, an increase of initial graft tension from 20 N to 80 N increased the peak load from 68 N to 123 N and the valley load from 4 N to 16 N at the 1st cycle. There were significant differences in each parameter between the two grafts. 2) For each FGT complex, the peak and valley loads decreased rapidly in the early phase and slowly in the late phase during cyclic loading under each initial tension. 3) For the BTB graft, the increase of initial graft tension increased both the peak and valley loads to the approximately same degree at each cycle throughout the experimental period. The peak and valley loads at the 5000th cycle were 92 N and 0 N, respectively, in Group B20, while 184 N and 17 N, respectively, in Group B80. 4) For the FT graft, there were no significant differences in the peak and valley loads between Groups F20 and F80 after the 1000th cycle. The peak and valley loads at 5000th cycle were approximately 30 N and 0 N, respectively, in each group. 5) The initial graft tension did not significantly affect the linear stiffness or the ultimate failure load of each FGT complex after cyclic loading in each group. Linear stiffness and ultimate failure load in Groups B20 and B80 were significantly higher than those in Groups F20 and F80.

Discussion

The mechanical conditions in this study simulated those in continuous passive motion exercise for the knees during approximately 2 weeks after ACL reconstruction. For the BTB graft fixed with interference screws, an increase in initial graft tension of 60 N significantly increased the peak and valley loads even at the 5000th cycle. For the FT graft secured with sutures, however, the effect of the increase in initial graft tension on the peak and valley loads disappeared by the 1000th cycle. This study demonstrated that the effect of initial graft tension on biomechanical behavior of the FGT complex with ACL reconstruction during and after submaximal cyclic loading is significantly different between the BTB graft fixed with interference screws and the FT graft secured with sutures. However, an increase of initial graft tension of 60 N did not significantly affect the biomechanical properties of the FGT complex with each graft in failure tests.
As to clinical relevance, when surgeons determine the initial graft tension in ACL reconstruction using the BTB graft and interference screws, they should take it into consideration that the effect of an increase in initial graft tension on the peak and valley loads continuous for a relatively long period, because excessively high tension may give adverse effects to remodeling of the graft. In addition, when surgeons use the FT graft in ACL reconstruction, they should recognize that graft tension applied intraoperatively decreases rapidly in the early rehabilitation phase. Initial graft tension of 20 N may be too low because not only the valley load but also peak load become close to zero immediately after surgery.

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Electromyographic Analysis of Trunk Muscle in College Golfers with or without Low Back Pain

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INTRODUCTION

The low back pain (LBP) occupied the majority in golfing injuries. However, there are no studies made a comparison between EMG activity of trunk muscle in golfers with or without the low back pain. So we evaluated trunk muscle activity in college golfers.

MATERIALS AND METHODS

Sixteen (6 subjects with LBP and 10 healthy subjects) right-handed college male golfers underwent EMG activity amplitude evaluation using surface electrode telemetry of the following trunk muscles: upper rectus abdominis, lower rectus abdominis, obliquus externus abdominis, erector spinae. The golf swing was divided into three phases: the first phase; ball address to the completion of the backswing motion, the second phase; the completion of the backswing motion to ball contact, the third phase; ball contact to the completion of the swing.

RESULTS

In the subjects with LBP, EMG activity in the lower rectus abdominis and left obliquus externus abdominis in the third phase was significant lower than that in healthy subjects ($p<0.05$). In the subjects with LBP, EMG activity in the erector spinae in all phase was significant higher than that in healthy subjects ($p<0.05$).

DISCUSSION

In the third phase, the decrease in EMG activity in the lower rectus abdominis and left obliquus externus abdominis was observed in subjects with LBP. Watkins et al. proposed that the importance of the left obliquus externus abdominis muscles during the follow-through periods suggests their role in decelerating the trunk after the swing. We consider that the golf swing in the golfer with LBP increase the burden on low back. In all phase, the increase in EMG activity in the erector spinae was shown in subjects with LBP. Shirado et al. described EMG activity in the back muscle was high in the patients with LBP at any time. The same can be said with our study.

CONCLUSION

We made a comparison between EMG activity of trunk muscle during the swing in college golfers with or without LBP. In EMG activity in subjects with LBP, the decrease in the lower rectus abdominis and left obliquus externus abdominis and the increase in the erector spinae were observed. This study suggests that the golf swing in golfers with LBP increase the burden on low back.

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P-120

In vivo dynamics of muscle-tendon complex during stretch-shortening cycle exercise

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Introduction

The stretch-shortening cycle (SSC) is a natural component of muscle function in many daily activities, such as running, jumping and throwing. The dynamics of muscle-tendon complex (MTC) during SSC exercises have been so far evaluated from joint actions, because the behavior of a muscle during contraction in humans cannot be directly observed. Recently, real-time ultrasonography enables in vivo muscle scanning and offers promise for a realistic determination of changes in muscle architecture (e.g. Fukunaga et al. 1997). The purpose of this study was to investigate the behaviors of fascicles and tendon structures during SSC exercises in humans.

Methods

Seven healthy males (24.7 ± 1.6 yrs, 168.6 ± 2.8 cm, 68.5 ± 9.8 kg; mean ± SD) participated as subjects. They performed to down their heels (dorsi-flexion; DF) from a toe-standing position (ankle joint angle; 120 °) and immediately performed to raise heels (plantar-flexion; PF) until a toe-standing position at two different frequencies (SLW; 0.3 Hz, FST; 1.0 Hz). The SLW and FST exercises were performed on a force platform (Kistler). In SLW, the vertical reaction force did not change significantly during exercise. In FST, the vertical reaction force was about 1.5 times of body weight at the changing phase from DF to PF (ankle joint angle; 90 °).

The ultrasonic apparatus (SSD-2000, Aloka, Japan) was used to obtain a longitudinal ultrasonic image of the medial gastrocnemius muscle (MG) at the proximal level 30% of lower leg length. The ultrasonic images were recorded on a video tape at 30 Hz, synchronized with recordings of a clock timer for subsequent analysis. Measurements of fascicle length (L_F) and fascicle angle (A_F) were performed on-line using a dedicated of software (DIG-98, DITECT, Japan). The MTC and tendon length of MG (L_{MTC} and L_T) was calculated from the formula proposed by Grieve et al. (1978). Electromyographic (EMG) activity was recorded from MG by means of bipolar surface electrodes. Kinetic and kinematic data were obtained using electrogoniometers and force plate.

Results

The L_{MTC}, L_F and L_T were lengthened at DF and shortened at PF, respectively (Figure 1). In SLW the changes in length (i.e. increaing during DF and decreasing during PF) were basically in phase for both fascicle and tendon structures, with constant values of mEMG levels. In FST no significant changes in fascicle were observed at the first half of PF (90 ° to 105 °), even if abrupt shortening of tendon structures, with this being accompanied by a rise in mEMG levels.

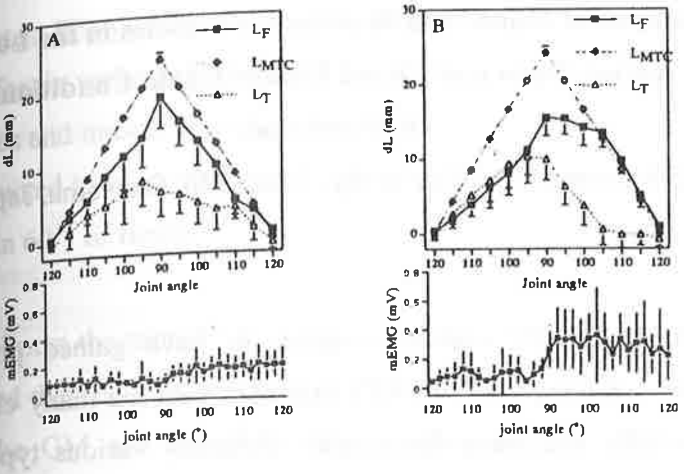

Figure 1
The changes in the L_F, L_{MTC}, L_T and mEMG during SLW (A) and FST (B) exercises.

Furthermore, the L_F at the changing phase from DF to PF was significantly shorter in FST (54.4 ± 5.5 mm) than in SLW (58.2 ± 5.4 mm).

Discussion

The major finding of this study was that the L_F at the same joint angle was longer at PF than at DF in FST. These interesting finding might be caused by the differences in the shortening velocities of fascicle and tendon structures. Bobbert et al. (1986) stated that without a compliant tendon triceps surae muscles would not have been able to meet the requirement of combining a high angular velocity of plantar flexion with a large plantar flexion moment during jumping. Furthermore, the previous studies using animals showed that the shortening velocity was lower in muscle fiber than in whole muscle during isokinetic contraction due to more compliant aponeurosis (Lieber et al. 1992). In the present study, the rapid shortening of tendon structures controlled to lower V_F in the first stage of PF in FST. In other words, the fascicles would showed nearly "isometric contraction", which have a benefit from more advantageous force-velocity properties of the working muscles. The present results suggest that tendon structures are influenced so much for the dynamics of MTC during SSC, thus the dynamics of MTC had been made considerable efficiently.

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P-121

Activation Patterns of Mono- and Bi-articular Muscles in the Lower Extremity during Open and Closed Kinetic Chain Conditions

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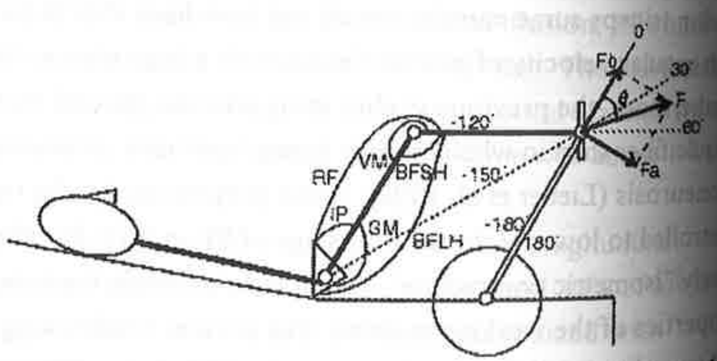
INTRODUCTION

"Closed kinetic chain" (CKC) exercises appear to have gained popularity over more traditionally used open kinetic chain (OKC) exercises because many clinicians believe that CKC exercises are safer and more functional. Recently various types of CKC exercise method have been developed[1]. But little information is available on the definition of CKC. This study was conducted upon the hypothesis that the co-activation of the quadriceps and the hamstrings during CKC exercise is explained by the coordination of mono- and bi-articular muscles in the lower extremity, with its activation patterns decided by force direction.

MATERIALS AND METHODS

Eight healthy young male subjects aged 21 to 22 years (21.0 ± 0.5) were tested. Muscles tested were; gluteus maximus (GM) and iliopsoas (IP), vastus medialis (VM) and biceps femoris short head (BFSH), rectus femolis (RF) and biceps femoris long head (BFLH) (Fig.). The CYBEX 6000 isokinetic dynamometer was used. Subjects were positioned supine on the testing bench with the backrest fixed at 15° from horizontal. A custom made foot plate and load cell was attached to the tip of the dynamometer arm. Angle referencing was performed by placing the knee in 60° of flexion with the dynamometer arm 60° from horizontal (Fig.). The isometric force at right angles to the axis force generated by the right lower extremity (Fa) was measured by the CYBEX 6000. The load cell measured the axis force (Fb). The actual force (F) was calculated from the two component forces. Forces were normalized to the greatest value for each subject. The EMG activity from six muscles was recorded during isometric leg press and pull movements in all directions (360°) around the center of the foot, with maximal effort in the sagittal plane. EMG data were acquired with surface electrodes on GM, VM, RF and BFLH, and with fine wire electrodes on IP and BFSH. Those were integrated and



normalized to the greatest IEMG value for each subject. Each subject was instructed to exert maximal voluntary effort in various directions.

To quantify knee forces and muscle activity in CKC (leg press) and OKC (knee extension), each subject was instructed to exert maximal voluntary effort in knee extension in the OKC setting with the knee in 60° of flexion.

RESULTS

All subjects showed almost the same EMG patterns during CKC Conditions, whereby the RF and the BFLH reversed their activity levels in the ranges between 30° and 60° and between -120° and -150°, the GM and the IP muscle, in the ranges between 0° and 30° and between -150° and -180°, and the VM and the BFSH, in the ranges between 60° and 90° and between -90° and -120°. Thus, two pairs of the antagonistic mono-articular muscles as well as the pair of bi-articular muscles showed criss-cross activity patterns in each pair of the opposing ranges. In the other ranges than the opposing pair of ranges where the criss-cross patterns appeared, one muscle of the antagonistic pair of mono- as well as the bi-articular muscles showed full activity level and the other antagonist of the pair showed almost nothing. The pressing force was largest when the force was directed from hip joint to the center of the foot (30°). At this direction only quadriceps (RF and VM) were activated. Co-activation of quadriceps and hamstrings were observed in the range between 30° and 60°. OKC exercises produced more rectus femoris activity while CKC exercises produced more vasti muscle activity.

DISCUSSION

Steindler described that a CKC is one in which the terminal joint meets with some considerable external resistance which prohibits or restrains its free motion[2]. According to these results, when the maximal pressing force exists in the range between hip to foot direction and knee to foot direction, co-activation of quadriceps and hamstrings occur and the force is greatest. By controlling the force direction, it will be possible to control muscle activation patterns. An understanding of these results can help in selecting appropriate exercises for knee rehabilitation and training.

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P-122

Pelvic movement pattern during squatting

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INTRODUCTION

We often observe patients with hip joint less mobile tended to have their lumbar spine hyper-mobile. For example most of the patients with hernia of lumbar intervertebral disc showed hyper-flexion mobility at their lumbar region, whereas hip joints limited toward flexion. It can be assumed that pelvic movement greatly influences to the hip and lumbar movement. The purpose of this study was to verify the basic behavior of the pelvis during squatting.

METHODS

Thirty-two healthy subjects volunteered in this study. The subjects were asked to make full squat from standing without their heels off. Segmental movements of the body were detected by a three-dimensional motion analysis system [VICON370, Oxfordmetrics-NAC] and two forceplates [Kistlar]. The squatting movement started from standing position followed by full squatting and ended to standing again. We defined the first half of the movement, i.e. from standing to full squat as descending phase and the second half, i.e. from full squat to standing as ascending phase. After measuring, pelvic and hip movements were normalized by the time spending for each squatting. We simultaneously recorded lumbar movement in five subjects in this study. Their lumbar movements were analyzed by other motion analysis system of the spine.[CMS70P, Zebris].

RESULTS

Behaviors of the pelvic tilt were characteristically common to all subjects. Each phase has one peaked wave. Namely it starts with anterior tilt of pelvis and followed by posterior tilt. So that, there were double pelvic actions in one squatting movement. And at the moment of full squat, pelvis showed posterior tilt. (Fig.1)

On the contrary, lumbar kept flexing during squatting and it showed maximally flexed at full descending.

DISCUSSION

We assumed that this double pelvic action was attributed to the way of squatting without heels off. Normally subjects must correspond their center of gravity to the center of foot

pressure during the squat. At the time of full squat position, they were obliged to put the center of gravity out of the balls of their feet. Actually they moved the center of gravity more forward during descending phase in order to get rid of falling back.

We investigated the relationship of pelvic tilt and joint moments before. And we found that the angle of the pelvic tilt was significantly correlated with the difference between hip and knee extension moments throughout the squatting. The larger the difference, the more the pelvic tilted anteriorly. Namely, the angle of pelvic tilt changed consistently with the hip and knee extension moments during squatting.

CONCLUTION

Thirty-two healthy subjects were analyzed their pelvic movement during full squatting without their heels off and also detected their lumbar movement in five subjects.

There were double pelvic actions in one squat we defined. Also at the moment of full squat, pelvis showed posterior tilt.

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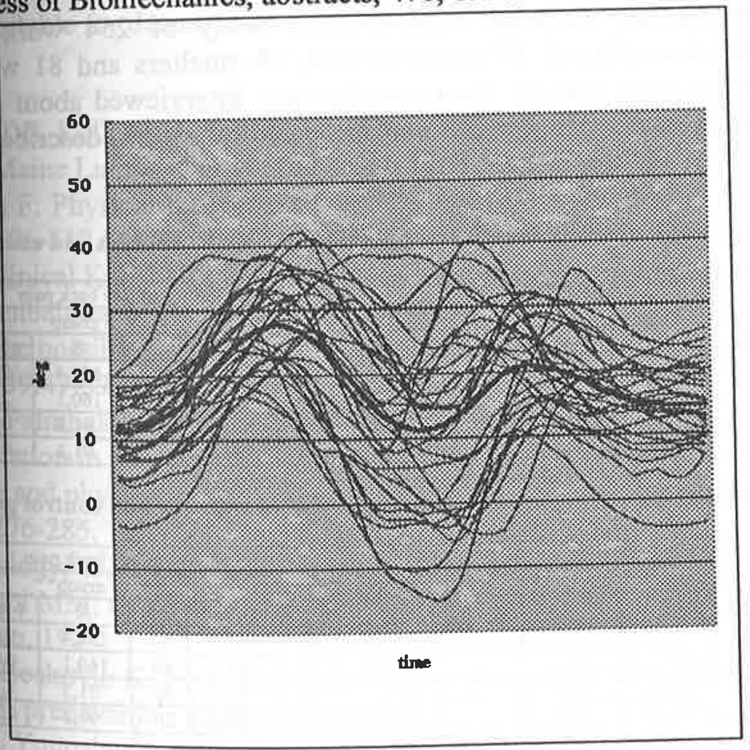

Fig.1 Angle of anterior tilt during squatting.

P-123

The lenght of hamstring muscles of workers with different proffesional loading

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INTRODUCTION: In the case of hamstring muscles shortening active flexion of the trunk is not folloved by movement of the pelvis and consecutive loading of the lumbosacral juncture takes place (Wels, 1962). This biomechanical explanation supports clinical assumption that hamstring muscles shortening contributes to the onset of the low back pain (Calliet, 1977). In addition, muscle shortening appears as the consequence of low back pain. By disturbing normal biomechanics of the body it prevents the person from keeping the ergonomic principles in activities of daily living and professional work (Biering-Sorensen, 1984). This provokes the aggravation of low back pain. The lenght of the muscles can be measured by the two methods. First, the flexion movement of extended lower extremity in the hip joint, in supine position , "hip flexion" method (HFL). Second, the measurement of the range of calf extension in the knee joint flexed at 90^0 , "knee extension" method (KEXT). On the basis of kinesiologic analysis it seems that both methods would give approximately the same ranges of mivement (Brunnstrom, 1962; White, 1978). But, during our practical work with low back pain patients, for whome we measured the hamstring muscles lenght (HML) using both methods, we noticed that measured values often do not coincide. We decided to compare evaluating value of the two methods of muscle lenght measurement by investigating persons with different occupations. We escepcially paied attention to hamstring muscles lenght in person with and without report of previous low back pain.

METHODS: The investigation covered a prospective study of 254 workers with different proffesional loading. We investigated 95 metalworkers, 78 smelters and 81 worker as a control group in respect to professional loading. Every worker was interviewed about any history of low back pain. The lenght of the hamstring muscles was measured by the two described methods.

RESULTS:

Table 1. Comparative analysis of hamstring muscles lenght (HML) of metalworkers and control group

without history of low back pain							with history of low back pain						
HML	metalwork.		control gruop				HML	metalwork.		control gruop			
	N	X	N	X	t-test	p<0,05		N	X	N	X	t-test	p<0,05
KEXT	40	144,2	31	146,4	0,6	-	KEXT	55	148,7	50	158,4	2,9	+
KEXT	40	147,3	31	150,1	0,8	-	KEXT	55	151,1	50	160,1	2,9	+
HFL	40	98,1	31	96,7	0,5	-	HFL	55	91,8	50	91,3	0,5	-
HFL	40	98,0	31	96,7	0,3	-	HFL	55	91,4	50	91,3	0,2	-

Table 2. Comparative analysis of hamstring muscles lenght (HML) of smelters and control group

without history of low back pain							with history of low back pain						
HML	smelters		control gruop				HML	smelters		control gruop			
	N	X	N	X	t-test	p<0,05		N	X	N	X	t-test	p<0,05
KEXT	48	149,3	31	146,4	0,7	-	KEXT	30	161,7	50	158,4	0,8	-
KEXT	48	151,0	31	150,1	0,2	-	KEXT	30	163,7	50	160,1	0,9	-
HFL	48	99,2	31	96,7	0,9	-	HFL	30	93,0	50	91,3	1,1	-
HFL	48	99,2	31	96,7	0,9	-	HFL	30	91,5	50	91,3	0,2	-

DISCUSSION: Using the methods of hamstring muscle lenght measurement we obtained different avarage values of hip and knee range of movement. The difference is statistically significant. This indicates that the degree of the measured muscle shortening can be related to the used measuring method. The lenght of hamstring muscles was significantly shorter when the "knee extension" method was used. Professional tasks of metalworkers who had no history of low back pain contribute to hamstring muscles shortening, but this shortening is of mild degree and can be established by the "knee extension" method only. Irrespective of the method used in the smelters group no correlation of proffesional work and muscle shortening was observed. In workers with history of low back pain the shortening of hamstring muscles was revealed by "hip flexion" and "knee extension" methods. In metalworkwrs group it was found that muscle shortening connected with low back pain increased the shortening coused by professional factors. However, the overall shortening of hamstring muscles in metalworkers with low back pain was not greater than in case of workers of other professions, where professional factors had no influence on the muscle lenght (smelters).

CONCLUSION: The degree of hamstring muscles shortening can be correlated to the measuring method. "Hip flexion" method can be considered to be more exact as it reflects the maximum lenght which hamstring muscles can reach in passive movement. "Knee extension" method revealed lower average range of movement compared to "hip flexion" test. "Knee extension" method may be considered of higher diagnostic sensitivity which makes the method more suitable for the diagnosis of hamstring muscles shortening in workers with certain profession, like metalworkers. Higher diagnostic sensitivity of this method can be explained by dynamic stretch of the distal partof the two joint muscles only, whichactivates the muscle and tendon afferents in a different way comparedto simultaneous dynamic stretch of both ands of the muscle, as in the hip flexion test.
Both methods are suitable for detection of hamstring muscles shortening in connection with the low back pain.

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P-124

Stretch reflex sensitivity in human elbow and ankle muscles – implication for role of stretch reflex during quiet standing –

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Introduction

In humans and other animals, stretch reflex has the important role in maintaining muscle tone. The tonic muscular contractions are typically observed in those muscles, so-called "anti-gravity" muscles during quiet standing. Stretch reflex sensitivity in the anti-gravity muscles, therefore, is assumed to be higher than in flexors or upper limb muscles. Little is known, however, as for the standardized stretch reflex sensitivity in different human muscles. In the present study we assess the stretch reflex sensitivity from relation between the input joint rotational velocity and the output stretch reflex EMG response in upper arm and lower leg muscles.

Methods

Subjects were ten neurologically normal males. Their right elbow and ankle muscles were tested. Stretch reflex EMG responses were recorded from the following eight muscles, i.e., the biceps brachii, the brachioradialis, the triceps brachii long head, the triceps brachii medial head, the soleus, the medial gastrocnemius, the lateral gastrocnemius, the tibialis anterior. Specially designed torque motors were used to apply various velocities (50-400 deg/s) of ramp and hold rotations (RHR) to the elbow or ankle joint. The RHRs were given at rest and during weak muscle contraction (9% of maximum voluntary contraction). EMG activities were recorded by using surface electrodes (Ag/AgCl, diameter = 5 mm) with an interelectrode distance of 15mm. The stretch reflex EMG activities elicited were divided into the short- (M1) and long-latency (M2) components, and relation between the RHR velocity and magnitude of each reflex component was analyzed with the minimum least square method. From the linear regression equation fitted to those data (Fig 1), the predicted stretch response value (SR@300) at the given input was obtained as the measure for the reflex sensitivity.

Results

Fig 2 demonstrates group means (+ s.e.) for the SR@300 of both reflex components in each muscle. There was a general tendency that M1 responses are dominant in the ankle extensors, while M2 responses are dominant in the elbow flexors, extensors and the tibialis anterior, when the M1 and M2 responses are compared. Overall, the stretch reflex responses in the soleus were markedly greater than the other muscles. Even the M2, which is not dominant component in the soleus, was comparable to those in the arm muscles.

Discussion

The results in the present study revealed that the reflex response to the standardized joint stretch stimuli in the soleus was markedly greater than the other muscles. It has been known that in the elbow muscles, the long latency component, M2 is dominant, while the short latency M1 is dominant in the ankle extensor muscles. This pattern was basically preserved in our results. To our surprise, however, the level of even M2 in the soleus was comparable to those in the elbow muscles. This greater stretch reflex sensitivity in the soleus is considered to match the functional requirement of this muscle, although it is generally accepted that the stretch reflex action is not utilized or at least suppressed during human quiet standing. Together with the result in our accompanying paper (Masani et al. in this congress) it is suggested that the higher reflex sensitivity in the soleus is necessary to maintain a certain level of tonic activity, which increases stiffness around the ankle joint during quiet standing.

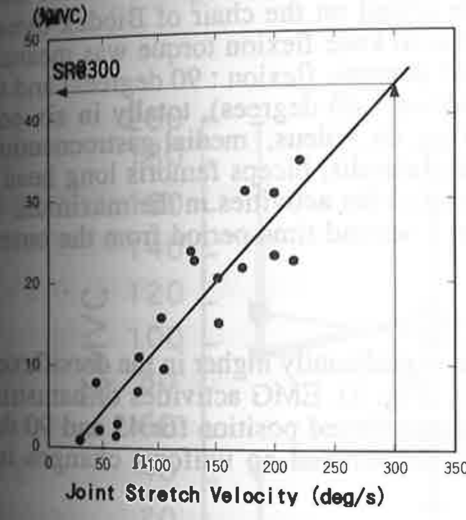

Fig 1 A typical example for the relation between the joint stretch velocity and reflex response, and the SR@300 derived from the linear regression line.

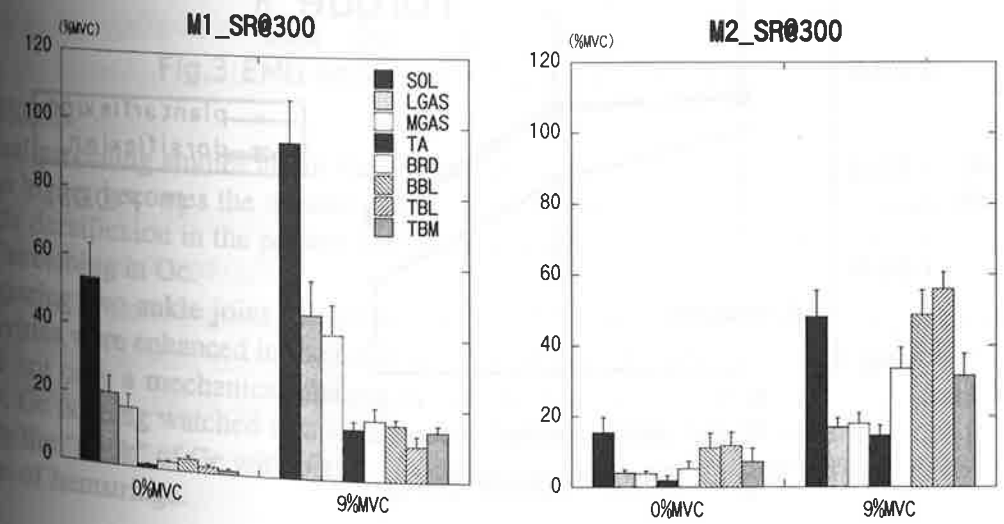

Fig 2 Comparisons of the SR@300 among all muscles investigated.

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Isometric Knee Flexion is Reinforced in the Dorsiflexed Ankle Position through the Function of Biarticular Gastrocnemius

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INTRODUCTION

Considering their significant mass and substantial moment arm about the knee joint, gastrocnemius muscles (Gc) can be strong knee flexors. In virtue of their biarticulality, not only the angle of knee joint, but also the condition of ankle joint may affect the tension of Gc through the change of muscle length. From these points of view, Gc contribution on the knee flexion can be evaluated by the analysis of generated knee joint torque and muscle activities in relation to the change of ankle joint position. The purpose of this study was thus to investigate the mechanical effect of Gc length on the knee flexion torque and its possible neural influence on the activities of knee flexors in the thigh.

METHODS

Ten male subjects (174.8±6.8cm, 70.8±14.2kg, 20.2±1.7yr) conducted isometric knee flexion in various knee and ankle positions. Subjects were seated on the chair of Biodex dynamometer with the upper body and thighs fixed firmly. Maximum knee flexion torque was measured about three knee joint angles (full extension : 0 degrees, 45 degrees, flexion : 90 degrees) and two ankle joint angles (dorsiflexion : 90 degrees, plantar flexion : 60 degrees), totally in six conditions. Surface EMGs were recorded from seven leg muscles, i.e. soleus, medial gastrocnemius (GcM), lateral gastrocnemius (GcL), tibialis anterior, vastus lateralis, biceps femoris long head (Bf) and medial hamstrings (Mh). The EMGs were normalized to the activities in the maximum voluntary contraction (MVC) . Analyses were made about the 1 second time period from the onset of knee flexion torque.

RESULTS

The maximum torque in isometric knee flexion was significantly higher in the dorsiflexed than in the plantarflexed ankle position for each knee angle (Fig. 1). EMG activities of hamstrings were significantly higher in the dorsiflexed than in the plantarflexed position for 45 and 90 degrees of the knee joint angles (Fig. 2). On the other hand, Gc showed no uniform changes in muscle activities according to joint angles (Fig. 3).

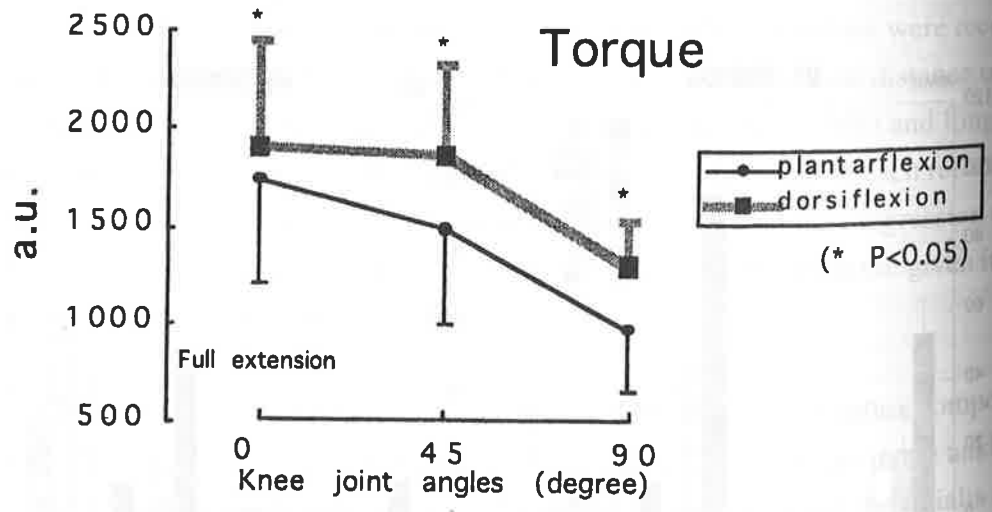

Fig.1 Knee flexion torque

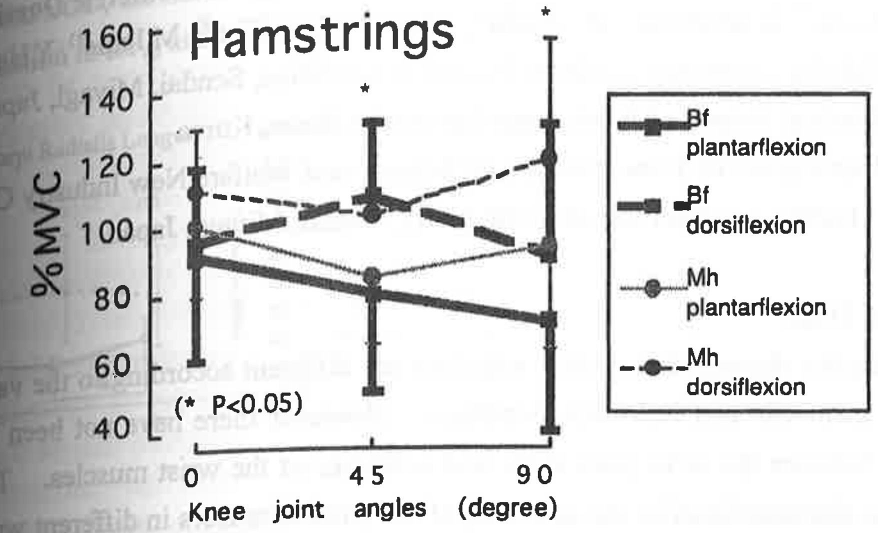

Fig.2 EMG activities of hamstrings

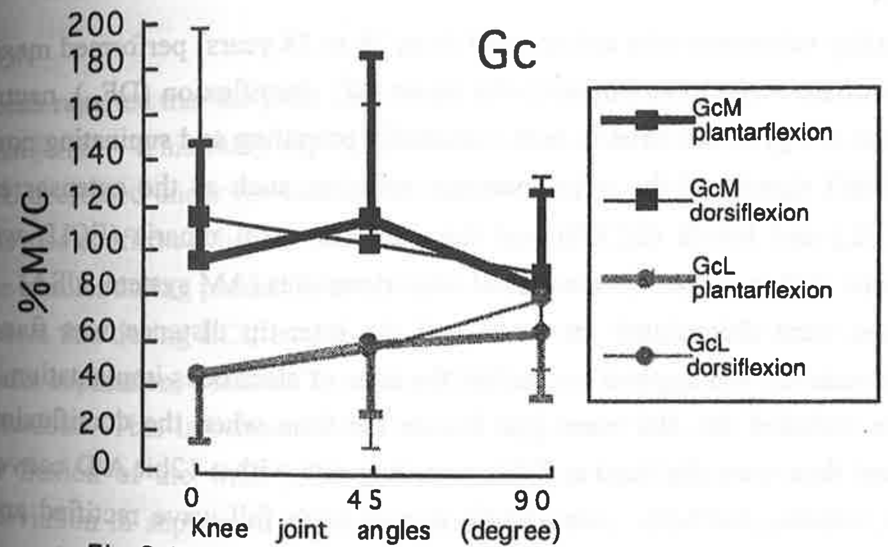

Fig.3 EMG activities of gastrocnemius

DISCUSSION

Several preceding studies about the ankle plantar flexion have shown that the more elongated Gc is, the higher becomes the tension of Gc. The significant augmentation of knee flexion torque with ankle dorsiflexion in the present study seemed to have been caused firstly by the mechanical effect of stretching in Gc.

Comparing two ankle joint conditions, although there is no apparent changes on hamstrings, their activities were enhanced in the dorsiflexed position. This result suggest that the ankle position produces not only a mechanical change in Gc but also certain neural effect in the hamustrings. Recently, Gc is being watched as a stabilizer of the knee joint. A decline of the knee joint stability caused by the "slack" of Gc with plantar flexed ankle can be an explanation of the inhibition to the activation of hamstrings.

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EMG Activities of the Wrist Extensors under Maximum Isometric Dorsiflexion

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INTRODUCTION

Some studies showed that muscle activities are different according to the values of joint angle under isometric and isokinetic condition. However there have not been reported the relationship between the wrist joint angle and activities of the wrist muscles. Therefore we examined the characteristics of the activities of the wrist extensors in different wrist positions under two forearm positions, supination and pronation by analyzing EMG signals of normal subjects under isometric condition.

METHODS

Six healthy volunteers (six males, aged from 28 to 38 years) performed maximum active dorsiflexion of the wrist joint isometrically under 40° dorsiflexion (DF_{40}), neutral and 40° palmar flexion (PF_{40}) of the wrist in both maximally pronating and supinating positions of the forearm. EMG signals of the wrist extensor muscles, such as the extensor carpi radialis longus (ECRL) and brevis (ECRB) and the extensor carpi ulnaris (ECU) were detected through bipolar Teflon-coated stainless steel wire electrodes (AM system, USA). The tips of the electrodes were deinsulated for 2mm and the inter-tip distance was fixed at 5 mm. Electrical stimulation was applied to confirm the sites of electrodes implantation. The EMG signals were recorded for 500 msec just before the time when the dorsiflexion force was maximum and then were digitized at 2kHz sampling rate with a 12bit A/D converter (AD12-16U(98)EH, Contec, JAPAN). Also EMG signals were full-wave rectified and integrated (IEMG). IEMG values of the wrist muscles were normalized with the values in 40° wrist dorsiflexion under maximum foerarm supination.

RESULTS

In supination of the forearm, the normalized IEMG values of ECRL and ECRB during maximum active wrist dorsiflexion were significantly larger in PF_{40} than in neutral ($P<0.05$). In contrast, those of ECU were significantly smaller in PF_{40} than in neutral ($P<0.05$). In pronation, there was no significant difference among the normalized IEMG values of these muscles in any wrist positions. The normalized IEMG values of ECRL and ECRB were significantly lager in forearm pronation than in supination in every wrist positions($P<0.05$).

With respect to ECU, the normalized IEMG values in supination were significantly lager than those in pronation in DF_{40} and neutral ($P<0.05$) (Figure 1).

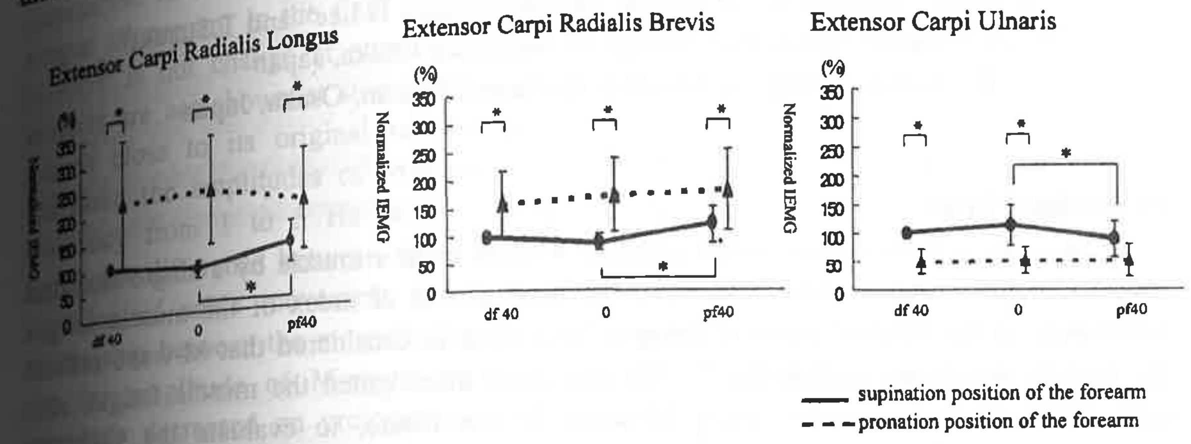

Figure 1 IEMG values from the extensor carpi radialis longus, extensor carpi radialis brevis and extensor carpi ulnaris under maximum isometric voluntary wrist dorsiflexion (n=6, ＊:$P<0.05$)

DISCUSSION

It has been reported that the joint angle may affect activities of the muscles which act as movers of that joint. This study showed that activities of ECRB and ECRL increased while those of ECU decreased under forearm supination when the wrist dorsiflexed from neutral to PF_{40}. It was also confirmed that IEMG values of the ECRB and ECRL were larger and those of ECU were smaller during pronation as compared with supination in any wrist positions.

It is known that during ECU acts as a dorsiflexor rather than an ulnar flexor of the wrist joint in forearm supination, while ECU mainly affects ulnar deviation of the wrist joint during forearm pronation. This is because ECU has a longer moment arm relative to the axis of dorsopalmar flexion of the wrist joint and a shorter moment arm relative to the axis of radioulnar deviation in supination as compared with in pronation[1)]. In addition, the above mentioned phenomena may be also supported from our EMG data that ECU activity was larger in supination than in pronation during maximum wrist dorsiflexion under isometric condition.

Thus, it is likely that the roll of three muscles, ECRL, ECRB and ECU, differs in either different wrist angles or different forearm positions. This may be due to mechanical factors such as length and tension of the muscle and/or joint positions.

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P-127

Relationship between the M-wave Amplitude and the Joint Movement during Repetitive Stimulation – Study in the Tibialis Anterior Muscle –

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INTRODUCTION

M-wave is a compound action potential evoked from a muscle by a single electrical stimulation to its motor nerve[1]. M-wave has used as one of index of the muscle fatigue assessment in the field of physical therapy, because it is considered that M-wave reflects the muscle membrane excitability[2,3]. We also have investigated the muscle fatigue after task of isometric contraction using M-wave. In the future, to evaluate the voluntary movement using M-wave, we need to record many data during voluntary movement and we have to investigate the influence for M-wave during the movement by twitch due to electrical stimulation to evoke M-wave. Therefore, to clarify the relationship between the amplitude of M-wave and the joint movement occurred by twitch due to electrical stimulation to evoke M-wave, we compared the amplitudes of M-wave from the tibialis anterior muscle in the different conditions with or without joint movement study.

METHODS

The subjects were 8 males with a mean age of 24.6 ± 3.0 (19~28) years and a mean height of 170.9 ± 5.1 (163~180) cm. The subjects were fixed the knee joint at slightly flexed position in the sitting. M-wave was recorded from the tibialis anterior muscle after stimulation of the deep peroneal nerve at the just below head of the fibula. And M-wave was recorded under "free condition" and "fixed condition." The "free condition" is not to fix and the other "fixed condition" is to hold on subject's ankle joint at slightly plantar flexed position as the same angle as free condition using the belt and a plate and we fixed ankle and toes movement occurred by twitch due to electrical stimulation. The stimulating conditions were as follows: intensity of supra-maximum, duration of 0.2 ms, frequency of 1, 2, 3, 4, and 5 Hz, and number of 10 times, respectively. A recording electrode was placed on the tibialis anterior muscle and a reference electrode was put on the lateral malleolus of fibula. We set up the band pass filter from 20 Hz to 2 kHz. We analyzed the peak to peak amplitude of M-wave. And we compared with the amplitudes of M-wave under free condition and fixed condition of ankle movement in the same condition of stimulus frequency.

RESULTS

There was no significant difference between the amplitudes of M-wave under free condition and fixed condition of ankle movement in all the stimulus frequency from 1 to 5 Hz.

DISCUSSION and CONCLUSION

M-wave is a compound action potential evoked from a muscle by a single electrical stimulation to its motor nerve[1]. And M-wave has used as one of index of the muscle fatigue assessment in the field of physical therapy[2,3]. It has report that the amplitude of M-wave is not change at stimulus frequency from 1 to 5 Hz, because the movement artifacts are not shown at stimulus frequency from 1 to 5 Hz. As the reason, the muscle returns close to its original relaxed position until the next stimulus.[1] Therefore, we compared the amplitudes of M-wave in fixed condition and free condition at stimulus frequency from 1 to 5 Hz in this study. As the result of this study, there was no significant difference between the amplitudes of M-wave under free condition and fixed condition of ankle movement in all stimulus frequency from 1 to 5 Hz. About the relationship between the muscular length and the amplitude of M-wave, there is the report that the amplitude of M-wave increased on shortening of muscular length and the amplitude decreased on prolongation of muscular length[4]. Therefore in this study, we speculated that there was possibility that the amplitude of M-wave from the tibialis anterior muscle differ under free condition and fixed condition of ankle joint movement. However, no significant difference between the amplitudes of M-wave under free condition and fixed condition was shown. From the result of this study, we considered that the amplitude of M-wave from the tibialis anterior muscle was not influenced in different conditions with or without joint movement due to twitch at stimulus frequency 1 to 5 Hz.

In conclusion, as the fundamental information of the stimulus frequency and the joint movement occurred by twitch to evoke the M-wave from the tibialis anterior muscle during voluntary movement, we suggested that the amplitude of M-wave was same in the fixed condition of joint movement occurred by twitch due to electrical stimulation from 1 to 5 Hz.

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Comparison of surface Electromyographic Parameters of Quadriceps femoral Muscles during Sustained Isometric Knee Extensor Contractions and Static Contractions in One-Legged Standing

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INTRODUCTION

Electromyography (EMG) has been used to examine the neuromuscular activity of the knee muscles under different muscle contraction conditions. However, comparison of the EMG fatigue patterns of quadriceps femoral muscles during open kinetic chain (OKC) and closed kinetic chain (CKC) has not been reported. The purpose of this study, therefore, was to investigate the effects of exercise posture on the EMG fatigue patterns of quadriceps femoral muscles during isometric knee extension and one-legged standing.

METHODS

All measurements were obtained from healthy volunteers, 10 male, with the mean age of 22.4 years old. All subjects were fee of musculoskeletal, cardiac, pulmonary and metabolic disorders. Surface EMG signals were recorded throughout the contractions from the rectus femoris (RF), and vastus medialis (VM) muscles. With surface EMG, the followings were measured or calculated; 1) the averaged EMG (AEMG) value during the maximum isometric contraction (MVC) with the hips flexed to 0 degrees (lying) and the tested knee flexed to 30 degrees, and 2) the percent MVC (%MVC) value of VM during one-legged standing with the knee joint flexed at 30 degrees normalized to the respective AEMG values of VM produced at MVC, and 3) the value of AEMG and median power frequency (MDPF) during continuous isometric contraction at %MVC and static contraction of one-legged standing maintained contraction for 2 minutes. At least 1.5-hour rest was allowed between the fatigue tasks. The values were analysed statistically by Student t-test and statistical significance was accepted at p<. 05.

RESULTS

During continuous contraction of one-legged standing, although the MDPF value of RF was significantly decreased, the AEMG value of RF was no changed significantly. In addition, during continuous isometric knee extensor contractions, the AEMG value of RF and VM was significantly increased and the MDPF value of RF and VM was significantly decreased at the end of the fatigue task.

DISCUSSION

This study was designed to investigate the effects of exercise posture on the EMG fatigue patterns of quadriceps femoral muscles during OKC and CKC. In this study, the muscle activity of VM was almost equal in the beginning of the fatigue tasks. However, the EMG fatigue pattern of quadriceps femoral muscles was differences between the fatigue tasks. This might suggest that quadriceps femoral muscles have different roles in the static fatigue tasks.

CONCLUSION

Although many study concerning fatiguing contractions was reported, the different role of femoral muscles did not make it cleared. This study suggested that further investigations are necessary to study the effects of exercise posture on the EMG fatigue patterns of quadriceps femoral muscles.

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Comparison of Oxygen Uptake and Muscle Activity in Lower Extremity during Walking Exercises on Land and in Water

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INTRODUCTION

As it costs a great deal to construct theraputic pool with large space and maintain its water and room temperature,attention is paid to water treadmill constructed at a small cost in recent years.Water treadmill has the possibility to decide precise load and reports as to it is gradually increasing.Recentry,reports as to the influence of water immersion levels on cardiorespiratory responses have increased gradually,however not all of them have come to the same conclusion.We have not held the same view on oxygen uptake ($\dot{V}O2$) and examination of electromyogram (EMG) in the water.The purpose of this study was to examine the influence of gripping the fixed bar or not and EMG in the water.

METHODS

The subjects were 10 healthy,male volunteers,they were mean age 21.9±1.8,mean height 173.4±6.1cm,mean weight 68.6±7.4kg.The used instruments were aqua cyser 100R by Ferno for water treadmill walking,Vmax29c by Sensor Medics for measuring $\dot{V}O2$.The subjects performed treadmill walking for three minutes both in water and on land.Three levels of water immersion were set:Xiphoid process,nabal and greater trochanter.$\dot{V}O2$ and EMG were measured during exercise.The used instrument for EMG was ME-3000P by Mega Electronics,EMG of four muscles were recorded (tibialis anterior,vastus medialis muscle,gastrocnemius muscle,straight muscle abdomen).The protocol for measurement was that the treadmill belt was speeded gradually until 4km per hour and the subjects walked for three minutes at the same speed.Cadence was 100steps per minute.The protocol was same both in water and on land.The water temperature was kept at 33℃,the air temperature was kept 23℃.T test was used for the data analysis.

RESULTS and DISCUSSION

Significant differences of $\dot{V}O2$ were observed by not gripping the fixed bar at each water immersion level.$\dot{V}O2$ values in gripping the fixed bar was lower than that in not gripping.Muscle activities of straight muscle abdomen on land were significantly lower than that in water and decreased at the lower water immersion level.we thought that the $\dot{V}O2$ differences at the water immersion levels were influenced by antigravity muscle activities decreasing caused by buoyancy and that $\dot{V}O2$ values in not gripping the fixed bar were higher by trunk muscles activities increasing for postural maintenance.

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Relation of Pinch strength to Finger distance

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<Introduction>

Pinch strength is basic kinesis of finger function, and we use one of clinical evaluation (1985,virgil).
Maximum pinch strength have previous reported hand functional position .
Fewer report have attempted to have maximum pinch strength , as a whole discussion of finger distance , however(1991,Nichimaru).
We reported pinch power was strength (4cm than 1cm), and radiocarpal, intercarpal joint was strength extention than flextion last year before (1998,Okazaki).
More modern study using similar methods have reported strength three pinch patterns of lateral pinch and palmar pinch and tip pinch last year.
More than finger distance were strength the men pinch patterns of all , and the all subjects have reported lateral pinch > pulp pinch > tip pinch(1999,kinoshita).
It is the purpose of this study to define more accurately relation of Pinch strength to Finger distance, to add to relation of Finger span.

<Sample and Method>

There were 130 subjects, including 67 men and 63 women, who ranged in age from 18 to 34 years (M = 20.31±3.81)
Position of evaluation was method in a previous paper (1996,Louis R. Amuundsen).
Lateral pinch and pulp pinch and tip pinch(1999,kinoshita) make use of finger distance of tree pattern(1cm,2.5cm,4cm) , and have on the average three times.
We based on (1999,kinoshita) , the method discusses the other relation of length and finger span , volume , grip strength , power of vertebral column extensor muscle result obtained in a follow up .
Machine of evaluation used Hydraulic Pinch Gauge PC 5030HPG (PRESTON) , was method in a previous isometric twitch .

<Result>

① Relation of Pinch Position to Pinch strength
Relation of Pinch Position to Pinch strength was lateral pinch > pulp pinch > tip pinch .
② Relation of Pinch strength to Finger distance
Maximum pinch strength of the men was finger distance of 4cm , and lateral pinch(average 9.28±2.07kg) ($p<0.01$).
Pulp pinch (average 6.14±1.86kg) and tip pinch (average 4.64±1.44kg) was finger distance of 1cm , however($p>0.05$) .
Maximum pinch strength of the women was finger distance of 2.5cm , and lateral pinch(average 6.72±1.00kg) ($p<0.01$).
Tip pinch (average 3.11±1.18kg) was finger distance of 2.5cm , however($p>0.05$) , and Pulp pinch (average 4.67±1.60kg) was finger distance of 1cm ($p>0.05$) .

③ Relation of Pinch strength to Finger distance
The people of all were not Relation of Pinch strength to Finger distance.
The women were Relation of finger distance to basal body power , however (r =0.500~0.772) .

<Summary>

Maximum pinch strength of the men was finger distance of 4cm, and lateral pinch, and maximum pinch strength of the women was finger distance of 2.5cm, and lateral pinch.
Not Relation of Pinch strength to Finger distance.

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Fundamental Research on the Autonomous Adaptive Human Interface Used EEG and EMG

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INTRODUCTION

What is the human interface (HI) is the connection part between the human and the machine or computer. The followings are included on the human interface: Keyboards, mice, software variously, internet and so on. In order to realize the usable human interface, the intuitive and comprehensible operation has been emphasized which is called the direct manipulation. In such an approach, it is impossible to closely adapt to the individual preference: that is also an important side in essential human interface.

Our purpose is to develop the autonomous adaptive interface which closely adapts to the individual. We adopt electroencephalogram (EEG) and electromyogram (EMG) as an evaluation signal of the feedback. The details of the researches used EEG and EMG as the interfaces are shown in the reference [1][2][3][4]. In this research we attempt to quantify user frustration and extract the characteristic vector from EEG and EMG when people operate the machines. In this paper we will report about the results of fundamental experiment to separate automatically discomfort and not-discomfort by using Artificial Neural Network (ANN).

METHODS

The outline of our proposed supervised interactive learning method is illustrated in **Fig.1**. As the application of our system we adopt the control system which will control the behavior of Khepera robot using the physiological signals, EEG and EMG. Three types of units are in this system as follows;

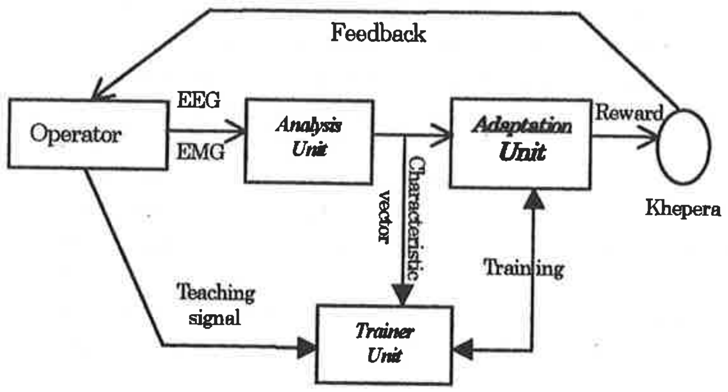

Fig.1 The outline of a proposed controlling system of Khepera robot using EEG and EMG

1. Analysis Unit, which extracts the characteristic, vector from the physiological signals by using ANN
2. Adaptation Unit, which adapts to the personality, recognizes comfort and discomfort, and then generates the control signal for rewards of RL in Khepera robot
3. Trainer Unit, which trains the teaching signal of the operator to Adaptation Unit based on and characteristic vector from Analysis Unit.

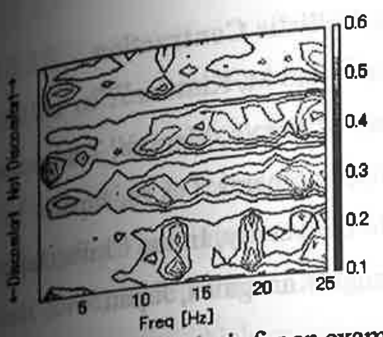

Fig.2 Result of FFT analysis for an examinee.

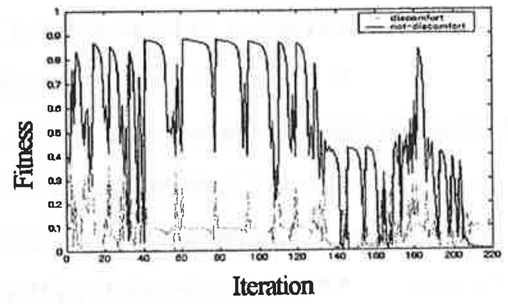

Fig.3 Fitness curve for two training patterns: average of discomfort and not-discomfort

RESULTS

As the basic experiments we experimented for 20 examinees under the situation of not-discomfort and discomfort in order to obtain the characteristic vector from EEG. The method of measuring EEG was the international electrode method. The measured channels were 4 as follows; F7, F8, T5 and T6. The sampling rate was 50Hz. We set 18 terms for all; 7terms as discomfort situation, 4 terms as not-discomfort situation and 7 terms as the situation of neither discomfort nor comfort. Fig.2 shows the result of FFT for an examinee. From this result we adopt BP, which is one of ANN, to recognize two situations: discomfort and not-discomfort. Fitness curve for two training patterns will be shown in Fig.3.

DISCUSSION

The results of FFT per examinee pointed out the possibility to separate the discomfort and not-discomfort. Learning to recognize two situations automatically used ANN was successful, whose inputs are the correlation of each channel's spectrum and each 4 frequency bands (Fig.3). However we realized respectively large difference on the learning efficiency per examinee by the type of input data: the correlation of each channel's signal, the spectrum after FFT with 4 frequency bands for each channel and so on. It is necessary to choose input signal type per person carefully in order to implement the HI which closely adapts to the individual.

CONCLUSION

From the results of 20 people's fundamental experiment, we ascertained the possibility to recognize comfort and discomfort from EEG. There are significant differences per person, so it is necessary to use learning method such as ANN to extract the characteristic vector with on-line. To solve this problem we will measure EMG on the face simultaneously. To recognize comfort and discomfort it is effective to measure the movement of eyebrows. The future direction of this study will be to implement the controlling system of Khepera robot on-line by using EEG and EMG interface.

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Variation in First Agonist Burst during Ballistic Contraction

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INTRODUCTION

Wide variation in integrated electromyography (iEMG) of first agonist burst has been observed during ballistic contraction, even when human subjects generated same levels of isometric force amplitudes (Yoneda et al. 1983a; 1983b; 1988). Furthermore, variation in frequency response of motor units has also been observed in ballistic contraction (Oishi et al. 1988; Yoneda et al. 1986). However, these variations have not been observed in ramp and fast ramp contraction. We predicted that the variation is related to the orientation of force exerted, because Yoneda and his colleagues measured only one component of force. In this study, we analyzed the relationship between orientation of resultant force and iEMG of the first agonist burst in order to clarify whether the variation is due to difference of orientation of force.

METHODS

Four male volunteers participated in our experiments. The subjects sat on an experimental chair with their right knee fixed at 90 degrees (full extension = 0deg). We instructed them to produce knee extension force "as fast as possible", and to start the force production by themselves (Fig. 1). Each subject performed 30 trials at a force range of less than 50 % of maximal voluntary contraction (MVC). Three components of forces were detected by using a specially designed force transducer together with surface EMG signal on vastus medialis muscle. We calculated iEMG of first agonist burst, and then calculated peak amplitude and orientation of the resultant force for each trial in all subjects.

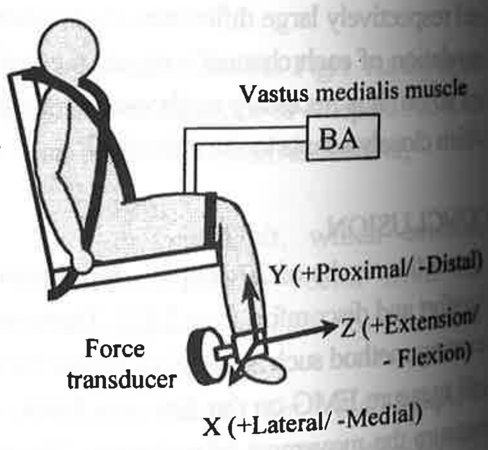

Fig.1. Experimental set up and three components of force defined in the present experiment. Surface EMG was recorded from right vastus medialis muscle. We defined three components of force as drawn above.

RESULTS

Orientation of resultant force during the fastest isometric knee extension was not constant between trials. We next calculated variation in the first agonist burst as expressed by standard error of estimation in regression line analyzed from the relationship between peak amplitude of resultant force and integrated EMG. Although the iEMGs increased with peak amplitude of resultant force, wide variation of agonist iEMG was observed in all subjects examined. We selected the trials in which orientation of resultant forces were the same, and then analyzed the variation again. As a result, the wide variation still remained.

DISCUSSION & CONCLUSION

In the present study, we confirmed that wide variation in the agonist iEMG was observed during ballistic contraction and that the variation was not related to orientation of resultant force actually exerted. Yoneda et al. (1983; 1983) reported that wide variation in the first agonist burst was not observed during ramp and fast ramp contraction. Furthermore, Oishi et al. (1988) and Yoneda et al. (1986) reported that the same tendency was also observed in motor unit firing behavior. These results suggest that the variation might be due to diversity of motor unit firing behavior in the ballistic contraction. We concluded that the wide variation in the first agonist burst is a characteristic of ballistic contraction.

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P-133

The Effect of Motor Control on Oro-facial dysfunctions in Stroke patients under Indian conditions

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INTRODUCTION

Oro-facial dysfunctions following stroke are quite common. Often situations are frustrating and embarrassing leading to disturbed inter personal relationships as well. Videofluoroscopic studies in past have demonstrated delayed swallowing reflex. Effects of remedial measures are still under consideration and are being instituted time to time.

METHODS

Sixty (60) stroke patients with Oro-facial dysfunctions were evaluated within a period of one and half years. The missing components were identified. Accordingly Motor Control Programme were planned and initiated to train swallowing, to train various tongue movements and further to train various other Oro-facial activities including transference of learning in to ADL etc. under Indian conditions. The patients were evaluated on regular intervals.

RESULTS

Results were encouraging in male patients and were also gratifying when Motor Control Programmes were initiated within first few weeks of its occurrence.

DISCUSSION

The existing joint family structure in India, Illiteracy, Poverty and strong God fearing background have a decisive overall effect in the out come of the total rehabilitation management. The Motor Control Programme when instituted early at the hospital and thereafter, at home also considering the Psycho-social background of the patient has shown improved breathing control, regain confidence in the patients to socialise early.

CONCLUSION

Retraining for restoring early Oro-facial functions is vital. Techniques to improve tongue functions and swallowing needs constant attention and practice. It help regain in early rehabilitation out come. Improved Oro-facial function and control has a significant contribution in rehabilitating a stroke patient. Thus it must always be considered as part of total rehab. management.

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Effect of phenol block of femoral nerve for leg extensor spasms

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INTRODUCTION

The extensor spasms of leg , in which lower extremities become full extension rapidly with triggers,is an occasional symptom of central nerve system disorders. It is neccessary to treat the excessive condition of this hyperactivity for functional improvements. In the treatment of the extensor spasms, analgesic medications are unsatisfactory to relieve the sympton because of frequent unpleasant side effects. Phenol nerve block with intrathecal injection is generally effective . On the orther hand, peripheral nerve block for ext. spasms is unknown. The purpose of this report is to document that phenol block of femoral nerve relieves the extensor spasms clinically and electrophysiologically.

MATERIAL

We studied two patients.

・case 1 - The first case was a 45 years-old man with complete spinal cord injury at T4, 5 years earlier. He sustained bilateral the extensor spasms of leg and it was becoming worse for 2 years after. Because it had become difficult to transfer from W/C to bed, he admitted to our hostital for the treatment of extensor spasms.

・case 2 - the latter case was a 43 years-old woman with spinal cord degeneration which we couldn't diagnose. She had been aware of muscle weakness of lower extremities from age 13. When she was 20 years-old, she noticed the spasticity of lower extremities and muscle weakness of upper extremities. Since the age of 30, left extensor spasms started and they were becoming worse gradually. Because the extensor spasms disturbed her ADL, for example, sleep disturbance, difficulty in transfer and pain, she admitted to our hospital for treatment of it. Oral medications were insufficient to eliminate extensor spasms because of side effects and their intolerance.

METHODS

In order to assess muscle hyperactivity, we used surface EMG examination. We placed elecrodes on the quadriceps muscles' belly, then we observed H wave and M wave during electric stimulations before and after phenol nerve block. At first, we injected a femoral nerve trunk with 0.3% Lidocain and then confirmed the remarkable decrease of extensor spasms by surface EMG. With this procedure, they clinically improved without severe complications. Furthermore we observed the state of patients for several days and found no delayed side effects. Finally 2% to 5% phenol solutions were injected into the same nerve.

RESULTS

In both patients, the extensor spasms were clinically, completely eliminated by phenol blocks of femoral nerves. At those times, eletromyographically the threshold of H reflex ampulitude increased. The effect continued for more than 6 months.

DISCUSSION

Although chemical agents with intrathecal injection are useful for extensor spasms, it is possible that the side effects occur. Some investigators reported selective intrathecal phenol block was significantly valuable without systemic side effects nor disturbance of bladder, bowel or sexual function. On the other hand, peripheral nerve block has less side effects. The mechanism of extensor spasms appears identical with those of spasticity, so that we performed the block with femoral nerve because of the highest ampulitude of quadriceps muscle on surface EMG. In performing the injection, H reflex and M response have to be monitored by surface EMG, and knee jerks is observed. We'll attempt to do motor point block to imcomplete lesions' patients.

CONCLUSIONS

We could eliminate the extensor spasms of leg with phenol block of femoral nerve. The effect continued for more than 6 months without the side effects.

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Modulation of Use-dependent Plasticity in Adult Human Motor Cortex

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INTRODUCTION

The adult central nervous system has the ability to rapidly adapt and change according to environmental demands. This is a matter of great importance for the acquisition of new skills and for recovery after brain injury. Performance of repetitive voluntary movements is associated with functional reorganization in the human motor cortex, a phenomenon described as use-dependent plasticity (Classen et al.,1998).

METHODS

Mild and isolated thumb movements of consistent direction were elicited by focal transcranial magnetic stimulation (TMS). Subsequently, subjects were trained by performing brisk voluntary thumb movements in the opposite direction to the TMS-induced movements for 30 minutes at 1 Hz. Following training, TMS was delivered to determine post-training TMS-evoked movement directions. D-amphetamine (non-catecholamine sympathomimetic amines with CNS stimulant activity), lorazepam (GABA receptor positive allosteric modulator), dextromethorphan (NMDA receptor blocker), lamotrigine (voltage-activated Na^{+} and Ca^{++} channel modifier) and scopolamine (muscarinic receptor antagonist) were administered in different experiments in order to clarify the mechanisms underlying use-dependent plasticity and to access the chances to enhance this plastic changes.

RESULTS

A single dose of D-amphetamine accelerates the development and prolongs the duration of use-dependent plasticity. On the other hand, use-dependent plasticity was reduced by dextromethorphan and by lorazepam but was not affected by lamotrigine. Under the effects of scopolamine, training was much less effective in 6 out of 8 subjects.

DISCUSSION/CONCLUSION

Down-regulation of the effects of training by an increase in GABAergic tone and NMDA receptor block identify these mechanisms as operating in this form of plasticity and point to a LTP-like mechanism. Central cholinergic influences have a supporting role on use-dependent plasticity. Pre-medication with D-amphetamine can facilitate training-induced plasticity and these findings have implications for strategies to enhance rehabilitation of motor function.

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P-136

Phenol block treatment for varus deformity of ankle due to spasticity

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INTRODUCTION

The varus deformity of ankle makes the gait disorder in changing from swing phase to stance phase. We report the effects of phenol block treatment for varus deformity of ankle due to spasticity.

METHODS

The subjects were 4 patients with chronic hemiparesis and 1 patient with cerebral palsy, who had the varus deformity of ankle. All 5 cases had the moderate to marked increased tonus in involved lower extremities. Their mean age and s.d. were 62.2±19.1 year-old, and they were 3 male and 2 female.

The gait and standing posture were observed clinically and gait was analyzed before and after treatment.

All patients were observed using kinematic electromyography (EMG) of affected tibialis posterior muscle with wire electrode, and soleus and tibialis anterior muscles with surface electrode, before and after phenol block.

We injected 2% phenol solution to the nerves innervated to the tibialis posterior muscles. The point was searched and stimulated only nerve to tibialis posterior not soleus muscle by needle electrode with stimulating function.

RESULTS

Only two patients could walk before treatment, but three patients could stand only before treatment.

The patterns of kinematic EMG during walking or standing were classified to two.

In the first pattern, kinematic EMG showed the increased activities of tibialis posterior muscle at the point from the end of swing phase to the early stance phase.

In the second pattern, the kinematic EMG showed the normal activities of tibialis posterior muscle synchronized with soleus muscle.

After the injection of phenol solution, the stability of standing and walking was improved in all cases. And they could walk independently with cane or without cane.

The pattern of EMG became the normal pattern, although the amplitude of EMG of tibialis posterior showed the decreased activity. The spasticity also reduced by the treatment in all cases.

CONCLUSION

The improvement of the gait disorder, the instability of standing and the increased tonus are observed by the injection of phenol solution to the nerve of the tibialis posterior muscles for the patients with varus deformity.

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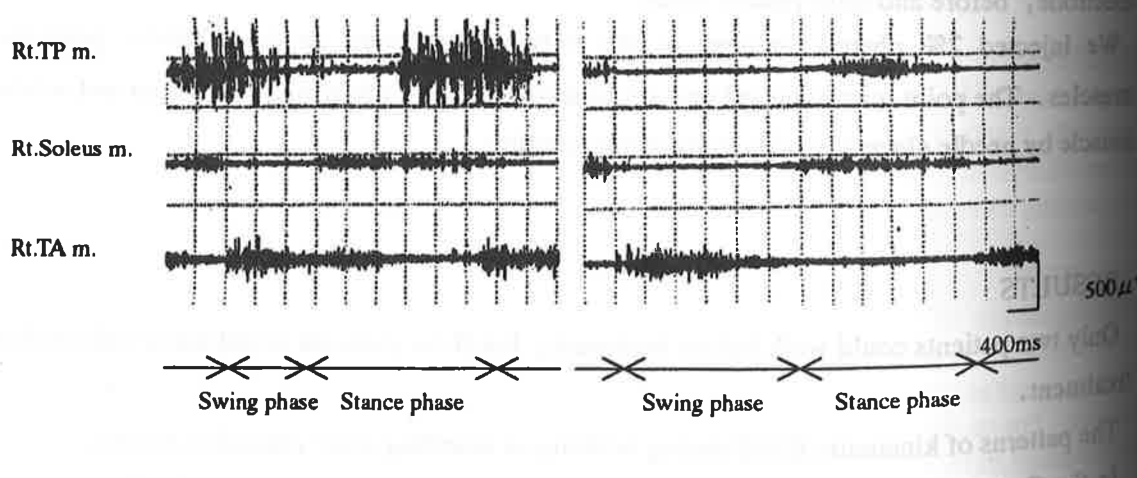

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A Study of the Fall from a Rocking Platform and a Thin Beam

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INTRODUCTION

Fall is the inability of the central nerve system to control the upright posture. This occurs mainly due to either disturbances acting on the human's body or intrinsic factors of the control system itself. This study was aimed at giving some insights into the instability of the postural control system. To do this, falls from a rocking platform and a thin beam were analyzed by means of motion video recording and electromyography.

METHODS

The experiments were done according to the ethic rules on the use of human subjects in researches. Ten healthy male subjects (age=21- to 38-yr age range) participated in the study after giving verbal informed consent. Kinematic data were obtained by means of a video camera (30 frames/s), which recorded selected points on the left side of the subjects. Reflective markers were attached on the ten recording points. Electromyographic (EMG) activity was recorded by using surface electrodes, which were placed on biceps femoris (long head, BF), rectus femoris (RF), tibialis anterior (TA), lateral gastrocnemius (LG), medial gastrocnemius (MG), and soleus (S) of both lower limbs. EMG signals were filtered, amplified and processed on a microcomputer. In the course of the experiments, the subjects stood on two unstable support surfaces: rocking platform (r=90 mm, heigth=100 mm) and thin beam (width=40 mm, heigth=130 mm). The landing onset of the falls was obtained from the force plate signals, which were also acquired.

PROTOCOL

The subjects were asked to stand on two unstable platforms with eyes open and closed, performing four tasks in all. Each task consisted of four 30 second trials with relaxing time between them. The subjects were given the following instructions: (1) Stand uprightly on the unstable platforms with the arms folded on the chest, (2) keep as possible as the equilibrium on the platforms without flexing the knee joints, (3) at the moment of the fall, step forward (FW) or backward (BW) naturally with the arms folded, (4) return back to the surface as the fall occurs and proceed the trial, and (5) in the experiments with eyes open, gaze at a point in the space right ahead, such that the head is aligned to the trunk.

RESULTS

(a) No significant differences in the EMG and kinematic patterns were observed between the experiments using rocking platform and beam.

(b) FW falls were characterized by flexion of the ankle plantar flexion and ventriflexion of the trunk, while in the BW falls, foot dorsiflexion and dorsiflexion of the trunk were remarkable.

(c) The fall process was divided into three phases based on the EMG activation patterns. The first phase (standing phase) was when the subjects stood successfully on the support surface. The second phase (critical phase) corresponded to the period of time for the subjects to prevent the fall. The third phase (fall phase) was the interval of time from foot off to landing, i.e., the swing phase.

(d) In the standing phase, the muscular activities were similar to that of the normal upright posture. In the critical phase, there were intense activities of flexors and extensors, which tended to burst in an alternated fashion, probably to try to keep the center of mass aligned to the earth's vertical. Co-activation of antagonist muscles were also observed in this phase. The fall phase presented the following muscle activation patterns. For BW falls: On the swing limb side, LG, MG and S were active from the beginning of the phase and set off before the burst activation of BF and TA, which were always seen and might be due to the knee flexion and foot dorsiflexion. After the activation of BF and TA, the triceps surae got activated again. On the stance limb side, the activation of RF, LG, S and MG were remarkable in the initial portion of the phase while TA was in the final. FW falls showed that on the swing limb side, there were a short activation of LG, S and MG in the beginning of the phase and then an activation of Q and TA followed. After the latter activation, there were again activation of the triceps surae. The first activation of the triceps surae might be interpreted as a kicking like movement at the foot off time. For the stance limb, LG, S, MG and BF activation in the beginning and TA burst activation at the end of the phase formed a pattern.

DISCUSSION

Researches on FW and BW locomotion have suggested that the hip angle of BW gait tend to be the mirror copy of those of FW gait, but the same does not hold for neither knee nor ankle [1,2]; there are marked differences between the two gait directions [1]. The results obtained in this study are similar to these findings. The studies of the stepping in spinal-cord-injured patients have suggested the existence of CPG in human [3]. Thus, it is likely that compensatory stepping at the falls is evoked through the CPG, which is triggered by the posture control system.

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Effect of sound stimulation for ataxia, part 1: effect in patients with deep sensory disturbance

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Introduction

It has been well known that movement of human is affected by feedback of somatosensory, visual, and equilibrium information. Effect of auditory feedback for kinetic movement has not been known in humans, even though sound gives information about localization and/or motion of it. We investigate the effect of sound stimulation for kinetic movement in ataxic patients.

Subjects and methods

Seven ataxic patients due to deep sensory disturbance were examined.

Experimental setup: All experiments were conducted in a sound-attenuated recording room. Subjects sat down a chair with their head fixed, with a sound source(speaker) at the tip of the second finger of ataxic forearm. Position information was obtained by 3 dimensional position sensor.

All 7 subjects underwent the, so-called, finger nose test(FNT) in 2 conditions;

A1: with eyes closed, without sound stimulation,

A2: A1 plus sound stimulation.

For sound stimulation, white noise was made from the speaker of the second finger which reached ears of subjects with 55 dB. In each condition, subjects underwent the FNT for 20 times in every one minute. Skillfulness of the FNT was measured by 3 factors: distance(DIS), velocity (VEL), and acceleration(ACC).

Results

In A1, the locus of the FNT fluctuated, and DIS increased. VEL and ACC dispersed. In A2, however, DIS, VEL, and ACC demonstrated marked improvement. By the sound stimulation, fluctuation of the FNT decreased, and dispersion of VEL and ACC improved (especially in ACC).

Discussion

The result demonstrated sound stimulation improved dysmetria and dyscompositon in patients with deep sensory disturbance. Therefore, our study suggest that sound stimulation can play a role in kinetic movement in humans under certain conditions.

Sound was reported to affect nystagmus, pinna movement, equiblium, and spatial cognition with regard to posture and motor control of mammals. However, it has been established that human do not use auditory feedback in kinetic movement. We found out that sound stimulation played a role in kinetic limb movement in human.

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Effect of sound stimulation for ataxia, part 2: effect in healthy volunteers with their limbs vibrated

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Introduction

We found the effect of sound stimulation for kinetic movement in ataxic patients. Human can use sound stimulation to modulate his motion under some pathological conditions. The mechanism of this phenomenon was unknown. We suggested that ataxic patients acquired a newly developing ability, or that human had the ability by nature but did not give full play to it. Then, we investigated the effect of sound stimulation for healthy volunteers.

Subjects and methods

Experimental setup: All experiments were conducted in a sound-attenuated recording room. Subjects sat down a chair with their head fixed, with a sound source(speaker) at the tip of the left second finger, and with 2 viblators on the left triceps muscle and left supraspinatus muscle. Position information was obtained by 3 dimensional position sensor.

Experimental conditions: Subjects underwent the, so-called, finger nose test(FNT). We settled three different conditions;

A1: with their eyes closed,

A2: A1 plus deep sensory disturbance (the left biceps muscle and supraspinatus muscle were vibrated with 70Hz),

A3: A2 plus sound stimulation (white noise was made from the speaker of the second finger which reached ears of subjects with 55 dB).

Experimental design: Subjects underwent a FNT of each condition with 15 minutes' interval. To exclude influence of practice, we classified order of conditions into 4 groups. Each group was of 5 subjects healthy right-handed subjects.

B1: A1 → A2 → A3,

B2: A1 → A3 → A2,

B3: A2 → A3 → A1,

B4: A3 → A2 → A1.

As control data, all subjects underwent FNTs for 5 times with their eyes closed, and without vibration or sound stimulation, at the end of examination.

Skillfulness of the FNT was measured by 3 factors: distance(DIS), velocity (VEL), and acceleration(ACC).

Results

DIS, VEL, and ACC were increased in A2 and A3 than A1, despite of experimental order. Difference between A2 and A3 was affected most by practice. Statistic difference was not found between A2 and A3, using the analysis of variance.

Discussion

The result demonstrated that healthy human commonly could not be affected by sound stimulation. Even though human had ability of using sound to modulate kinetic motion by nature, healthy human could not use this ability. Although human did not use this ability in usual regulation of limb motion, human could use sound information in some pathological condition.

Sound was reported to affect nystagmus, pinna movement, equiblium, and spatial cognition with regard to posture and motor control of mammals. Relation between sound stimulation and kinetic limb movement has not been reported.

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P-140

Functional MRI in patient with post-stroke mirror movement

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Introduction

Mirror movements are involuntary synchronous movements of one limb during intended movements of contralateral homogeneous body parts. Mirror movement involving distal hand may be seen in healthy adults, particularly in the context of fatigue and effort. It has also been associated with a number of pathological conditions, including hemiparesis due to adult-onset stroke. Some studies suggested that mirror movement may reflect the altered activity in the unaffected hemisphere.

We examined activating area of hemispheres in patients of post-stroke mirror movement using functional MRI (fMRI), and investigated a role of the unaffected hemisphere.

Subjects and Methods

Seven stroke patients with a history of hemiparetic stroke (6 males and 1 females; age, 62.3 years; SD 18.2) were identified. Clinical information on the stroke subjects are presented in Table 1. Three patients were hemorrhage, 3 were infarction, and one was arteriovenous malformation. All patients were right handed, and received motor function rehabilitation therapy. Duration from the ictus to functional MRI was 3 to 148 months (mean 43.9, SD 69.8).

Images were collected by a 1.5T MRI system (Magnetom Vision, Siemens), equipped with echo planar imaging (EPI) capabilities and a radio frequency (RF) surface coil. Sequence parameters: gradient-echo EPI, repetition time (TR) = 3000 ms, echo time (TE) = 60 ms, field of view (FOV) = 160 mm, resolution = 210 by 256. Five contiguous axial slices from the most rostral part of brain with slice thickness of 5 mm each were acquired. Subjects' heads were immobilized using foam pads. The EPI images were superimposed (using a two dimensional warping algorithm) on MR images collected at the end of each session in the same plane of session. Fifty images were obtained per slice over a four-minute period, during which subjects alternated between 30-seconds periods of rest and activity. Hand grasping of each side was performed 1Hz in all series. The cue to begin and to cease movements was a light tap on the foot. Subjects kept eyes closed at all times. All movements were monitored for accurate performance by one of the experimenters standing in the scanner room at the subject's side.

Results

Unaffected hand grasping of all patients demonstrated the contralateral (unaffected) primary sensorimotor cortex (SM1). Affected hand grasping of all patients also demonstrated the ipsilateral (unaffected) SM1.

Four patients showing mirror movement demonstrated activation of same area in the unaffected SM1. Three patients without mirror movement, however, demonstrated activation of different area in the unaffected SM1.

Discussion

Mechanism of cortical reorganization was mentioned as follows; (1)collateral splauting of unaffected pyramidal tract, (2)true recovery of affected pyramidal tract, (3)contribution of uncrossed pyramidal tract, (4)contribution of reticulospinal tract, (5)release of interhemispheric inhibition.

Positron emission studies of patients with adult-onset stroke and mirror movement in the unaffected hand during active movements of the paretic hand suggested that such mirror movement were related to increased activation in the unaffected sensorimotor cortex with preservation of activation in stroke hemisphere. Clinical observation of mirror movement of affected hand suggested these mirror movement might be explained by reduced transcallosal inhibition of ipsilaterally projecting corticospinal tract.

Our study demonstrated that the same region of unaffected SM1 did an important role in mirror movement. It suggested that in some patients cortical reorganization might be occurred with involving the unaffected SM1.

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Functional MRI of amputees during use of myoelectrical prosthetic hand

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Introduction

Motor reorganization following amputation is suggested to occur predominantly at the cortical level. The motor maps of muscles proximal to the stump are larger than the maps corresponding to the homologous muscles on intact side. It has not been known about effect of a prosthesis for the cortical reorganization of amputees. We investigated patients with amputation using functional magnetic resonance imaging (fMRI).

Subjects and methods

We examined forearm amputees using fMRI to observe cortical plastic change during myoelectric prosthesis using. Although common myoeloctric prostheses could pinch alone, we used a new one which could move by three dimension to act different hand functions. The system analyzed surface electromyography (sEMG) from two points of proximal muscles of the stump, and sent motor commands to move a prosthetic hand. Users learned a skill of different movements by visual feedback(Fig.1).

Images were collected by a 1.5T MRI system (Signa, GE, USA), equipped with echo planar imaging (EPI) capabilities and a radio frequency (RF) surface coil. Sequence parameters: gradient-echo EPI, repetition time (TR) = 5000 ms, echo time (TE) = 60 ms, field of view (FOV) = 200 mm, resolution = 64 by 64. Thirteen contiguous axial slices from the most rostral part of brain with slice thickness of 5 mm each were acquired. Subjects' heads were immobilized using foam pads. Forty images were obtained per slice over a four-minute period, during which subjects alternated between 30-seconds periods of rest and activity. All movements were monitored for accurate performance by one of the experimenters standing in the scanner room at the subject's side.

Images were analyzed by statistical parametric mapping (SPM96) analysis.

Results

Before use of the prosthesis, with the missing hand grasping task, fMRI of amputees without phantom pain demonstrated a broad activation on the contralateral M1(filling-in). On the contrally, fMRI of amputees with phantom pain demonstrated an activation shifting medially than the contralateral activation of healthy hand.

During use of prosthesis, however, the activation was located more laterally in the M1 area than one of no prosthesis.

Discussion

These findings suggested that the extent of cortical activation meant cortical plastic change.

In the primary sensory cortex, the concomitant changes in the pattern of sensory processing was not stable phenomenon, while the overall extent of reorganization is a rather stable. This may be due to the fact that alterations of sensory processing are not hardwired, but are rather mediated by an extensive and interconnected neural network with fluctuating synaptic strengths. Likewise, although the motor cortex representing the missing hand was reorganized, the function of the reorganizing region was still uncertain. The activation by using of the prosthetic hand may implicate cortical plastic change. This phenomenon may brighten therapeutic possibility of neuromodurating techniques using prostheses and virtual reality.

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P-142

The Study of Sensor Pegboard Test Method for Estimating 'Dexterity' of Myo-Electric Hand

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INTRODUCTION

Both hydraulic powered whole arm prosthesis with seven degrees of freedom and hand prosthesis with three degrees of freedom were developed by RSA(rotary servo actuator). And potable Hydraulic Pump Unit for the latter was developed. Using EMG signal, object control method was developed for the hand prosthesis and intention control method was developed for the arm prosthesis. In order to put the powered prosthesis to practical use, field tests were carried out and WIME hand(the electrical powered hand prosthesis with one degree of freedom) has been supplied in Japan. Degrees of freedom, ROM, forces, ADL, field tests and dexterity are the factors in estimating the hand and arm prostheses. This study deals with the dexterity of Myoelectric Hand.

METHODS

Five forearm amputees who are using WIME hands and 15 normals as the control group are tested by the newly developed sensor pegboard test method. This test is menu driven. By using touch sensor, the motions on the board are detected and the efficiency and performance are estimated statistically. Test menu is constructed by the factors of perception, judgement and motion. The factors are detected by WF, MODAPTS and Drivers Aptitude Test methods. Hemiplegic patients are tested, too.

RESULTS

Touch information includes Latent time, Response time and Working time. In the working time, there are repetitive micro motions. Each micro motion is detected statistically. Information about the peg position offers new aspects of subjects' characteristics. The test results of the amputees show similar patterns. Tapping speed is very low compared with that of normals. But picking speed turns faster. Both moving and constructing performances are more advanced. Patting speed is just half of that of normals, but selecting performance is better. Because prosthesis is a human machine system, both design of machine and training level of EMG control are estimated by this sensor pegboard test method.

DISCUSSION

Simple test items like pinch motion by prosthesis result in low efficiency, but a combined movement of machine and human produces as high efficiency as normals. Generally the results of the sensor pegboard test method indicate the need for improvement in the present prosthesis. So the results promote the redesign of the prosthesis.

In the case of hemiplegic patients, simple test menu line causes spontaneous behaviors and they get good results. Test menu is effective in the improvement of patients' judgement.

CONCLUSION

Man develops his working ability through learning. For the evaluation of the coordinate working ability, the sensor pegboard test method was developed in this study. The upper limb motions of the subjects are measured statistically at the micro motion level, and evaluated on many aspects of the capability of the upper limb of workers. In order to evaluate the working ability of the disabled and aged, it is essential to estimate accurately their individual ability, judge their individual aptitude and prepare a training program aimed at the utmost development of their latent possibilities.

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On-line Learning Based EMG Prosthetic Hand

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INTRODUCTION

Existing control methods of EMG prosthetic hands can be separated into two classes. One includes the methods employing learning mechanism in order to adapt to amputees' characteristics. The other includes all those methods with no learning ability. It was reported that, the former class of methods can realize the control for prosthesis with more degree-of-freedom (D.O.F.) [1)2)]. Nevertheless, it is the latter class of methods that are widely adopted in practical use.

A reason of this phenomenon is: in previous approaches of the first class methods, learning was only conducted in a learning phase before practical use, whereas, there was no learning occurred when prostheses were actually operated. However, generally some gaps exist between these two phases. Therefore, the learned system was not always adequate or completely appropriate for practical use. Moreover, those previous approaches cannot cope with unpredictable changes probably happened in operation, e.g., alternations of amputees' characteristics, variations of EMG sensor properties etc.

On the other hand, the mechanical parts of previous prosthetic hands usually have few D.O.F. by which the dexterity of human hands can hardly be achieved. The technical difficulty is that the ordinary mechanical design and machine methods cannot create prosthetic hands under the constraints assigned by human hands, including suitable weight, grasping force, and complex form. In this research, we make an effort to overcome the difficulty, emphasizing on the adjustable power transmitting mechanism, which enables the hand to move slowly when high power is needed and give low power when high speed is needed. This feature was ignored by previous researchers, however it is instinctive nature in human hands.

Accordingly, we have developed an on-line learning based EMG prosthetic hand which can execute the learning and practical use phase simultaneously and have developed an adjustable power transmitting mechanism for well-known tendon driven method, which adjusts speed and torque in response to loads [3)4)]. We will describe our approaches and performances as follows.

METHOD

A schematic diagram of the on-line learning based controller is shown in figure 1. EMG signals are transformed to control commands for driving prosthetic hands using Analysis and Adaptation Units. An amputee evaluates the current control by observing the movement of the prosthetic hand. When he/she judges the hand moving unsatisfactorily, he/she sends the teaching signal to Trainer Unit to make the Adaptation Unit re-learn immediately. More details can be found in 3).

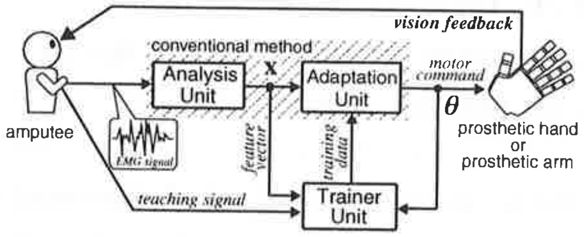

Fig. 1. Schematic diagram of the on-line learning based controller.

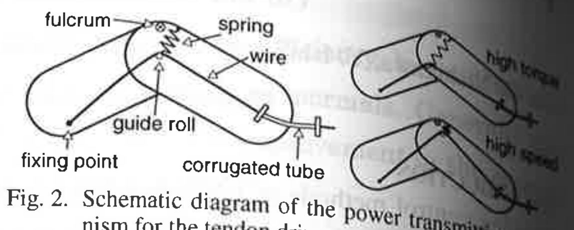

Fig. 2. Schematic diagram of the power transmitting mechanism for the tendon driven.

A schematic diagram of the adjustable power transmitting mechanism for the tendon driven method is show in figure 2. Adjusting the position of a guide roll by a spring, this mechanism achieves suitable speed-torque characteristics.

RESULTS

Several results indicating effectiveness of our methods are described as follows.

Using our on-line based controller, three normal subjects successfully control ten forearm motions from two channels of EMG. Two amputees successfully control six forearm motions from three channels of EMG. In both cases, subjects finished training courses within a maximum of thirty minutes. Besides, since the algorithm of the on-line learning is so simple that it can be embedded in the Pentium 200MHz class PC.

Our power transmitting mechanism realized following speed-torque characteristics. When high torque is necessary, the mechanism can give the torque six times stronger, at the speed six times slower than that in the high-speed mode. Moreover, this mechanism can be easily developed to multi-D.O.F. finger type, and further to dexterous hand. The estimated grip force of the combined dexterous hand will be 156 N.

CONCLUSION

This paper reported current achievement of our study of the on-line learning based EMG prosthetic hand. Future directions of this study are integration of the controller and dexterous hand and verification of this integrated prototype in clinical tests.

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P-144

Permeability of non-polarized near-infrared light

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INTRODUCTION

Linear polarized near-infrared irradiation is used as a standard treatment for wound healing and pain control. Although polarized light has been reported to be an effective treatment for wound healing, the effectiveness of polarized light as a treatment for pain control remains unclear.

METHODS

We obtained various tissues of an S-D rat, including skin, fascia, muscle, liver and bone, and examined the permeability of these tissues to near-infrared irradiation using a Super Lizer™ and a Laser Power Meter™ for both polarized light and non-polarized light.

RESULTS

The permeability of non-polarized light was found to be approximately three times more intense than the permeability of polarized light. (2.14~3.75× permeability of polarized light, average : 3.02×permeability of polarized light. Refer to Table 1.) Figures 1 and 2 show the relationship between tissue thickness and permeated light energy.

DISCUSSION

The output of the Super Lizer applied type-B lens unit is 1800 mW, which is greater than that of other devices. In addition, because the wavelength of the Super Lizer is 0.6~1.6 μm, the arrival range of near-infrared irradiation is deeper than that of other devices. The effectiveness of the Super Lizer has been reported for Raynaud's disease, post herpes zoster neuralgia, complex regional pain syndrome/reflex sympathetic dystrophy and other diseases. However, the efficiency of polarization has only been reported for wound healing. Deeply in vivo, polarized light is depolarized due to absorption, interference, reflection and the inherent optical activity of tissues. Tissue permeability to near-infrared irradiation was compared between polarized light and non-polarized light. The permeability of non-polarized light was found to be three times more intense than the permeability of polarized light. High output is generally expected to produce good results for treatments such as pain control. Obtaining higher output with the Super Lizer involves simply detaching the lens unit. However, care must be taken so as not to cause burns at the irradiation site. In future studies, we would like to clarify the safety range of the Super Lizer.

CONCLUSION

The present experiment shows that the permeated light energy of non-polarized near-infrared irradiation is approximately three times more intense than that of polarized near-infrared irradiation. We believe that the more intense light energy produces the higher efficiency.

Tissue	Thickness (mm)	B-type lens (mW)	No lens (mW)	Quotient (No lens/ B-type)
None		1126.25	2967.5	2.63
Skin (Neck)	0.8	448.5	1009.25	2.25
Skin (Groin)	0.5	427.25	1110	2.60
Skin (Back)	0.8	316.5	1005	3.18
Skin~Fascia (Back)	1	217.25	622.5	2.87
Skin~Fascia (Neck)	1.1	240.75	754.5	3.13
Fascia (Femoral region)	0.2	927.25	2187.5	2.36
Subcutaneous tissue~Fascia (Thigh)	0.4	404.75	1165	2.88
Skin~Muscle (Thigh)	5.4	66.25	248.5	3.75
Skin~Muscle (Thigh)	4	99.75	343	3.44
Skin~Muscle (Thigh)	2.5	137.5	466.25	3.39
Skin~Muscle (Thigh)	1.2	186.75	696	3.73
Muscle (Thigh)	8	195.5	419.5	2.15
Muscle (Thigh)	4	237	883.75	3.73
Muscle (Thigh)	2	439.75	1323.75	3.01
Skin~Cartilage (Ear)	0.5	420.5	1446	3.44
Liver	5	66.25	210.25	3.17
Liver	10	21	68.5	3.26
Bone (Cranium)	0.2	542.25	1271.75	2.35
Average				3.02

Figure 1 Skin~Muscle

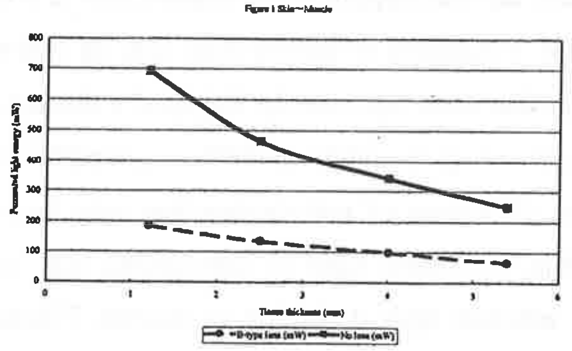
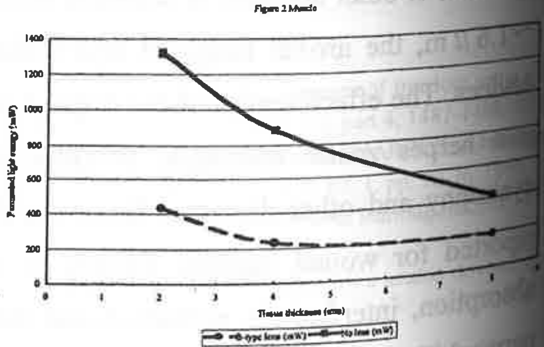


Figure 2 Muscle



P-145 Foot pressure distribution of artificial limbs in patients with below knee amputee by photoelastic methods

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INTRODUCTION

Fitness of artificial limbs and visual feedback effects on standing posture in patients with unilateral below knee amputee was investigated by a photoelsastic method.

SUBJECTS

Ten unilateral below knee amputees, 8 males and 2 females, ages from 20 to 46 year-old, were studied. They were all outpatients at Department of Rehabilitation, Chiang Mai University Hospital. The causes of amputees were traffic accidents, congenital anomaly and mines. PTB, PTS, and KUB type prosthesis were employed.

MEHTODS

Each subject kept standing on the platform of the photoelastic apparatus with eyes open first then eyes closed before and during watching photoelastc foot images on TV screen. Contact pressure acting on a small steel ball on the standing platform give rise to a sharp rings called "first fringe", which diameter corresponds to the actual local pressure. The number of first fringe and pressure distribution on the amputee and non-amputee foot were calculated.

RESULTS

Body weight was well loaded on the amputee side when subjects felt their prosthesis well fit, while it was not when they felt them uncomfortable. During visual feedback in those with well-fit prosthesis, body weight could be more loaded on the artificial limbs.

Conclusion

Photoelastic method can evaluate fitness of prosthesis, and may be an available training method to obtain more stabilized standing posture by visual feedback..

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P-146

Quantitative evaluation of writing using the Hiroshima University writing evaluation system

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INTRODUCTION

Motion analysis is very important to evaluate patient's function and the results can be used directly in medical treatment, especially in rehabilitation. In motion analysis, various information can be obtained from data that has been integrated by all other factors. Thus, useful information can be obtained from writing as a dexterity activity. The newly developed system would provide new data for use in hand writing motion analysis, function of upper extremity and motion dexterity. Therefore we developed computer system to evaluate the motion of writing and to discover the possibility of quantitative evaluation in writing. The new system simultaneously indicates strength of brush stroke, and pen holding pressure of the thumb, index and middle fingers and can perform frequency analysis from pressure variables. In order to determine the usefulness of this system, we compared the results obtained for a control group and those for a group of Parkinson's syndrome patients.

In the present study, the frequency is assumed to be an indication of a Parkinson's tremor.

METHODS

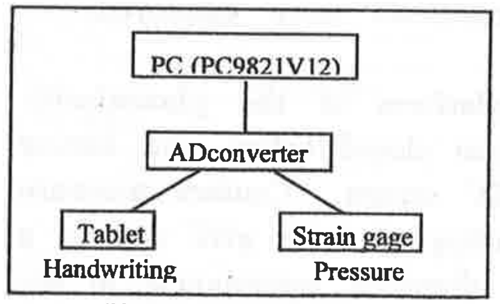

Fig.1 Structure of system

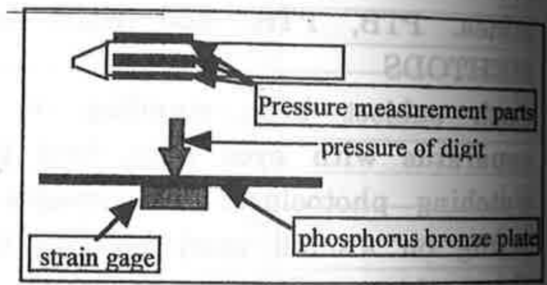

Fig.2 Structure of the pen

1) Purpose: The frequency of involuntary motions was determined using from pressure variables. Comparison between the control movements and Parkinson's movements gives an indication of the usefulness of our newly developed system.

2) Instrument: The Hiroshima University writing system was used to indicate the structure of the system (Fig. 1). This system is connected to a personal computer (PC: PC9821V12) and includes an AD converter and an amplifier. So various calculations are performed using the PC. The system is connected to a digitizing tablet and a stylus pen, which are used to indicate brush strokes to the PC. The stylus pen contains three strain gauges for measuring pressure variables from the thumb, the index finger and the middle finger (fig. 2). In the present study, frequency was obtained from pressure variables.

3) Subjects: 33 adults (Cont.: 22 males, 11 females, 25.9±4.4 years old), and 14 Parkinson's syndrome patients (Pa.: 5 males, 9 females, 60.5±11.5 years old) were explained in the present study. Duration of illness was 0.3 – 15.7 years. The purpose of this study was explained and consent was obtained from all subjects.

4) Sequence:
Subjects were asked to draw ① circles (30sec.) of approximately 6 cm diameter and ② points (30 sec.) by fixing the stylus pen on one point on the digitizing tablet. Peaks were defined as having a relative value above 10%; Analysis items were as follow:

1. Comparison of frequency, at trial ① between control and Pakinson's groups
2. Comparison of frequency, at trial ② between control and Parkinson's groups
3. Comparison of peak occurrence.

Table 1. Mean Frequency

		Circle	Hold	
Thumb	Cont.	1.41±0.55	2.30±2.89	**
	Pa.	1.30±0.55	7.66±1.50	
Index	Cont.	1.32±0.56	2.51±3.10	**
	Pa.	2.18±2.71	7.94±0.91	
Middle	Cont.	1.81±1.78	3.28±4.54	*
	Pa.	1.89±2.95	8.60±1.91	

* P<0.05 ** P<0.01

Table2.Peak occurence

		Circle	Hold
Thumb	Cont.	75.8%(25/33)	54.5%(18/33)
	Pa.	64.3%(9/14)	35.7%(5/14)
Index	Cont.	90.6%(29/32	65.6%(21/32
	Pa.	100%(14/14)	57.1%(8/14)
Middle	Cont.	68.8%(22/32	31.3%(10/32
	Pa.	72.7%(8/11)	87.5%(7/8)

RESULTS

(1) Circles: Mean peak frequency of the control group were 1.41 Hz (thumb), 1.32 Hz (index finger), 1.81 Hz (middle finger), and Parkinson's group was 1.3 Hz (thumb), 2.18 Hz (index finger), 1.89 Hz (middle finger). These findings showed no statistical significance.

(2) Points: Peak frequency of the control group was 2.3 Hz (thumb), 2.51 Hz (index finger), 3.28 Hz (middle finger), and that of the Parkinson's group were 7.66 Hz (thumb), 7.94 Hz (index finger), 8.60 Hz (middle finger). The level of statistical significance was P<0.05.

(3) Peak occurrence: At trial ①, peak occurrence of the control group was 68.8-90.6%, and that for the Parkinson's group was 64.3-100%. At trial ②, peak occurrence of the control group was 31.3-65.6%, and that of the Parkinson's group was 35.7-87.5%. Peak occurrence was higher in trial ① than in trial ②.

DISCUSSION

In trial ①, the peak occurence was confirmed to be 2-3 Hz in the control group and Parkinson's group. Since the FFT is sharp, the peak occurence is calculated. In trial ②, statistical significance was confirmed between the control group and the Parkinson's group. This indicates a physiological tremor or Parkinson's tremor. However, comparied to a previous study, our result is higher. The previous study identified postural tremors, and there may be a difference in the tremors identified in the present study. In future studies, this is a subject for further examination. Peak occurrence was appropriate, as shown by comparison with a previous study. Thus, the new system may be useful.

Conclusion

1. The Hiroshima University writing evaluation system was developed.
2. Trial ② for a point, the peak frequency to be confirmed 7.66-8.6 Hz in parkinson's group, and the findings were statistically significant. Trial ① for a circle showed no statistical significance.
3. The result for the exhibition or peak occurrence agreed with those of a previous study, thus indicating the usefulness of the newly developed writing evaluation system.

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Phantom pain of missing hand by stimulation to lip

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INTRODUCTION

Amputees usually presented Phantom pain which occurred by stimulation of stumps. Phantom pain were also reported to occur by stimulation of other body site. We experienced an amputee who demonstrated phantom pain by cold stimulation to his lip.

CASE PRESENTATION

A 49-year-old man admitted the Hokkaido University Medical Hospital in 1998. He cut the left forearm by a combine during farm work in Oct, 15,1996.

Soft dressing and delayed prosthetic fitting were undergone.

In March 1997. He put on a cosmetic hand. Then, he put on an body-powered hand prosthesis in 1998.

On admission, he complained the phantom limb.

Although he could move his phantom hand intentionally, it often showed involuntary grasping and brings about phantom pain.

Furthermore, he demonstrated phantom pain by cold stimulation to his lip. We evaluated functional reorganization of his hand and lip using functional MRI.

DISCUSSION

Phantom limb or pain of upper-arm amputees were occasionally strengthened by stimulation to lip. Ramachandran et al reported that an upper-arm amputee recognized on exact phantom limb by face stimulation. He also reported a similar patient with scapulo-thoraco amputee. These two patients showed phantom limbs by the stimulation to the stumps, axillae, and thoracic part. Halligans reported a similar phenomenon in a patient of upper-arm amputee. They named the part which occur phantom sensation by skin stimulation as " reference fields " and the phenomenon itself as " referred sensation "

They also explain the mechanism of the " referred sensation " using Penfield's cortical brain mapping. In the primary sensorimotor area, territory of hand presented between territory of face and shoulder. They suggested erroneous sprouting occurred from contiguous cortex to the area of the missing hand.

Ramachandrans suggested " presynaptic inhibition " might play an important role, silent connection might be presented between face and hand and be activated by amputation. He also suggested the site of " presynaptic inhibition " might affect to cortex or thalamus , because " reference fields " showed clear margin.

As mechanism of reorganization on the other hand, Halligans mentioned that face might have neual circuit to hand, because of presence of palmomental reflex. Plastic change was easily occurred in lip area. It plays an important role in the field of speech therapy.

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DOMINANCE OF ELECTRICAL BRAIN ACTIVITY ACCORDING TO ZONES AT READING ALOUD RHYTHMED AND UNRHYTHMED TEXT

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INTRODUCTION

The problem of nondifferentiation of lateral preference of speech muscles in stutterers, regardless of the lateral preference of the senses of sight and hearing and extremities, as well as the duration of Th. treatment commenced after the age of 10 and the success of Th. treatment with children aged 7, directed us towards studies of neurophysiology of the speech rhytm.

At this point we aimed to perceive ranging of electrical brain activity according to hemispherich recording points and frequency ranges-when reading aloud rhythmed and unrhythmed text.

METHODOLOGY

EEG recording was performed on the stuttering boy, aged 15. His psychomotor development was within normal state, with right lateral preference for senses of sight, and hearing, extremities and speech. Experimental task consisted of reading aloud 2 kinds of printed text (organized so as to be matter of emotional indifference). Task 1 was an unrhythmed text in Latin leters, without punctation marks and space between words, in further text (26). When reading, subjects task was to phonologically recognize the words and meaning. Task 2 a rhythmed text normally printed in Latin lettrs, in further text (27).

Comparasion at the state of rest, with eyes opened while reading. The results were obtained by calculation of difference in power of EEG waves - delta, theta, alpha, beta1 and beta2 according to points betwen the state of rest (task 0) and reading in the corresponding task (26,27). The obtained difference was them expressed in percentage of the calculated ones in relation to wave intensity at the state of rest.

RESULTS

Results are presented in tables 1 and 2.

DISCUSSION

Our subject showed right lateral preference for the senses sight and hearing, extremities and speech. Table 2 shows that hemispheric dominance of electrical brain activity confirms the aforementioned, but only in delta rhythm, left dominance in occipital and parietal, back temporal and central regions.

Our previous work stated that the unrhithmed text is read with particular increase of delta activity, which coincides with domination of delta activity during the period of speech and speech rhythm development, which is in accordance with the findings of authors (Rakovic, 1996) who say that mother language is generally memorized on low- frequency delta and theta activities, which later on become unconscious in adults.

Therefore, our discussion will be mostly based on delta rhythm. The expressed hemispheric dominance of the activity in table 2 shows equal distribution, 4 fields on the right and 4 fields on the left, which does not appear in any other frequency range. This ballance is supported by the hyphothesis of E. Jovanov, 1996 who says that: " Lower frequency presents a higher level of integration of information". Actually, all this shows that it is on this level of ballance that

the parametrization of primordial values is carried on, these valuas being universals of all languages.

Our previous works dealt with the quastion of a non dominante sense, extremity and muscle group, and reached the assumption that a non-dominant sense, or muscle group has a role of the active postulator by which the information about physical values of the tasks (activities) are reccieved; on the basis of this non-dominant field in non-dominant hemisphere enables dominant field- hemisphere to synchronously perform its specific function. In delta activity, significant difference in the increase of values in reading of the unrhythmd text (table 2) appeares in 7 fields out of 8; 4 on the right (twice on the both sides in Fp and F; twice on one side in T6 and T4- with the expressed inhibition at reading of the rhythmed text; and 3 on the left (twice on both side- F7,8 and O,1,2; once one side in C3 with the appearance of inhibition of the right. The difference in the increase of values at reading of the rhythmed text is found only parietally on both sides, more to the left, but whit significant difference of the increase in F3 comparing to F4 where the inhibition occurs.

Already in theta activity higher values appear at reading of the rhythmed text (asigned values) comparing to the unrhythmed text - in 7 out of 8 fields, in beta 1 in 6 out of 8, whereas in beta 2 there are 7 fields out of 8 for the unrhythmed text.

CONCLUSION

The aforementioned findings, from the neurophysiological point of view, confirm our experience that children with the disorder of speech rhythm, and offen non-differentiated lateral prefrence for speech, who came to the Th. treatment until the age of 5, successfully finish the Th. treatment until the age of 8, until the successful development of the ability for phoneme segmentation and word synthesis. During the period of speech development and dominant electrical brain activity on low-frequency level, in delta -theta rhythm, it is possible, by therapeutic models to stimulate from the periphery differentiation of muscle praxia for articulation, phonation, breathing, and lateral speech preference, thus enabling differentiation of functions on the central level, for successful, synchronous performance of speech production.

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Table1: The power relation of electrical brain activity according to points, between the state of rest (0) and the reading task of unrhythmed text (26) and between the state of rest (0) and the reading task of the rhythmed text (27) in percentage (%).

EEG Rhythm	Tasks	F7	F8	T3	T4	T5	T6	FP1	FP2	F3	F4	C3	C4	P3	P4	O1	O2
δ	0:26	81,96	267,92	-4,63	143,7	109.4	11,30	193,3	407,6	104,3	96,72	76,79	-24,5	55,56	=	59,43	3262
	0:27	31,19	252,2	-8,33	122,5	115,1	2,82	135,1	160,0	80,47	-1,46	42,86	2,16	73,02	9,43	42,62	18,09
θ	0:26	74,63	82,61	68,18	11,76	40,82	25,0o	172,7	113,6	79.55	51,43	-26,0	-2,27	-14,5	30,77	89,71	172,7
	0:27	53,73	102,2	72,73	29,41	40,82	46,15	189,4	136,4	111,4	48,57	-26,0	22,73	-16,1	23,1	88,24	223,6
α	0:26	=	-5,26	-12,8	-36,9	-43,8	41,4	32,65	12,0	-27,8	13,8	-50,0	-47,5	53,8	-43,9	-1,21	15,8
	0:27	20,34	24,56	2,56	-41,5	-17,8	-28,7	61,22	28.00	-3,70	-6,90	-36,2	-65,0	-26,1	-43,9	10,11	22,77
β1	0:26	66,67	24,24	20,0	=	5,0	-13,0	56,67	66,67	=	88,57	-21,4	-18,7	-31,0	-37,8	=	5,17
	0:27	88,89	30,39	16,67	28,00	-30,0	-19,6	90,0	63,64	23,08	115,7	-3,57	-3,13	=	-6,7	53,45	84,48
β2	0:26	111,8	84,00	52,38	57,89	60,0	36,0	240,6	380,8	29.03	278,0	-3,57	25,93	-10,0	-20,0	17,86	52,17
	0:27	70,59	56,0	42,86	42,11	75,0	20,0	162,5	242,3	25,81	173,7	-21,4	=	-15,0	-13,3	35,71	82,61

Table 2: The survey of power domination of electrical brain activity according to hemispheric regions for both tasks and the difference in activity power according to the tasks

EEG points	FP 1,2			F 7,8			F 3,4			C 3,4			P 3,4			O 1,2			T 3,4			T 5,6		
EEG Rhythm	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem	Rh.t	URht	Dom. Hem
δ		r ++	R		l ++	R		r ++	R		l+r-	L	l ++		L		l ++	L	l -	r +	R		r +	L
θ	l ++		L	r +	l +	R	l +		L	r +		- L		r +	R	r +		R	r +		L	r +		X
α	l ++		L	r ++		≈ -		l -	X≈	r -	l -	-X-		l -	-X-	r +		-X+	l+ r-		R-		l -	-R
β1	l ++		X	l ++		L	r ++		R		l -	≈ -		r -	≈ -	r ++		R	r +	l +	X	l ++		L
β2		r ++	R		l ++	L		r ++	R	l -	r +	R	l -	r -	X--	r ++		R		r ++	≈	l +	r +	L

Symbols used in the table:
R = occurance of larger power values on the right in both tasks
L = occurance of larger pover values on the left in the both tasks
X = crossed pover values according to tasks (- =inhibited)
≈ = same or approximate power vlues according to tasks (- =inhibited; + = inceased); diference below 10%
= = with out difference

URht= unrhythmed text
Rht = rhythmed text
l ++ = power increase of the activuty on both sides - more to the left
r ++ = power increase of the activuty on both sides - more to the right
l - = power inhibition of the activuty on both sides - more to the left
r - = power inhibition of the activuty on both sides - more to the right
+ or - = on one side with the side labelled

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Physiological Analysis of Effect of Negative air ion on Human

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INTRODUCTION

Negative ions in air have a purifying effect on hazardous substances, such as dust, mold spores, bacteria, etc., and they are used as air purifiers and in germ-free rooms. And high levels of negative ions have been detected in forests, at spas, and near waterfalls. They have been reported to related to human beings' feeling of comfort, and a great deal of research related to feelings of fatigue, comfort, and work efficiency has been already been reported[1,2]. The recently developed negative ionizer equipment ("shinki" ionizer; Geochto Ltd. Tokyo, Japan) sprays water through a nozzle and produces a large numbers of negative ions employing the Leonard's effect due to the destruction of waterdrops[3]. Theoretically this equipment does not produce activated oxygen because it has no electric discharge mechanism. We previously assessed the effect of negative ions on humans' physical response in sauna baths. In that experiment the sweat volume and body temperature raising effect were significantly higher when negative ions were present[4]. In this experiment, as a means of investigating the physiological effect on humans during rest in a 25 °C air temperature, 50% humidity environment in which humans are usually active, we prepared an artificial climate room.

METHODS

Preparation of the constant temperature, constant humidity, negative-ion-generating equipment.

In this study, we prepared a 10 m^2 (3600 cm long, 2700 cm wide, 220 cm high) experimental room. The equipment was arranged so that it was possible to control the temperature, humidity, and whether negative ions were added to the artificial climate from outside. The subjects were exposed to a 25°C, 50% humidity environment with or without negative ion loading for approximately 2-hour periods.

Flicker test

The subjects placed both eyes at a hooded window and staring at a flickering light, adjusted the speed of the flickering by turning a knob until the light no longer appeared to flicker.

Electroencephalograph

The surface electrical activity of the brain was recorded with an electroencephalograph (SyNAX1100, Nihon Electric Co.). A continuous 60-minute EEG was recorded with the subject at rest in the seated position with eyes closed.

Auditory evoked potential P300.

The method of measuring P300 in this study was to randomly mix a high-pitch tone (2kHz) with a low-pitch tone (1kHz) at a frequency of 25% and have the subject press the response button when the high-pitch tone was discriminated. The EEG response was summed until 30 correct responses were obtained.

RESULTS

When measured with an ion counter (KST-900 Ion Tester, Kobe Dempa K.K.), the background negative-ion count was usually about 100/cc, but when negative ion generator was activated, the ion counts were 5000/cc or more.

The flicker value, which is a measure of visual fatigue, increased 3.9%(standard error (S.E.) 3.2%) in the presence of negative ion loading. In the absence of negative-ion loading the flicker value decrease 2.4%(S.E.1.5%). The p-value of the difference was 0.053.

Assessment of auditory evoked potential P300 showed hardly any change in the latency nor in the amplitude

Examination of the mean proportions of alpha-waves on the EEG showed that the group exposed to negative ion loading maintained higher alpha2-wave (10 Hz to 12.75 Hz) values, in particular, than the group unexposed group. Alpha-waves have been already reported to increase when subjects relax and diminish when they become tired..

On the subjective impression scale, a higher percentage of subjects reported comfort when negative-ion loading was present (Table).

Table1: Subjective feeling scale

	Comfortable	No Change	Poor
With Negative Ion	6	8	1
Without Negative Ion	4	7	4

DISCUSSION

In the past reports of studies on the effect of negative ions in the air, the evaluations were based on subjective findings, such as feeling of fatigue, comfort, and work efficiency, but there were problems because the criteria were vague. We investigated the levels of fatigue, relaxation, comfort, etc., in humans in the presence and absence of negative-ion loading by means of the latest measurement techniques. Based on the subjects' own impressions, the presence of negative-ion loading was shown to be associated with higher levels of comfort levels and lower levels of fatigue. These findings seems to be acceptable with the fact that the alpha-wave component on the eyes-closed resting EEG was higher when negative-ions loading was present.

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P-150

Clinical Analysis of Acupuncture in Patients of Osteoarthrosis

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INTRODUCTION

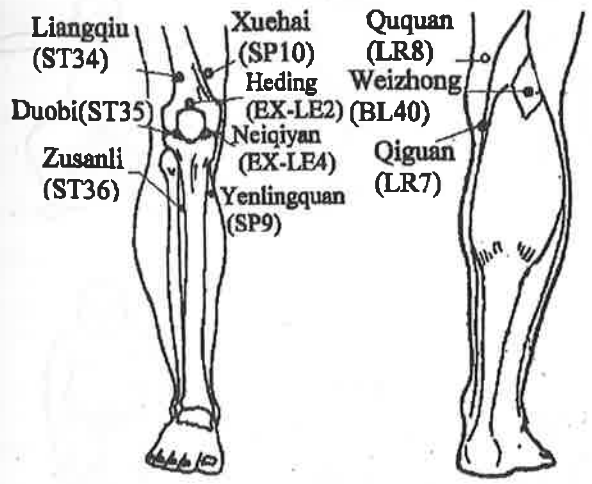
We treated 6 patients with acupuncture and physical therapy. We assessed pain and the ability of gait after the therapy (Standard of Japanese society of orthopedic surgery) and analyzed the effect.

OBJECTS

We analyzed six patients; age range is from 62 to 89 years old and the average age is 72.3 years old. Four cases were suffering from one side of knee joint with osteoarthrosis and other 2 cases were from both knee joints. They were diagnosed as osteoarthrosis by clinical symptom, physical examination and X-ray film.

METHODS

Acupuncture points were Xuehai (SP10, WHO), Heding(EX-LE2), Neiqiyan (EX-LE4), Yenlingquan (SP9), Liangqiu (ST34), Duobi (ST35), Zusanli (ST36), Ququan (LR8), Weizhong (BL40) and Qiguan(LR7). The acupuncture duration is 30 minutes once a week and 4 patient are treated 6 times (6weeks) and 2 patients are treated 4 times (4weeks).



During the therapy, we added the physical therapy; the massage of the knee joints, thigh, patellar ligament, both sides of patella, hamstring muscle, flexion and extension of knee joins within the range of motion. And we persuaded them the self-training program as the exercise for strength quardriceps and SLR(straight-leg-raising : at 45 degrees) exercise everyday.

RESULTS

The total score before the therapy is 40.0±14.8(mean±Standard deviation) in 6 patients. After the therapy, the average score improved to 58.3±10.3, and there were statistically different by paired t-test($p<0.01$) analysis. The improve of the score is significant in Pain-Gait score(5.0±4.5(before) vs 13.3±2.6(after)), 'Pain-Stairs' score(5.8±3.8 vs 10.8±3.8), ROM (20.0±5.5 vs 25.0±4.5), but the swelling score is no difference between before and after the therapy(9.2±2.0 vs 9.2±2.0).

CONCLUSION

Osteoarhrosis is not completely cureable pathologicaly. In this study, the complex therapy of acupuncture and the physical therapy shows the improvement of the disorders of patients. We recognized the reduced pain obviously and the improvement of ROM. The mechanism of acupuncture therapy is due to the dilatation of blood vessel and improvement peripheral circulation. And the stimulation of acupuncture was found to secretion endorphin and acetylcolin in the brain. Acupuncture is easy and good treatment.

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P-151

Senile Chronic Lumbago Treat with Kinesitherapy

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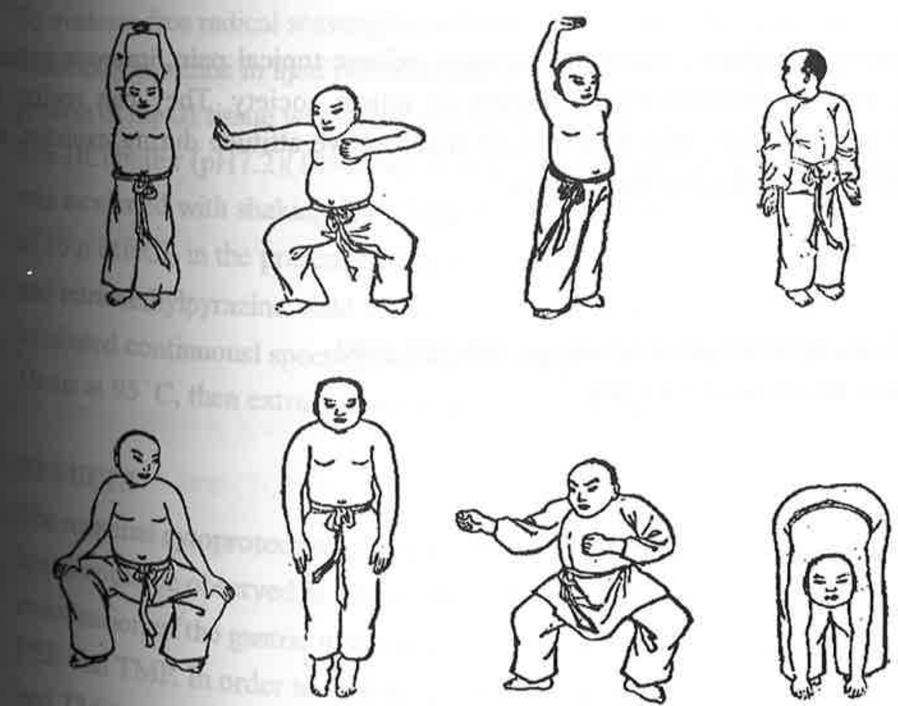
INTRODUCTION

The characteristics of senile chronic lumbago:1.It comes on slowly and the course of disease is rather long generally.2.Most of them were suffering from other senile chronic diseases. For example: Hypertension, heart disease, arteriosclerosis of brain, diabetes mellitus, chronic bronchitis, senile emphysema and so on.3.The therapeutic effect appears slowly and forward effect can't retain steadily.

The cause of senile chronic lumbago:1.lumbo-sacral strain 2.mascular rheumatism 3.Lumbar muscle sprain 4.Iliosacral arthritis 5.Fascitis

Although thermotherapy, electromagnetotherapy, massotherapy have good effect to the senile chronic lumbago, it is still difficult for the old people to go to the hospital to take physicotherapy every day by bus or on foot. For example: Usually he will spend one to two hours from home to the hospital by bus because of traffic jam in China. Trip and getting tired are often happened on the way and make their other senile chronic diseases more serious, so I suggest that it's good for the old patients to select the therapeutic exercises, and give them regular guides.

METHODS



1998-1999,15 cases, patients'age:65-81,and all of them suffering from other senile chronic diseases.1.Walking outdoor: walking speed is decided according to their body's specific condition.60-80 feet/minutes,15-20 minutes, one to twice a day or every other day generally.2.BaDuanJin(八段锦)(a kind of traditional Chinese exercise):The above maps show its' 8 movements. It's easy to learn. The position of standing and sitting are all acceptable. But it is better to be in standing position as possible as he can during the exercise.20-30 minutes, one to twice a day. Exercise quantity of the above mentioned two kinesitherapy that patients don't feel tired after exercise is good. Return visit is every third week.

RESULTS

7 cases improved after two weeks. Backache has alleviated.2 cases cured, backache disappear,10 cases improved after four weeks.6 cases cured,7 cases improved,2 cases still were not obvious improvement after six weeks.

DISCUSSION

Walking outdoor is a motion of the whole body's coordination, can be enhance the whole body's function of metabolism, promote the function of heart, lungs and nervous system. They have a breath of fresh air while enjoying the view along the way, happy and relaxed during walking. It can improve patients' low spirit and raise their confidence of curing sickness, reach physical and mental health finally. BaDuanJin is a slow and flexible motion, very suitable for old people. There are many movements of stretching back muscle. Persisting in exercising can enhance topical blood circulation, help to eliminate those things that cause pain, is conducive to improve resilience of back muscle and muscular strength, relax adhesion.

CONCLUSION

Therapeutic exercises can enhance patients' physique, relieve topical pain, improve patients' abilities of taking care of themselves, help them to retune society. They can realize the relationship of life and exercise, take part in with more active attitude during exercise, and make it to be a health care method of themselves.

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Effect of Antioxidants on Ethanol-induced Peptic Toxicity -An In Vivo Study

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INTRODUCTION

Acute p.o. administration of absolute ethanol (1.0ml) to fasted rats produced extensive necrosis of gastric mucosa. Pretreatment with p.o. administration of propolis ethanol extract (PEE) or tetramethylpyrazine (TMP), could prevent such necrosis effectively and dose-dependently. These protective effect of PEE and TMP are called "cytoprotection".

METHODS

Wistar rats were divided into eight groups with 10 animals each. Group 1 (control) received saline (2ml/Kg, p.o.)., Group 2 received absoulte ethanol (1.0ml, p.o.). Groups 3-5 received TMP at the doses of 50, 100 and 150 mg/kg p.o. respectively, Groups 6-8 received propolis ethanol extract at the doses of 1%, 5% and 10% p.o. respectively. Both propolis ethanol extract (PEE) and tetramethylpyrazine (TMP)were p.o. administrated at various doses 30 minutes before oral administration of 1.0 ml absolute ethanol. The animals were killed 1hr after absolute ethanol administration. The above procedure was according to Zhang et al., 1995.[1]

To evaluate free radical scavenging activity of propolis ethanol extract and tetramethylpyrazine in lipid peroxidation generated superoxide anion assay system. A protion of rat GI tissue was sliced and homogenated (13,000rpm, 3min) with 25mM Tris-HCl buffer (pH7.2)(10%w/v). In a glass test tube, 0.1 ml of the GI homogenate was incubated with shaking for 1 hour at 37˚C in Tris-HCl buffer (pH7.2), with 0.1ml of 30 μ MfeCl$_2$ in the presence of various concentrations of propolis ethanol extract and tetramethylpyrazine. Add 1.5ml of 1.0% TBA and 1.5ml of 20% acetic acid incubated continuousl spectrophotometer analysis at 532nm absorption spectrum.y for 1hour at 95˚C, then extract upper liquid solution for

RESULTS

The maximal cytoprotective effect against absolute ethanol-induced gastric mucosal lesion could be observed at 1 hour after PEE or TMPadminstration. A gross examination of the gastric mucosa showed a marked improvement in groups received PEE and TMP. In order to further investigate the gastric protective mechanism of PEE and TMP, superoxide scavenging effect was also conducted. Both PEE and TMP exhibited dose-dependently antioxidant effect in FeCl$_2$-induced lipid peroxidation in rat gastric mucosal homogenate.

CONCLUSION

It was concluded that the gastric protective mechanism of PEE and TMP could be contributed, at least in part, to their prominent superoxide scavenging effect, hence they could protect the gastric mucosa from superoxide induced gastric damages.

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Evaluation of hemodynamic change on forefeet in Dialysis Patients with Complicating Arteriosclerosis Obliterans (ASO)

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[INTRODUCTION]

The diagnosis of ASO of lower extremities can be made by the history alone or by the physical examination alone in the most patients. Particulary, the two major symptoms are intermittent claudication and ischemic rest pain. Intermittent claudication is pain or fatigue that occurs in a muscle or muscle group on excessive use. Ischmeic rest pain indicates an advanced stage of disease. Foutaine classification is usually used as the stage of ischemia on the lower extremities. By the way, the effects of these patiens on hemodynamic changes that occur during exercise (e.g. walking, cycle ergometer, calf-pumping etc.) are largely unknown. In this study, the dialysis patients with complicating ASO (HDpt) were examined using the walking exercise to evaluate the transcutaneous blood oxygen (TCPO2) related to physical fitness, such as hemodynamic responses.

[SUBJECTS]

The subjects consisted of 5 HDpt's and 5 NHDpt's (average age 59.8 years) all of whom were diagnosed as having Fontaine I -III and were able to walk continuously for 5 min at 3.5 km/h.

[METHODS]

$TCPO_2$ during exercise loading was measured in the sural region at the first therapeutic exercise and 2 months later ($TCPO_2$ monitoring allows noninvasive evaluation of peripheral hemodynamics). The recovery time from a value during exercise loading to a pre-exercise value and the difference ($\Delta PCPO_2$) between a pre-exercise value and a minimum value were compared between the two groups.

[RESULTS]

Therapeutic exercise produced shortening of the recovery time and decrease of the $\Delta TCPO_2$ ($p<0.05$). Comparison between the two groups in recovery time and $\Delta PCPO_2$ revealed no significant difference.

[CONCLUSION]

These results suggest that the waking exercise would be relatively recovered to the hemodynamic pattern on the calf in HDpt's with complicating ASO.

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ELECTROMYOGRAPHIC ANALYSIS OF ABDOMINAL MUSCLES DURING THE PERFORMANCE OF VARIOUS FORMS OF SITUP EXERCISES

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Introduction: The question of which type of situp is most effective in developing abdominal musculature has been frequently asked, but never satisfactorily answered. Through an electromyographic analysis during the performance of situp exercises, it is possible to determine quantitatively which muscle is the most active in each form of exercises. It was the purpose of this study to compare electromyographically the functions of the rectus abdominis (upper and lower portions), the external oblique muscles, and the paraspinal muscles during the performance of 4 common forms of situp exercises.

Method: The rectus abdominis, the external oblique muscles and the paraspinal muscles were studied electromyographically in ten healthy male subjects (ages between 22 to 29 years) performing 4 forms of situp exercises including hook lying situp, crunch, leg raise and hanging leg raise. The 4-Channel SPIRIT EMG-EP system, Nicolet Biomedical Inc., was utilized and the action potentials were captivated by surface electrodes. Peak-to-peak amplitudes and numbers of phases of the tracings were analyzed and thus determined how active each muscle was.

Results: The lower portion of rectus abdominis was most active during hook situp (Amp = 740.8 ± 252.1 uV, P = 0.0062 and APP* = 21.6 ± 6.0, P = 0.0001) whereas the external oblique muscle presented the most intense activity during the hanging leg raise (Amp = 983.7 ± 159.3, P = 0.2436 and APP = 28.0 ± 4.6, P = 0.0871). In the hanging leg raise exercise, the upper and lower portion of rectus abdominis, the external oblique muscle and the paraspinal muscle exerted the highest activities as compared with those in the other types of exercises (Amp P = 0.0047,P = 0.2114, P < 0.0001 and P = 0.0037 respectively and APP P = 0.0207, P = 0.3937, P < 0.0001 and P = 0.0093 respectively). APP* = Amplitude-Phase product = Amplitude (mV) X number of phases.

Discussion: The primary finding of this study is the great intensity of the hanging leg raise exercise for the upper and lower rectus abdominis, and the external oblique muscle. The fact that the legs are heavy and relatively long levers accounts for the great strain on the rectus abdominis that must counteract the hyperlordosis of the lumbar spine by the intense iliopsoas contraction. On the hanging leg raise exercise, the paraspinal muscles at the lumbar spinous levels also exerted the highest activity as compared with that in the other type of exercise. This could be drawn to the fact that in attempt to pull the legs upwards, the body had to contract the back muscles with some force in order to help hold the lower part of the body above the ground with the iliopsoas and rectus abdominis. The lower rectus abdominis was the most active on the hook lying situp. Leaving the legs free in the hook situp seemed to place greater strain of the rectus abdominis which was attributed to reduction of the biomechanical potential of iliopsoas to assist the movement.

Conclusion: The hanging leg raise is the most intense exercise using the rectus abdominis and external oblique muscles, however, the unwanted activity of paraspinal muscles is also high.

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ELCTRODIAGNOSTIC CHANGES IN TRUE NEUROLOGIC TOS

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ABSTRACT:

TRUE NEURLOGIC TOS IS A VERY RARE DIAGNOSIS BUT OTHER TYPE OF TOS DISPUTED TYPE IS A COMMON DIAGNSIS BUT HAS NO OBJECTIVE BASIS AND IS VERY CONTRAVERSIAL. ACCORDING TO COMMONLY ACCEPTED CRITERIA

-LOW ULNAR SNAP &CMAP

-LOW MEDIAN CMAP

&NORMAL MEDIAN SNAP

WITHIN ABOUT 2000 EMG FILES OF OUR PATIENTS IN 3 YEAR PERIOD WE FOUND ONLY 13 PATIENT WITH FULL CRITERIA AND EVALUATED .

IN ALL OF THEM ULNAR SNAP WAS DECREASED AND IN 50% IT WAS SIGNIFICANT (MORE THAN 50%). DECREASE IN MEDIAN

CMAP WAS MORE CONSIDERABLE THN ULNAR CMAP .

IN 1 PATIENT TOS WAS BILATERAL AND IN 1 IT WAS WITH CTS (DOUBLE CRUSH).

IN 4 PATIENTS THERE WAS ATROPHY . ADSON TEST WAS POSITIVE IN 40% OF PATIENT .

Tuesday, June 27

Free Paper

O-51

A Comparison of Surface EMG and Clinical Measures of Altered Motor Control and Spasticity after Spinal Cord Injury

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INTRODUCTION: Spasticity is a common sequellae of spinal cord injury (SCI). Development or selection of management methods for spasticity is complicated by the absence of appropriate means for objectively and quantitatively monitoring spasticity and upper motor neuron dysfunction. A widely accepted definition of spasticity was presented by Lance[1970], namely that spasticity is a "velocity-dependent increase in tonic stretch reflexes ... with exaggerated tendon jerks ... as one component of the upper motor neuron syndrome". Young[1989] broadened the definition to include the Babinski response, velocity-dependent increase in tonic stretch reflexes, exaggerated phasic stretch reflexes, hyperactive cutaneous reflexes, increased autonomic reflexes and abnormal postures to describe manifestations of excessive involuntary motor activity which he defined as spastic paresis. However, there is general agreement that, at present, there exists no ideal "gold standard" against which to compare putative systems for assessing the spastic individual.

Of more immediate concern to spastic SCI individuals than hypertonicity are the spasms, or involuntary muscle activity, which they frequently experience. In this paper, we mean centrally-generated neuromuscular activity associated with SCI, which, when present, is problematic for those subjects[Barolat and Maiman, 1987; Young, 1994]. Attempts to objectively quantify such behavior have been made based upon extended recordings of EMG activity[Brand and Delhaas, 1992; Tepavac et al., 1992].

We have described a multi-channel surface electromyographic (sEMG) technique called brain motor control assessment (BMCA) which provides a basis for comprehensive assessment of spasticity[Sherwood et al., 1996]. We propose that sEMG data capture the "excitability" of the subjects, which we suggest is the best measure of altered motor control or spasticity. To explore the utility of the sEMG method to characterize altered motor control (spasticity) in subjects after SCI and as an initial effort to develop an index of that altered control based on the sEMG measurements, we report sEMG observations during passive limb movement, tendon taps and plantar stimulation[Sherwood et al., 2000; Zupan et al., 1998]. We analyzed this data from 97 subjects with SCI to investigate our ability to utilize sEMG results to distinguish among the subjectively determined Ashworth categories for these subjects who exhibited varying degrees of spastic behavior and spasticity.

METHODS: A convenience sample of 95 male and 2 female veterans with cervical or thoracic SCI were studied. Subjects exhibited a range of severity of lesions, with 42% classed as AIS A, 29% as AIS B, 18% as AIS C and 11%, AIS D.

The protocol was conducted in two parts carried out after placement of surface electrodes over major muscle groups of the lower limbs. The first part consisted of a clinical examination of muscle tone from passive hip and knee flexion[Ashworth, 1967], tendon taps to adductors, quadriceps and triceps surae muscles[Bates, 1991] and plantar reflexes[van Gijn, 1978], evaluated using published scales.

The second part was the execution of the BMCA protocol, for which pairs of recessed, silver-silver chloride surface electrodes were placed over major muscle groups of the lower extremities (quadriceps, adductors, hamstrings, tibialis anterior and triceps surae. sEMG signals were amplified with a gain of 5,000 and a bandwidth of 40 Hz to 600 Hz (-3 db) and were digitized at 1800 samples per second (s/s) per channel with 12 bit accuracy. Data were collected in strict accordance with a more extensive protocol[Sherwood et al., 1996], from which we report here results for the same maneuvers repeated during the electrophysiological evaluation.

Clinical data were scored according to published clinical scales as previously described[Priebe & Sherwood, 1995]. The original full bandwidth sEMG data were reduced post-hoc using a root mean square (RMS) algorithm to an sEMG envelope with an effective sampling rate of 20/s, and then averaged for each muscle channel over a 5-second window following maneuver initiation. Tendon tap responses were analyzed as peak-to-peak (p-t-p) voltages within a time window from 15 to 75 ms following the tap delivery. Both average and p-t-p voltages were corrected by subtracting immediate, pre-maneuver activity levels, RMS and p-t-p respectively.

Data Analysis

Two methods of summarizing the sEMG data were utilized to address the relationship between the clinical (Ashworth) and quantitative (sEMG) assessments of altered motor control and spasticity. As the "expected" activity in a healthy subject is zero, for the first analysis, we chose to summarize the sEMG data by using, for the right side only, the average of the 5 muscle groups measured. This average we have denoted by ALR (average limb response). Then to consider the relationship between ALR and the Ashworth score we have used analysis of variance with the Ashworth categories (4 levels) and phase of movement (2 levels - flexion and extension) as independent variables (or factors) and ALR as the outcome (or dependent variable).

The second analysis was a multivariate analysis of variance using as the outcome a five element response vector (RV). Each element of this vector represents the response, for the right side only, of a single muscle group (Q, A, H, TA, TS) to one phase of movement (flexion or extension). The independent variables (or factors) for this multivariate analysis were the Ashworth categories (4 levels) and phase of movement (2 levels) with the response vector as the outcome. The five individual response elements (muscles) were included to determine if there are differences in the patterns of motor activity between the Ashworth categories.

RESULTS: The clinical hallmark of spasticity as ordinarily construed, is the resistance to passive stretch. In individuals with spasticity after SCI, passive movements may activate the muscles stretched as evident both in the perceived resistance to stretch and in the electromyographic activity in those muscles. We shall illustrate the type of surface electromyographic (sEMG) activity elicited by these passive maneuvers in several subjects selected to demonstrate some of the possible responses to the maneuvers. Responses include a reproducible activation of the hamstrings with accompanying resistance to movement, and similarly activation of the quadriceps during the extension phase of the movement.

While the clinical examiner may perceive resistance in the form of opposing torque generated about the joint or joints moved, the sEMG signals revealed any spread of activation to other muscles in the same limb or even to muscles of the contralateral limb. In some instances, this spread of activity nevertheless resulted in little or no perceived torque due to the uncoordinated pattern of such activity, and indeed, occasionally opposing forces generated in antagonistic muscles. Thus, the sEMG data generated during passive movement usefully describe the behavior of the spinal motoneuron pools during and after the conclusion of such movements, for a period of time selected in the analysis (here 5 s).

sEMG data recorded during passive maneuvers and averaged over the five muscle groups on one side differed significantly in those with different Ashworth scores ($F = 19.59$, df 3 & 178, $p < 0.001$). However, such average scores differentiated only the highest Ashworth scores. Multivariate tests showed significant differences in the five muscle responses between Ashworth categories ($F = 5.01$, df 15 & 480, $p < .001$). Not surprisingly, statistical differences were less clear between Ashworth scores 0 and 1 than between other combinations.

Mean tap amplitudes were on the order of 300 μV for Q and TS, and 125 μV for the A muscle groups. Analysis of tendon tap responses revealed a correlation of 0.57 ($p < 0.01$) between the

magnitude of the tap response and the Bates score given. However, the sEMG picture of responses to tendon taps reveals a much more complex picture, including spread of activity to other muscles, about 20% of the time ipsilaterally and 5% contralaterally, judged conservatively as responses > 50 μV, more than five times the noise level. In addition to the reflex response within the defined window appropriate for a monosynaptic reflex, we also found phasic (12%) or tonic (7%) activity induced by the tendon taps in these subjects.

Plantar stimulation evoked withdrawal responses in those patients with heightened excitability. Correlation of right side sEMG responses to right plantar stimulation with the van Gijn (clinical) score was 0.44. While there was a general agreement of clinical and sEMG scores, there were a number of exceptions as evidenced by the relatively low correlation. The score "4" on the van Gijn scale represents a response to a very low stimulus strength, which was not evaluated in the BMCA protocol.

DISCUSSION: By recording sEMG data it is possible to directly measure the behavior of the neuromuscular system in a variety of conditions. We propose that these measures are relevant to the subject's underlying pathophysiological, spastic condition. Proper interpretation of the quantitative sEMG data requires knowledge of the recording situation and most importantly, full appreciation of the event or maneuver leading up to the recorded activity. Employment of fully documented "controlled inputs" makes it possible to interpret the results of the recording.

The premise upon which this paper is based is that altered motor control following SCI or spastic paresis[Young, 1994] is most often and most directly evident as increased excitability of spinal motoneuron pools[Taylor et al, 1984; Milanov, 1994; Dimitrijević & Nathan, 1967]. This increased excitability is manifested in a variety of features, including exaggerated phasic and tonic reflexes, spasms and altered voluntary control. Regardless of the mechanism (loss of inhibition, changed properties, etc.), motoneuron hyperexcitability is undoubtedly centrally involved in all these manifestations of spasticity.

Accounting for Discrepancies There is a general perception, perhaps because of the variability in motor control observed when studies are not well-controlled, that sEMG data is highly variable. However, we previously demonstrated that the methods used in this study are quite reproducible, with test-re-test correspondence as high as 0.97 with averaging[Sherwood et al., 1997]. Thus, the sEMG data reflect the expressed motor control, and by controlling the sources of variability in motor control, one can gain a representative and reproducible impression of that control through the sEMG data.

What is the "right" answer? We propose that, when sEMG and clinical values suggest conflicting results, the "right" answer is the one which is most useful in the management of spastic paresis, for example, in decision making regarding pharmacological interventions. Selection of such interventions intended to modify neuromuscular functions is more appropriately based upon the sEMG measurements rather than upon perception or measurement of increased torque. The sEMG result more closely corresponds to the inappropriate neuromuscular function than does the torque-based result. Assessments which evaluate the effectiveness of a particular intervention based only on net torque may occasionally yield confounding results compared to assessments which are based on the total neuromuscular activity evoked by this particular maneuver.

Conclusions The lack of an acceptable "gold standard" for assessment of spasticity prevents establishment of criterion-related validity for sEMG measures. The ability to objectively record the sEMG data and reduce to numbers does not equal the ability to *assess* spasticity in the subjects in whom the measures were taken[Kondraske, 1989]. Nevertheless, the presented data correlates to a limited degree with accepted clinical scales, and thereby achieves at least some degree of criterion-related validity. To achieve content validity, all these measures must be incorporated into a multi-dimensional scoring system[Priebe et al., 1995].

In summary, the multi-channel, sEMG approach described in this paper provides an important method of assessing motor behavior under a variety of circumstances. Data obtained are quantitative, reproducible and clinically relevant. This technique may be directly applied to repeated observations on the same subject to describe changes in motor control with treatment, e.g., as the uncertainty of the inverse problem may be assumed a constant. Remaining problems with this technique include the identification of appropriate coefficients that will permit transformation of the sEMG data into an absolute, pooled firing rate data space, taking into consideration biophysical differences among subjects. ***The fact that the data as currently processed seems to yield valid results suggests that neglecting this theoretically important transformation is not a major source of error.*** Nevertheless, continuing efforts should be made to improve the absolute accuracy of this data through such transformations, and continued studies are needed to identify the limits of accuracy of the data, and to determine the relevance of the derived scores.

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Assessment of Paraspinal Muscle Fatigue During Repetitive Lifting in Patients with Chronic Low Back Pain

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INTRODUCTION The assessment of paraspinal muscle function plays an important role in the management of patients with low back pain (LBP). Previous studies of static, isometric trunk extension have shown that when one or more paraspinal muscles are deconditioned, inhibited by pain, or are effected by mechanical deficits, a predictable change in the electromyographic (EMG) spectral and amplitude parameters occur during fatiguing contractions [Roy and Oddsson 1998]. Recent work has demonstrated that it is possible through signal processing algorithms based on time-frequency analysis procedures to derive spectral estimates of the EMG signal during dynamic contractions [Knaflitz and Bonato 1999, Roy et al. 1998]. Results suggest that frequency modulation in the time-frequency distribution of the surface EMG signal acquired from paraspinal muscles can be used to characterized muscle fatigue during repetitive lifting. The clinical relevance and applicability of this new approach to the assessment of paraspinal muscle impairments in patients with LBP during functional tasks, and their relationship to functional limitations, has not yet been explored. This paper describes preliminary findings from a clinical study in progress designed to address these questions. The EMG procedure for analyzing repetitive lifting was implemented to objectively measure muscle dysfunction in patients with LBP participating in a functional rehabilitation program.

METHODS Ten subjects with chronic LBP were recruited following informed consent after admission into a 10 week work rehabilitation program. Subjects were evaluated on a battery of clinical tests and their functional capacity was assessed using the Physical Work Capacity Evaluation (PWCE) [Lechner et al. 1994]. Surface EMG signals were recorded from 2 contralateral paraspinal muscle sites (L2 and L5 spinal levels) during repetitive lifting and lowering of a weighted-box in the sagital plane. The weight of the box was set to 50% of the subject's maximum safe lift as determined by the PCWE [Lechner et al. 1994]. The subject performed a "free lift" (i.e. combined trunk and knee flexion) from mid-shank to waist height at a rate of 12 lifts per minute for 4 minutes. The EMG data were analyzed by computing the instantaneous median frequency (IMDF) over successive cycles of the lifting task [Knaflitz and Bonato 1999]. A specific phase of each lifting cycle was selected corresponding to the peak RMS amplitude of the EMG signal. The IMDF was then computed for each of these phases during the lifting task. IMDF cyclical behavior, indicating periods of fatigue and recovery, were quantified by Lomb spectra.

RESULTS AND DISCUSSION Data from two patients undergoing a comprehensive reconditioning program for work-related injury are presented in *Figure 1*. Both LBP patients are of similar age and occupation and are otherwise healthy. They represent extreme cases, where one of the patients has relatively little pain-related disability (Oswestry score = 22% disability) and the other a high level of pain-related disability (Oswestry score = 65% disability). The time-course of the IMDF for one paraspinal muscle (Right L5) is illustrated in *Figure 1A*. For both patients there is an overall decrease between the initial IMDF and final IMDF. Whereas the IMDF time-course in the patient with minimal disability is characterized by large alternating phases of increase and decrease during repetitive lifting, the subject with the high level of disability shows less frequency modulation. Previous studies in healthy controls have found similar fatigue/recovery behavior of IMDF as our patient with minimal disability. The Lomb spectrum for both patients indicate that the IMDF cyclical behavior in the patient with minimal disability is approximately three times that observed in the patient with high disability. The results suggest that Lomb spectra of the IMDF time-series may provide a useful index to contrast patients with different levels of disability.

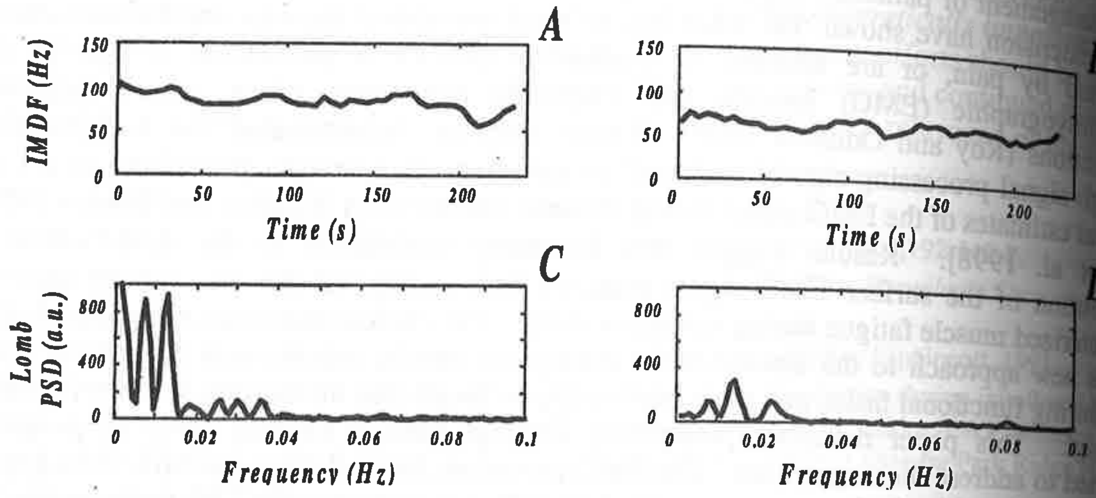

Figure 1 A and B Time-course of IMDF, C and D Lomb spectrum (PSD) of IMDF time-series from left paraspinal L5 muscle for 2 LBP patients during a 4 minute lifting protocol. A and C are from the patient with minimal disability, while B and D are from the patient with high disability.

CONCLUSION The preliminary findings suggest that the time-frequency analysis procedure was successful in deriving EMG spectral parameters to characterize fatigue in LBP patients during dynamic "real-world" tasks such as lifting. The procedure identified a different pattern of fatigue and recovery in paraspinal muscles during repetitive lifting in those patients with extreme disability. Further analysis is underway to establish whether this finding is consistent among a larger number of patients with LBP. Results from this pilot study will serve as an important first step toward developing and extending the technique to clinical and ergonomic research settings.

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O-53

Changes in muscle force and volume following Surface Therapeutic Electrical Stimulation in patients with hemiplegia

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INTRODUCTION

Therapeutic electrical stimulation (TES) has allowed improvement of the motor function of paralyzed extremities. In recent studies of TES to lower extremities of hemiplegia, peroneal nerve was mainly stimulated. The main purpose of TES was the reduction of spasticity (1,2). There are few reports about increasing voluntary muscle force and volume following TES in hemiplegia. The other hand, TES to complete paraplegic patients by using percutaneous electrodes increased muscle force and volume (3).

The aim of this study is to evaluate the changes in muscle force and volume following TES in those with hemiplegia and to show the minimum clinical protocol of surface TES (STES).

METHODS

1) Subjects: Hemiplegic patients (1 man and 3 women) participated in this study. Their average age was 50(+-21) years old. The average time elapsed from onset of stroke was 71.5 months. One patient could walk without devices, others could walk with a T-cane or a short leg brace.

2) Electrical stimulator: Stimulation was applied by means of two pairs of surface electrodes and stimulator. The electrodes were placed along the peroneal nerve in the fossa poplitea and over the head of the fibula, and along the femoral nerve in the femoral triangle and over the lateral vastus muscle, respectively. The electrode was 70 x 90 millimeters in size and consisted of rubber and gel. The stimulator made by OG GIKEN Co. Ltd. with two channels output was used. Pulse width was 0.3 milliseconds, stimulation frequency was 20Hz, and pulse amplitude was 0 - 100 volt. Stimulation of the muscles was done for 15 min. twice a day.

3) Clinical procedure: The patients were asked for two weeks hospitalization to evaluate pre-TES status and to learn self-stimulation procedures. The procedures such as placement of electrodes and manipulation of the stimulator were checked every time. After discharge, TES was continued in their homes. Evaluation of TES and confirmation of the procedures were done in every month.

4) Muscle force tests: The voluntary isometric muscle torque of knee extension was measured with the knee flexed at 90 degrees by a strain gauge transducer which was set 23 cm distal to the center of the knee joint.

5) Computed tomography (CT): A CT scan was taken at the middle point of femur. The cross-sectional area of the quadriceps femoris was determined with the help of a computer, and the increased ratio was calculated.

RESULTS

1) Self-stimulation procedures: Three patients could place electrodes precisely by themselves even after discharge. The muscles stimulated showed enough contraction.

2) Muscle force test: Voluntary isometric muscle torque of knee extension showed increase about 30% in four patients.

3) CT: The cross-sectional areas of quadriceps femoris were increased in four patients.

DISCUSSION

For hemiplegic patients, it is very difficult to place electrodes on affected extremities by using unaffected hand alone. At first four days of initial learning period in the hospital, patients could not put electrodes to the precise places. However, they acquired ability of self-stimulation at the end of hospitalization. In this study, STES showed increase of voluntary muscle force and muscle volume. Main problems of gait disturbance in hemiplegia are spasticity and muscle weakness. The result suggested that STES could be a new clinical approach to hemiplegia.

CONCLUSION

In the correct way of self-stimulation to hemiplegia, their voluntary muscle force and volume were increased.

ACKNOWLEDGEMENT

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0-54

Effect of Fatigue on the Activity of the Ankle Flexor Muscles in Running.

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INTRODUCTION

Fatigue fractures occur in bones in response to repetitive stresses when the body's ability to adapt is exceeded. Recent studies have shown that, as a result of fatigue, there is an increase both in the impact acceleration on the shank (1) and in the strain rate on the tibia (2). Clinical and experimental evidence suggests that the stress injury take place at the site in which the maximum tensile stress due to bending is present. Contraction of muscles on the tensile side of a bending bone acts to limit the tensile strains there, helping to protect the bone from fracture risk. Muscle fatigue can, therefore, compromise the protective action provided by the muscles to the shank by reducing the dampening effect and accelerating the initiation of stress fractures. One important question is whether, as a result of fatigue, an imbalance between the activities of the plantar and dorsi flexor muscles of the ankle develops. The aim of this study was therefore to test whether, with progressing fatigue in long-distance running, an imbalance in the activities between the ankle flexor muscles accompanies the increase in shank impact acceleration.

METHODS

Fourteen male recreational runners volunteered to participate in this study. All subjects were provided with similar plain running sneakers. During running, the respired gas was continuously sampled for determination of the gas exchange and ventilatory variables. End tidal CO_2 pressure ($PETCO_2$) was used for indicating both the anaerobic threshold (AT) and global fatigue (1). The running tests were performed on a treadmill for a duration of 30 min at a steady speed exceeding the AT level of each subject by 5%. A light-weight (4.2 grams) accelerometer was externally attached above the tibial tuberosity of the right leg to monitor impact acceleration. EMG of the tibialis anterior and gastrocnemius muscles was also monitored during running and its processing included integrated EMG (IEMG) and mean power frequency (MPF).

RESULTS

The average of the individual running speeds for all the subjects tested was 12.71± 0.68 km/h. Averages of $PETCO_2$, impact acceleration on the shank, MPF and IEMG of the gastrocnemius and the tibialis anterior muscles, are summarized in the Table 1. The results indicate that, with the development of fatigue, changes in the ankle flexor muscle activity took place in addition to the increase in impact acceleration. The development of loading imbalance was demonstrated by the myoelectric signals of the gastrocnemius and tibialis anterior muscles. The IEMG of the gastrocnemius muscle did not change suggesting a maintained activity of this muscle. In the tibialis anterior muscle, however, both MPF and IEMG decreased substantially indicating that activity of this muscle is reduced due to fatigue.

DISCUSSION

We have addressed two major fatigue-related factors taking part in exposing the shank to stress fractures risk. One is increased intensity of the impact acceleration on the shank

Table 1. Averages for all the subjects (n=14) of $PETCO_2$, impact acceleration and EMG results for gastrocnemius (GA) and tibialis anterior (TA), including MPF and iEMG. Running speed, just exceeded the anaerobic threshold and the results (Mean (SD)) are shown for different stages of the 30min running duration.

Parameters	Running time (min)						
	1	5	10	15	20	25	30
$PETCO_2$ (mmHg)	43.9 (1.4)	45.1 (2.9)	43.5 (3.6)	42.5 (3.1)	40.6 (2.6)	39.5 (2.7)	37.1* (2.5)
Impact accel. (g)	6.9 (2.9)	8.6 (3.7)	10.0 (4.7)	10.5* (4.7)	10.1* (4.7)	10.7* (4.0)	11.1* (4.2)
MPF (Hz) GA	102.3 (13.5)	105.4 (15.6)	106.4 (15.9)	109.4 (15.9)	112.5 (16.6)	114.9 (15.1)	115.5* (15.3)
MPF (Hz) TA	90.6 (15.0)	80.3 (14.0)	78.6 (10.7)	76.8 (14.7)	74.7* (14.5)	73.8* (19.9)	72.8* (19.3)
iEMG GA	——	0.89 (0.16)	0.82 (0.12)	0.83 (0.19)	0.81 (0.23)	0.73 (0.19)	0.75 (0.19)
iEMG TA	——	1.15 (0.50)	0.82 (0.37)	0.72 (0.37)	0.68* (0.35)	0.60* (0.30)	0.54* (0.20)

* Significantly different ($P<0.05$) when compared to the early stages of running.

accompanying the decline in $PETCO_2$ the latter expressing metabolic fatigue. The second is the increasing imbalance between the ankle's antagonistic flexor muscles resulting from changes in the activities of these muscles. Muscles have an important role in bone loading, particularly bending. Since bone is weaker in tension than compression, it should be of interest to protect the bone from excessive tensile stresses. Co-contraction of antagonistic muscles do help in providing that protection by (a) compound bending lowering the tensile stresses on the bone; (b) stabilizing the lower leg at heel strike while loading occurs; and (c) serving as effective shock absorbers to lessen impact on the shank due to the initial heel contact. Thus, when imbalance between the muscles develops and the muscles that span the tensile surface of the bone become less active than those of the opposite one the result is a decrease in the protection abilities of the muscles.

ACKNOWLEDGEMENTS

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O-55

Relationship between Joint Force/Muscle EMG and fMRI-Measured Brain Activation

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INTRODUCTION

The study of central nervous system (CNS) mechanisms underlying voluntary movements or muscle actions requires a thorough understanding of the relationship between the CNS signal and muscle activation. Single-cell recordings in motor areas of monkey brain have shown a direct relationship between neuron discharge rate and force exerted by upper limb joints (1,2). However, it is uncertain if single-cell information can represent activities of an entire cortical field (e.g., motor cortex) or the whole brain. The purposes of this study were to (i) determine the relationship between human brain activity measured by functional MRI (fMRI) and handgrip force and EMG of finger flexor muscles and (ii) examine the activation relationship between different cortical motor fields.

METHODS

Subjects: Ten healthy volunteers (8 men and 2 women, age = 31.3±6.5 years).

Force and EMG recording system: Handgrip force was measured by a hydraulic system incorporated with a pressure transducer. The output of the transducer was amplified, digitized (100 samples/s), and recorded on hard disk of a laptop computer. Bipolar surface EMG was measured by silver-silver electrodes with heavy-duty, shielded wires that connected to the amplifiers. The EMG signal was digitized (1,000 samples/s) and recorded on hard disk of the laptop computer. The pressure transducer, signal amplifiers, and data acquisition system were located outside of the MRI room to minimize interference between the two systems (MRI and force/EMG).

Procedures: Bipolar electrodes were attached to the skin overlying the following muscles of the right arm: flexor digitorum superficialis, flexor digitorum profundus, and extensor digitorum. The subject was positioned in the MRI chamber (supine) with the head stabilized by padded restrains and by taping the forehead to the frame of the head coil. Based on the maximum force obtained with the subject positioned in the MRI machine, the submaximal force levels (20, 35, 50, 65, and 80%) were calculated. At each force level, fMRI images were collected during a rest (baseline) period before the contraction and during the contraction period. In each period, 20 brain slices (each 6 mm thick) were imaged and each was repeated 10 times (200 images total). A 3-min interval was provided between two levels of contractions. Five subjects performed the contractions in ascending order and the other five in descending order. All images were collected on a SIEMENS 1.5T VISION system using a circular polarized head coil and an interleaved multi-slice gradient echo EPI pulse sequence (TR/TE =1.2/22 ms). The field of view was 128 x 128 mm and matrix size was 256 x 256; thus, the pixel size was 2 x 2 mm.

Data analysis: The force signal was averaged across the entire contraction, and the true percentage was calculated at each level. The EMG of each muscle was rectified and averaged (AEMG) over the 5-s period prior to the image collection. The AEMG of each muscle was normalized to the maximal AEMG of the muscle. The fMRI data analysis was performed using the MEDx 3.2 software package (Sensor Systems, Inc., Sterling, VA). The images in each 25-s data collection period were averaged (each slice was an average of 10 images). Each slice in each period was then compared to the corresponding slice of the rest period on a pixel-to-pixel basis using *t*-tests. The number of activated pixels (based on an activation threshold of *z*-score ≥ 2.5) and amplitude of *z*-scores were calculated in the entire brain (20 slices) and in the following individual cortical fields: primary motor cortex, primary sensory cortex, premotor cortex, areas 5 and 7 in the parietal lobe contralaterally and ipsilaterally; and supplementary motor area, cingulate gyrus, prefrontal cortex, and cerebellum bilaterally. Statistical analyses involved correlating the handgrip force with fMRI data and the EMG signal with fMRI data for different regions of the brain and for the whole cortex. Additionally, we also examined the correlation between fMRI signals between different regions of the brain.

RESULTS

There was no difference in the data quality between the conditions with and without operation of the force/EMG recording system with the MRI machine (3). There was a strong correlation between the handgrip force and fMRI signal and between the EMG and fMRI signal in different cortical fields. Almost all the cortical areas showed a significant positive relationship between the two variables (muscle and brain signals). We also noticed a significant correlation between fMRI signals in different regions of the brain.

CONCLUSION

The results indicate that the degree of muscle activation is directly proportional to the amplitude of the brain signal as determined by fMRI measurement. The correlation between fMRI measurements suggests that perhaps multiple motor-related cortical fields are involved in controlling this type of muscle activation.

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O-61

A Study of Motor-Evoked Potentials by Transcranial Magnetic Stimulation in Children with Cerebral Palsy (Spastic Diplegia)

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INTRODUCTION

In our previous study, we clarified that Transcranial Magnetic Stimulation (TMS) appears to be safe for use in children [1-3]. In the present study, we report on the plasticity of the central motor system in patients with cerebral palsy, and the ability of patients with cerebral palsy using the motor-evoked potential (MEP) as revealed by TMS.

METHODS

The subjects included 24 children with cerebral palsy (spastic diplegia) who were between 4 and 15 years old. Informed consent was obtained from all subjects and their parents.

A standardized examination procedure was used: the subject lies supine and as relaxed as possible, but in a fully awake state, with electrodes attached bilaterally to the abductor pollicis brevis (APB) and the abductor hallucis brevis (AHB) muscles over the thenar eminence. The cerebral cortex was stimulated by a single-pulse using the Magstim (M200), a magnetic stimulator, at C3, C4 or Cz (the international 10-20 electrode standard) over the scalp according to the Nihon standard technique. The Magstim produces a maximum magnetic field of 2.0 tesla with an 8-shaped stimulator coil. The stimulation that was strong enough to evoke muscle response was produced by applying 30 to 90% of the Magstim's output capacity, and was not given more than 20 times to any subject.

RESULTS

The MEP of spastic diplegia were divided into 3 types, labelled I, II and III.

Type I: Responses from upper extremities were evoked by stimulation over the motor area of the cerebrum for the upper extremities, and responses from lower extremities were evoked by stimulation on the motor area for the lower extremities, respectively. The latency of MEP from upper extremities was normal, but the latency of MEP from lower extremities was sometimes prolonged.

Type II-a: Responses from upper extremities and also from lower extremities were seen by the stimulation of the motor cerebrum for the upper extremities. Stimulation on the Cz area induced a response from the lower extremities also.

Type II-b: The same results from stimulation to the motor area for the upper extremities was observed, but stimulation on the Cz could not induce any responses in the lower legs.

Type III: A response was seen only in the upper extremities by the stimulation of the cerebrum, but no response appeared from the lower extremities.

The patients with type I MEP were able to walk by themselves. The type II patients were able to walk with some supports; the type III patients were not able to walk.

DISCUSSION

The prognosis of patients with spastic diplegia who showed type I MEP was extremely favorable. In type I, the responses from upper and lower extremities were shown respectively. Also, the result of MEP in lower extremities was the same as the normal response, but the latency was prolonged. The periventricular leucomalecia is slight in type I, and the pylamidal tract of the lower legs exists as normal. In type II, the central motor nervous system of the lower extremities was damaged alongside the periventricular area, because of leucomalecia. The cerebrum of the motor area for the lower extremities could not control the movement of the lower legs. The new neuronal network is made for lower extremities in the central nervous system of upper extremities, and the lower extremities can be controlled by this system. It is thought that this phenomenon was the result of plasticity in the central nervous system of the cerebrum. The prognosis of the patients with type III MEP was not favorable. They cannot move their lower legs by themselves, because the plasticity was not observed in their brains. Overall, we can predict the movement prognosis of patients with spastic diplegia using MEP.

CONCLUSION

The MEP of spastic diplegia is divided into 3 types: type I, type II and type III. We can estimate the function and predict the movement prognosis of patients with spastic diplegia using MEP.

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O-62

Abnormal Electrodiagnostic Studies in Litigated Vs. Non-Litigated Cases: Is There A Difference?

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INTRODUCTION

Electrodiagnostic studies are used to determine whether there are physiologic abnormalities that can explain neuromuscular symptoms in medical evaluations. If a medical condition is in a litigated case of accident or injury, is the incidence of abnormal electrodiagnostic studies greater or lesser than non-litigated cases?

METHODS

The electrodiagnostic studies of 150 cases covering a one-year period of time, evaluated by a board-certified (ABEM) physiatrist, were reviewed. The review of 77 litigated and 73 non-litigated cases determined whether the cases had either normal or abnormal findings.

RESULTS

Null Hypothesis: There is no difference between litigated and non-litigated cases in electrodiagnostic findings.

Alternative Hypothesis: There is a difference between litigated and non-litigated cases in electrodiagnostic findings.

The data is nominal (categorical) with the Chi-Square statistic being appropriate to test the hypotheses. Observed frequencies in the data are:

	Normal Finding	Abnormal Finding	Row Total
Litigated	53	24	77
	(43.12)	(33.88)	
Non-Litigated	31	42	73
	(40.88)	(32.12)	
Column Total	84	66	150

$X^2 = 10.57$

Referring to a table of a chi-square statistical distribution, utilizing an alpha level of 0.05 and 1 degree of freedom - the value reads 3.841.

Since 10.57 exceeds 3.841, we reject the null hypothesis and report a significant difference between electrodiagnostic findings in litigated versus non-litigated cases.

DISCUSSION

Electrodiagnostic studies are more likely to be abnormal in patients who are not in litigated cases. The litigation process uses medical evaluations including electro-diagnostic studies to determine if there is objective evidence to support claims of injury due to accident. In litigated cases, evaluation of subjective complaints with physiologic studies such as EMG and NCS's can help determine whether there are objective findings to support the subjective neuromuscular complaints. Secondary gain issues may also be operant in litigated cases.

CONCLUSION

Patients involved in the litigation process are less likely to have objective documentation of neuromuscular symptoms by electrodiagnostic evaluation than patients in non-litigated cases.

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O-63

Effects of Antagonistic Voluntary Contraction on Motor Evoked Potentials in the Forearm Differ between Dominant and Nondominant Sides

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INTRODUCTION. In our previous reports enhancement of transcranial magnetic stimulation (TMS) - induced motor evoked potentials (MEP) and H-reflex inhibition during antagonistic voluntary contraction were demonstrated in the forearm [3] and leg muscles [2] using conventional surface electromyographic (EMG) recording. Antagonistic MEP facilitation was confirmed using needle EMG recording to eliminate cross-talk effets [3]. In this study we compared between dominant and nondominant sides the effects of voluntary contraction and motor imagery of agonist and antagonist muscles on MEP in the target (agonist) muscle.

SUBJECTS AND METHODS. Bilateral extensor carpi radialis (ECR) and flexor carpi radialis (FCR) muscles were studied in 13 healthy subjects. All used their right hand for writing. TMS at a intensity 10% above the resting threshold was performed using Magstim 200™ and a round coil (outer diameter, 14 cm). When stimulating the right (left) hemisphere, clockwise (counterclockwise) coil current was used so that the coil current flows posteriorly over the motor cortex. MEP were recorded from each side of the ECR and FCR using concentric surface electrodes (outer diameter, 2 cm) to reduce cross-talk effects. Stimuli were delivered at rest, during imaging extension or flexion of the wrist, and during voluntary contraction of either agonist or antagonist muscles at 10%, 20%, 30%, and 40% of maximal voluntary contraction (MVC). Activity of each muscle was monitored by an EMG biofeedback device that displays the mean value of rectified signals every 0.1 sec on a visual scale. Four stimuli were delivered under each condition. Peak to peak amplitudes of the MEP were measured and averaged for each subject and condition. The Friedman test was used to analyze differences in MEP amplitudes at rest, during imagery, and agonist or antagonist contraction. The Wilcoxon signed-rank test was used to compare each pair for MEP amplitudes.

RESULTS. MEP were enhanced during agonistic imagery and agonist voluntary contraction compared with rest. The degree of MEP facilitation increased in the order of imagery, 10% MVC, 20% MVC, 30% MVC, and 40% MVC for all the examined muscles. MEP also were enhanced during antagonist voluntary contraction ≥ 20% MVC in all examined muscles except right ECR in which MEP were facilitated during 40% antagonist contraction. MEP amplitude did not differ between rest, antagonistic imagery and 10% antagonist contraction for the left ECR and FCR (nondominant side). In contrast, for the right ECR and FCR muscles, MEP during 10% antagonist contraction were significantly smaller than that during antagonistic imagery ($P < .05$) while there was no statistically significant difference in MEP amplitude between rest and antagonistic imagery (Table).

Table. MEP amplitudes (mean (standard error), mV). *, $P < .05$.

	right ECR	left ECR	right FCR	left FCR
Agonist contraction				
40% MVC	0.734 (0.129)	0.761 (0.037)	0.701 (0.174)	0.959 (0.193)
30% MVC	0.582 (0.095)	0.605 (0.123)	0.529 (0.090)	0.779 (0.182)
20% MVC	0.480 (0.084)	0.591 (0.143)	0.475 (0.082)	0.590 (0.117)
10% MVC	0.342 (0.062)	0.410 (0.107)	0.319 (0.058)	0.590 (0.102)
Agonistic imagery	0.168 (0.030)	0.226 (0.089)	0.105 (0.037)	0.435 (0.056)
Rest	0.085 (0.012)	0.105 (0.026)	0.029 (0.015)	0.087 (0.050)
Antagonistic imagery	0.094 (0.017)	0.091 (0.027)	0.055 (0.029)	0.061 (0.035)
Antagonist contraction				
10% MVC	0.055 (0.011)	0.090 (0.020)	0.028 (0.011)	0.060 (0.040)
20% MVC	0.106 (0.025)	0.127 (0.020)	0.069 (0.028)	0.116 (0.060)
30% MVC	0.086 (0.021)	0.121 (0.020)	0.041 (0.012)	0.199 (0.098)
40% MVC	0.127 (0.023)	0.132 (0.027)	0.074 (0.023)	0.172 (0.072)

DISCUSSION. We used concentric surface electrodes to reduce cross-talk effects, and could detect difference in MEP enhancement between each consecutive pair of facilitation level from agonistic motor imagery to 40% agoist contraction. In a previous report of the hand muscle, we demonstrated MEP facilitation by motor imagery [1]. In this study MEP were enhanced by agonistic imagery, but not by antagonistic imagery. It is suggested that MEP facilitation induced by motor imagery is specific for the imaged movement. We believe that during antagonistic contraction both facilitatory and inhibitory mechanisms for the MEP are involved, and conclude that reciprocal inhibition exceeds facilitation during weak antagonist contraction in the dominant side, and are comparable with facilitation in the nondominant side; facilitation exceeds inhibition during stronger antagonistic contraction for both sides of the muscles.

ACKNOWLEDGEMENTS. This research was supported by a grant from the Ministry of Education, Science and Culture of Japan (no.10838039).

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O-64

Facilitation and Inhibition effects on Event-Related Potentials and Reaction Times in Patients with Parkinson's Disease.

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INTRODUCTION

Patients with idiopathic Parkinson's disease (PD) show a variety of specific and general cognitive deficits. The PD sometimes shows linguistic disorders. To evaluate information processing as well as motor execution and inhibition in PD, event-related potentials (ERPs) and reaction times (RT) were studied using a lexical recognition paradigm and a relatively complex oddball type paradigm.

METHODS

Sixteen patients with idiopathic PD without cognitive dysfunction (7 males and 9 females; mean =63.5 years) and 16 healthy age-matched control subjects (6 males and 10 females; mean=62.1 years) participated in the present study.

In the lexical recognition paradigm [1], stimuli consisting of S1 (word) and S2 (word or nonword) were presented on CRT. Three S1-S2 pairs (nonword, unrelated and related word conditions) were presented. All the word stimuli were common Japanese nouns constituted of two kanji (ideogram or morphogram) characters. The subjects were instructed to indicate whether S2 was a word or a nonword by pressing either of the two buttons.

The oddball paradigm was composed of target stimuli, frequent nontarget, rare nontarget category deviant stimuli and rare category deviant relevant stimuli. Each stimulus was composed of two Japanese phonetic characters ('hiragana' or 'katakana'). The subjects were instructed to press a button in response to target stimuli and disregard other stimuli.

The EEG was recorded from 17 electrode sites of the International 10-20 System referred to linked earlobes. In each paradigm, the EEGs were averaged for individual conditions.

RESULTS

In the lexical recognition paradigm, the N400 latency did not show significant differences between the controls and PD. The N400 amplitudes elicited by nonword and unrelated word were significantly smaller in PD than in controls. The PD showed significant differences in the mean N400 amplitude between the nonword and related word conditions.

The RT was significantly longer in PD than in controls. The individual PD showed greater variability in RT than the controls. The controls and PD showed significant differences in RT among the nonword, unrelated and related word conditions.

In the oddball paradigm, the N2 components elicited by deviant stimuli were smaller in PD than in controls. The P3 latencies were significantly longer in PD than in controls. In PD, error rates were higher and surface EMGs recorded from extensor and flexor muscles of the forearm often showed muscle activity in response to nontarget stimuli, although no overt errors of button press were detected.

DISCUSSION

Semantic facilitation and inhibition effects on RT were not impaired in PD. The differences in N400 amplitude between the controls and PD as well as smaller amplitude differences among conditions in PD may be attributable to alteration in attention and strategy for language information processing in PD.

The surface EMGs in response to deviant stimuli may indicate that the PD was always prepared to press a button, because of the motor symptoms. These findings suggested that response programming and response adjustment were different in PD. The PD has fewer attentional resources and difficulty in switching attention and strategy. Thus, the P3 latencies were delayed and the N2 amplitudes in response to category deviant stimuli were smaller in PD.

CONCLUSION

Although RT was prolonged, language information processing was not impaired in PD. Response selection in decision stages and sensorymotor inhibition were impaired in PD without cognitive dysfunction.

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O-65

In Vivo Study of the Carrying Angle of the Elbow by means of a Electromagnetic Tracking System

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INTRODUCTION

Usually, the carrying angle is clinically assessed with a (2-D) goniometric measurement of the angle between the longitudinal axes of the upper arm and forearm (or between the humerus and ulna). Hereby, the elbow is held in extension. Some authors defined the carrying angle as the angle between the longitudinal axis of the ulna and a line, perpendicular to the axis of elbow flexion [1-3]. This approach requires knowledge of the position and orientation of the helical axis and is for that reason not applied in the present study.

The mean value of carrying angle is significantly higher in women than in men, but shows wide ranges in both sexes [4-6].

A progressive decrease of the carrying angle as a function of increasing elbow flexion was demonstrated in a 3-D kinematic study, performed on cadaveric elbows, using a radiological technique [7]. Subsequently, this mechanism was confirmed in healthy volunteers by means of a Vicon system [5].

METHODS

The kinematic recordings were preceded by a goniometric measurement of the carrying angle in extension. The changes in carrying angle were recorded using an electromagnetic tracking device (Flock of Birds) with two receivers, operating in a "master-slave configuration". The system was steered by newly developed software [8]. The transmitter was located at the lateral side of the elbow joint, at a distance of approximately 30 cm and perpendicularly oriented towards the anatomical frame of the upper arm. To obtain a procedural standardization, the upper arm was positioned into a gutter-shaped support. The master sensor was fixed at the distal end of the deltoid muscle by means of an elastic bandage. Mounted on a special build support with incorporated Velcro-strap, the slave sensor was placed proximally to the styloid process of the radius. Subjects were asked to keep their forearm in supination during the entire testing procedure.

Three flexion-extension recordings were averages and statistically analyzed in both the left and the right elbows of 20 volunteers without a history of elbow pathology (10 males and 10 females - mean age: 25 years).

RESULTS

The three subsequent kinematic recordings revealed no statistical significant differences ($p < 0,05$), correlation coefficients equal or superior to 0,992 and standard deviations of their means equal to or smaller than 0,8°.

In elbow extension, a mean carrying angle of 16,7° ± 2,6° was found in the female and 11,6° ± 3,2° in the male subjects.

The valgus angle progressively decreased with flexion, at the end changing into a mean varus angle of 1,6° ± 2,3° in women and 1,8° ± 2,9° in men.

Statistical significant differences in carrying angles between both sexes were recorded from 0 to 30° of flexion ($p < 0{,}03$ for left and $p < 0{,}01$ for right elbows). The differences disappeared beyond 30° of flexion.

Statistical significant differences ($p < 0{,}05$ to $p < 0{,}001$) were found between the related flexion and extension courses. However, these differences were smaller than 0,6°.

DISCUSSION AND CONCLUSION

Progressive decrease in carrying angle as a function of elbow flexion was successfully traced by the electromagnetic tracking system. The differences between the carrying angle in men and women (with a mean value of 5,1° in extension) disappeared from flexion angles beyond 30°. This finding confirms previously reported results, obtained with an imaging based system [5]. The actual presented measures of carrying angle in extension revealed larger values. Considering that comparable subgroups were investigated in both studies, an explanation may be found in differences in research design. Nevertheless, the actual results fit into mean values between 7 and 18° for men and between 13 and 22° for women, reported earlier in the literature [6]. The study confirmed a rather congruent motion path of elbow flexion and extension, particularly when the foream is kept in supination.

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O-66

Motor Imagery Tuned to Auditory Rhythm Increases Motor Cortical Exicitability : Effect of the Contents of Imaged Task.

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INTRODUCTION

Motor imagery is mental rehearsal of motor execution. It has been reported that motor imagery is capable of exciting many cortical areas, such as premotor cortex, supplementary motor cortex and sensorimotor cortex (1). In our previous study, motor imagery tuned to auditory rhythm augmented motor evoked potentials (MEPs) (2). In terms of motor cortical programming,we also demonstrated that the amplitude of movement related cortical potential (MRCP) was greater in a tuned finger movement than in self-paced movement (3).

In order to verify whether the excitability depends on the contents of the motor imagery, we studied 5 subjects by using transcranial magnetic stimulation technique during tuning to auditory rhythmic cues .

METHOD

Five healty subjects participated in the study. All gave informed consent and the procedures had the approval of the local ethical committee. The melody contained three rhythmic tone bursts every 500 ms fot each. Subjects were required to have the imagery of either abduction of the right index finger (AB) or right-hand grip (GP), turning to the third phone of a melody of the triple time (at 1000 ms after the first sound). MEPs were recorded from the right first dorsal interosseous (FDI) muscles at various time intervals from the first sound (Time=0). The peak-to-peak amplitude of MEPs with the motor imagery of either AB or GP (Image+T) and that of MEPs without the image (T) were evaluated after 8 trials at each time. In addition, H-reflex was also recorded from flexor forearm muscle by stimulating median nerve.

RESULTS

In AB task, the excitation ratio of MEPs was 10.5 ± 5.4 (M$\pm$SE) at 1000 ms. MEPs were significantly increased at 1000 ms by the image of AB ($p<0.05$). In contrast, the ratio in GP was 1.7 ± 0.3. There was significant difference between two tasks.

The H-reflex had remained unchanged even in the AB task.

DISCUSSION

In our study, motor cortical activation was observed by the image of AB task, but not by that of GP task. There has been reported that cortical neuronal activity in monkey is prominent in precision grip than in power grip (4). These results suggest the possibility that cortical motor output is affected differentially by the different kinds of motor imagery.

CONCLUSION

Activation in motor cortex by motor imagery depends on the contents of imaged task.

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O-67

The Correlation between the Blink Reflexes (BRs) and Exogenous Auditory Evoked Potentials (AEPs) in Patients with Parkinson's Disease (PD)

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INTRODUCTION

Parkinson's disease (PD) is usually considered to be a pure disorder of movement based on nigro-striatal degeneration neuropathologically. But there is some evidence of subtle receptive disorders involving primary sensory symptom, especially true paresthesias, numbness, tingling and burning.

For the analysis from electrophysiological view points, the blink reflexes (BRs) and exogenous auditory evoked potentials (AEPs) were carried out between patients with Parkinson's disease and hospital control subjects.

METHODS

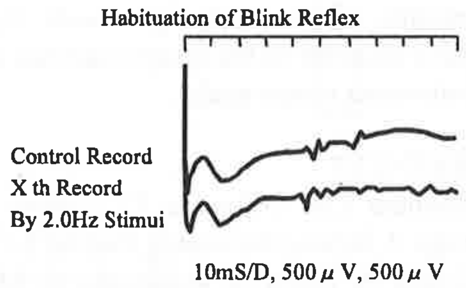
Materials consisted of 41 Parkinson's disease patients with long duration of illness and 42 age-matched hospital control subjects (controls).

The habituation index (HI) of R2 response from BRs was measured following a modification of the method described by Penders & Delwaide[1) 2)].

This index was defined as the fastest stimulation frequency at which the tenth stimulus of a series still evoked a response R2 with an amplitude at least 20% of that of control values (Figure).

Figure

F.H. 72 Y.O Female Patient
With Parkinson's Disease



The exogeneous AEPs (auditory brain-stem responses : ABRs and middle latency auditory evoked responses : MLRs) were recorded from the scalp at the midcentral position (Cz) and bilateral ear lobules (A_1/A_2) according to the international 10-20 system electrode placement and serving as a ground electrode on the forehead

RESULTS

The results of the mean frequency in Parkinsonian patients and the control subjects were 1.8 ± 0.3, 0.7 ± 0.2 (Mean$\pm$SD) Hz respectively. In Parkinson's disease patients, there were the significant prolongation in W1-W5 interpeak latencies of ABRs and decreased amplitude in Pb component of MLRs, particularly on dementia patients[3) 4)] (Table).

Table

Mean Latencies (ms) of All Auditory Brainstem Responses (ABRs) Variables in Patients with Parkinson's Disease (PD) and Age-matched Hospital Control Subjects (Controls)

Latency ±SD(ms)		PD (N=41)	Controls (N=42)	t-Values
I	(Lt)	1.80±0.14	1.78±0.17	NS
	(Rt)	1.75±0.12	1.74±0.27	NS
II	(Lt)	2.89±0.30	2.81±0.30	NS
	(Rt)	2.90±0.11	2.83±0.16	NS
V	(Lt)	6.09±0.34	5.69±0.29	5.04353*
	(Rt)	6.13±0.35	5.73±0.18	4.08302*
I-V	(Lt)	4.21±0.32	3.89±0.27	3.94148*
	(Rt)	4.26±0.31	3.90±0.22	4.28983*

*P<0.001

DISCUSSION

One may conclude this habituation deficit is itself dependent upon a functional disturbance of the nigro-striatal inhibition system with dopamine lack.

On the other hand, the observed delay in W5 especially originating from the midbrain disclosed significance of a central conduction delay at the brain-stem to midbrain level, possively involving reticular activating system[5].

The results of this study agree with the co-existence between some evidence of a subtle receptive disorder in the central nervous system and impairment of nigro-striatal influence on the brain-stem motor nuclei.

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P-201

Effects of Silent Period in Gastrocnemius during Standing on the Forward Tilting Plate

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INTRODUCTION

Although falls in the elderly are common and are associated with appreciable morbidity and morality, there have been many investigations of their causes. These studies make two important points: elderly with poor physical fitness tend to fall, and accident/environmental-related factors are the main causes of falls. Sheldon suggested that the change in sway with age was due to a change in the ability to control random movements that originated centrally, and that increased sway in the elderly was due to loss of cells in the brain stem and cerebellum. By the way, silent period emerges as a cessation of electrical discharge is applied either directly or percutaneously to a nerve controlling a muscle during its continuous contraction. Therefore, shortening of silent period during standing position indirectly shows increased excitability of α motor neuron might be caused by postural-controlling mechanism in the higher center.

In this study, we examined the effect of silent period evoked from the gastrocnemius (GM) muscle by electrical stimulation to the tibial nerve in the standing position on the forward tilting plate.

METHODS

The subjects of this study were 10 healthy elderly persons, ranging in age from 58 to 88 years (a mean age of 65.8, 7 males and 3 females). They had no marked deformity in the lower limbs and the spine. The control group consisted of 10 healthy young persons (a mean age of 21.3, 5 males and 5 females).

The subjects were ordered to stand straight on the flat floor or on the 20-degree forward tilting board with the ankles touching each other. The subjects were instructed to give even weights on both legs. The braces were worn on the both knee joints, which were flexed in the extension of the knees (Fig.). Thereafter, maximum electrical stimulation at random was applied to the right tibial nerve to elicit the surface EMG of the GM muscle. During measurements on silent period, the subjects were instructed to open eyes and closed eyes, respectively. Differences were evaluated by Student t-test, p values less than 0.05 were taken as a statistically significant difference.

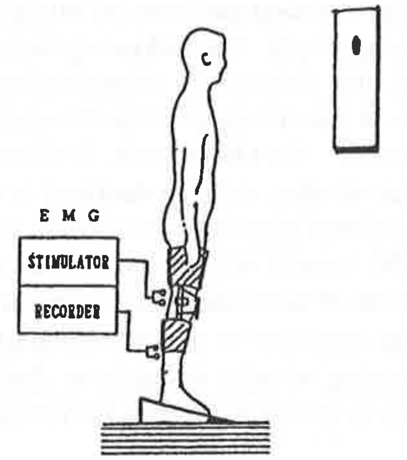

FIG. Method of silent period measurement in the upright position on the forward tilting plate. The angle of the forward tilting board is 20 degrees. The subjects with eyes opened were instructed to look at a target in the front.

RESULTS

Silent period at rest was longer in the elderly group than in the young group in the both standing positions with a difference of about 15.6 ms in the straight standing position and about 26.0 ms in the forward tilting position while the subjects close their eyes (Table).

TABLE Comparison of silent periods between young and elderly in the both standing positions

(Mean±SD)

GROUP	EYES CONDITION	FLAT	FORWARD TILT
Young (n=10)	open	163.9±13.7	148.3±12.6*
	closed	168.5±11.6	151.3±11.4*
Elderly (n=10)	open	188.6±19.5	162.6±20.2 ┐
	closed	191.7±22.7	187.3±24.3 ┘*

*p<0.05

The difference in silent period between the two eye conditions while the subjects close their eyes was 3.0 ms in the young group and 25.3 ms in the elderly group. In young group, the silent period in the forward tilting position was significantly shorter than that in the straight standing position in the both eye conditions. Therefore, in elderly group, the silent period in the forward tilting position while the subjects close their eyes was significantly longer than their eyes opened.

DISCUSSION

Silent period at rest in the elderly group was prolonged by about 15.6 ms and 26.0 ms in the straight standing and forward tilting positions as compared to silent period in the young group, respectively. The following factors are considered responsible for prolonged silent period in the elderly: 1) degeneration of the bones and joints and relaxation of the ligaments in the elderly disturbs the alignment of the standing posture. This in turn reduces the activity of the GM muscle. 2) Slow down of the velocity of nerve impulse conduction, 3) muscles atrophy, and 4) a decrease in the ability to control posture in the upper center.

In the elderly with the eyes closed, electromyography reveals a decrease in the activity of the GM muscle and a phasic contraction of the tibialis anterior (TA) muscle. This phenomenon of backward fall is thought to be produced by the release of excess Ia afferent impulse in response to a physiological decline in postural control. This gives the upper center wrong sensory information that the GM muscle is stretched, because discharge of TA muscle is included during a backward shift of the gravity center.

CONCLUSION

These results obtained suggest that the standing posture in the elderly is controlled by the reflex mechanism responding to peripheral stimuli such as optical sensation and proprioceptive sensations of antigravity muscles.

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P-202

Posture control and activity of erector supinae muscles during lateral shift of center of gravity in sitting

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INTRODUCTION

The lateral shift of center of gravity (COG) in sitting is usually used for activities of daily living. Therefore, it is important for the one of sitting balance training in physical therapy. We have particularly attended for the activity of erector supinae muscles (ES) during the lateral shift of COG for balance training, since the ES activity is very important for posture control. However, how the ES activity is related to the movement is not well understood. The purpose of this study was to analyze relationship between the ES activity and posture control during the lateral shift in sitting.

METHODS

Five healthy young subjects were studied. The electromyography (EMG) of erector supinae muscles, trunk alignment and center of pressure (COP) during the lateral shift of COG in sitting were measured. The EMG signals (TELEMG, BTS) were recorded bilaterally from three parts; (1) lower lumbar part (LL), (2) upper lumbar part (UL), and (3) lower thoracic part (LT). Bipolar surface electrodes were placed over the muscle belly. The data were sampled at 500 Hz. Kinetic data were recorded using force plate (9287, Kistler) at 500 Hz of sampling frequency. Kinematics were recorded synchronously with the other signals using a four camera system (ELITE, BTS), then the data were sampled at 50 Hz. Reflective markers were placed on the following landmarks; (1) paries, (2) acromion, (3) spinous process of C7, (4) spinous process of Th12, (5) anterior superior iliac spine, and (6) posterior superior iliac spine. The lateral shift in sitting was classified into three movements (Fig.1); (1) lateral bending of trunk, (2) reverse lateral bending of trunk, and (3) combined movement. The direction of the COG shift was right side. Subject sat on the experimental chair made of steel pipes. They were instructed to initiate movement immediately after an auditory and a light cue signals, and to execute movement at normal and fast speed, respectively. Three trials were done at the each of movements and speeds, respectively.

RESULTS

The acromion parts initially moved at the most of trials. The COP trajectory moved to left side immediately after cue signal at all trials. Thereafter, the trajectory rapidly moved to

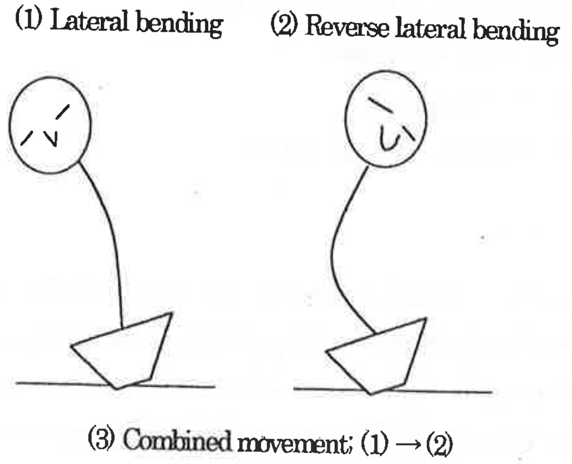

Fig.1 Classification of movements

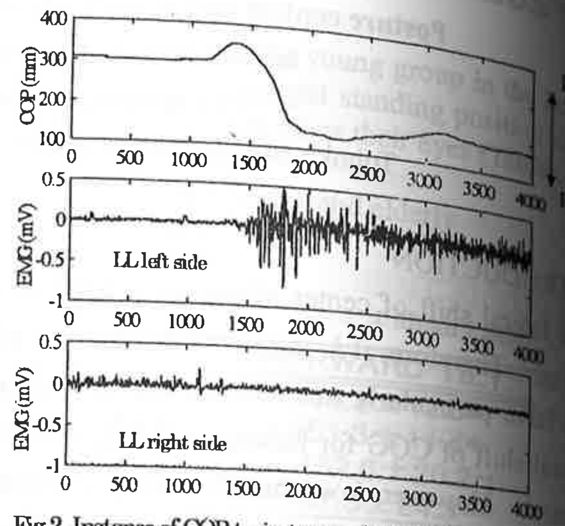

Fig.2 Instance of COP trajectory and EMG of LL during fast combined movement

right side that was the direction of COG shift (Fig.2). The EMG activity of left LL increased after the COP trajectory moved to right side for the most of trials (Fig.2). The right LL activity indicated a various change in the lateral shift (Fig.2). Although the EMG activity of UL indicated a tendency as same as the LL activity, the LT activity indicated a difference tendency.

DISCUSSION

The COP trajectory during the lateral shift in sitting was similar to that of a lateral leg raising task in standing: the COG shift towards the supporting foot is preceded by an early displacement of the COP towards the moving leg[1]. This characteristic COP thrust initiates the COG shift towards the supporting side. The change of the LL activity may be related with this characteristic COP thrust. However, the primary factor of the change in the COP trajectory wasn't clarified because the decrease of the right LL activity didn't precede the change obviously in the COP trajectory.

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P-203

Somatosensory inputs modulate Soleus H-reflex during static posture under water immersion in human

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INTRODUCTION

Recent studies on postural modulation of soleus H-reflex in human suggested that the stretch reflex is not stereotype, but rather is modifiable in accordance with circumstances[1)]. Visual, vestibular, and somatosensory systems receive the circumstances and modify the motor output. It was hypothesized that sensory systems would modulate the segmental reflex in order to maintain static posture[1)]. In this study, we investigated soleus H-reflex during upright standing under diminished somatosensory inputs using water immersion in human.

METHODS

Soleus H-reflex and M-response were measured in eleven healthy males. The institutional ethical committee approved this study and the subject gave informed consent. The subject stood upright inside a double vinyl chloride bag for waterproof and was fixed on the tilting bed in a test tank (Shimadzu Co., Japan). The tilting conditions were supine and standing in the order (control condition). Next, the tank was filled with water (34℃) to the subject's neck level in the same tilting condition (water immersion condition: WI) to decrease body weight bearing by buoyancy[2)]. H-reflex was evoked by incremental stimulations of tibial nerve at popliteal fossa. The peak-to-peak amplitude of H-reflex at the motor threshold was used for statistical analysis. Two-way (tilting × WI condition) repeated measures ANOVA were demonstrated to compare the conditions. The alpha level was 5% in this study.

RESULTS

The recording and stimulating sites were kept dry. There were not any background activities of soleus and tibialis anterior muscles. The forms of H and M waves did not change between the conditions (Fig.1). Only the main effect of the tilting was found to be significant ($F_{1,10}$=28.25; P<.001). Six of the subjects whose H-reflex ratio (standing/supine) was less than 90% were further analyzed to compare between the control and WI conditions. The difference of the ratio between the two conditions was 25.1% (95%CI, −1.9% to 52.0%, Fig.2).

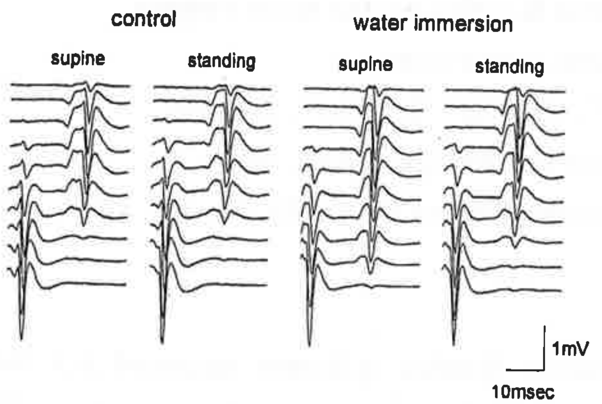

Fig.1 Typical traces of H wave and M wave with incremental stimulation intensity in the control and the WI conditions (subj 1).

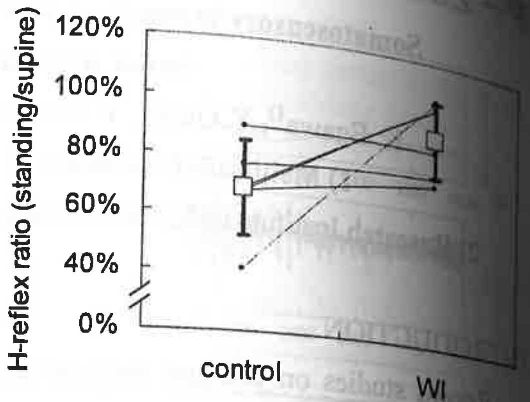

Fig.2 Mean and standard deviation (error bars) of H-reflex ratio (standing/supine) in the control and the WI condition (n=6).

DISCUSSION

Previous study suggested that postural modulation of H-reflex was caused by tonic vestibular inputs[3] or presynaptic inhibition[4]. In the six subjects, the modulation was not seen in the WI condition. The changes in vestibular inputs in the control condition were the same as in the WI condition in this study. The results suggested that not only vestibular inputs but also the other sensory (somatosensory or visual) inputs modulate soleus H-reflex. Decreased weight bearing by the buoyancy would diminish the activity of cutaneous or joints receptors. Groups II or III afferents from these receptors converge on motoneurons (MNs) disynaptically. Therefore one mechanism was speculated that the interneurons between the somatosensory afferents and MNs would decrease the reflex gain by pre- or postsynaptic inhibition. In this mechanism, somatosensory inputs from cutaneous or joint receptors may play an inhibitory effect on the soleus motoneuron pool tonically.

CONCLUSION

Our findings indicated that somatosensory inputs would modulate the excitability of soleus motoneuron pool in order to maintain static posture in human.

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P-204

Control in Motor Units of Lower Extremity Muscles in Stance Phase and Swing Phase during Fast, Free and Slow Walking Speeds

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INTRODUCTION

We investigated changes in median power frequency (MdPF), integrated electromyography (IEMG), its rate of partial frequency zone to whole zone in right lower extremity muscles during early stance phase and swing phase at fast, free and slow walking speeds in normal adults. We also examined a control of the recruitment and firing rate of motor units in those muscles during early stance phase and swing phase.

METHODS

Ten healthy volunteers without signs of neuromuscular disorders (4 men and 6 women), ranging in age from 22 to 38 (mean 30) years participated in the study.

Using a digital metronome, the subjects were requested to walk on level ground for a distance of fifteen meters at three different walking speeds ; fast (1.69 m/s), free (1.2 m/s), and slow (0.69 m/s).

The muscles we chose for this study were the right vastus lateralis (VL) and medial hamstrings (MH). A pair of Ag-AgCl surface electrodes, one-centimeter in diameter (Nihon Koden, co, Japan) in a bipolar lead system were applied over the central belly of each muscle. They were placed parallel to the muscle fibers two centimeters apart and secured to the skin by a piece of tape. Analog signals from the electrodes were converted to digital signals and stored in a PC card by means of an 8 channel PC card recorder (Teac DR-C2 ; Teac, co, Japan). Signals taken at a sampling time of 0.2 ms were analyzed using a new method in a computer program called "MemCalc" [1].

The mean MdPFs, IEMG values and its rates of partial frequency zone to whole zone of the VL and MH were compared between early stance phase and swing phase in each identical walking speed.

RESULTS

In zone for the whole frequency from 20 to 1000 Hz, the mean IEMG values of the VL and MH for early stance phase were greater than those for swing phase in each identical walking speed. In the zone of low frequency, the mean rates of VL for early stance phase was significantly lower than those for swing phase during each identical walking. Contrary to this, in high frequency zone the mean rate of VL for early stance phase was significantly greater than that for swing phase during fast and slow walking. In the zone of high frequency the mean rates of MH for early stance phase was significantly lower than those for swing phase during fast and free walking speeds. However, the mean rate of MH for early stance phase was significantly greater than that for swing phase during slow walking.

DISCUSSION

It was considered that the VL for early stance phase was selectively controlled to recruit the larger motor units in fast-twitch muscle fibers to compare for swing phase during fast and slow walking , because in high frequency zone the rates of IEMG values of that muscle for early stance phase were significantly greater than those for swing phase during fast and slow walking. The MH in early stance phase during fast and free walking was selectively controlled to recruit the smaller motor units in slow-twitch muscle fibers, because in the high frequency zone the rates of IEMG value of the MH for early stance phase were lower than those for swing phase during fast and free walking.

CONCLUSIONS

In conclusion, the different motor controls for each muscle were delicately performed between early stance phase and swing phase during changes in walking speed.

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P-205

Validity and Reliability of the Body Trunk Muscle Rigidity Measurement in Dynamometer

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INTRODUCTION

It is conceivable that muscle rigidity of the body trunk, is bringing about a great influence to the daily life. We tried the measurement and fixed quantity of muscle rigidity of the body trunk.And, I examined about the validity and reliability of the measurement.

METHODS

Parkinsonian patient(17 peoples). Males 11 peoples, womans 6 peoples. Average age 61years old. Yahrl stage Ⅱ:2 peoples, Ⅲ:9 peoples, Ⅳ:5 peoples, Ⅴ:1 people.Normal person were 12 peoples.We produced the bed as a testee becomes to, facing upward a knee set up place. A body trunk was moved rotatory passively by using the CPM device of the dynamometer. I checked the electric discharge of the backbone standing muscle of the thoracic vertebra surroundings with surface electrodes.The torque at the time of a rotation was measured with the dynamometer simultaneously.The description of rotatory direction made a throwing down of both knees to the left side and a projection of the waist on the right side a right rotation.

RESULT

The muscle electric discharge was seen in the backbone standing muscle of the right thoracic vertebra surroundings at the time of voluntary right rotation.The muscle electric discharge was not admitted at the time of passive rotation.The muscle electric discharge similar to the normal person was admitted at the time of voluntary rotation in the parkinsonian patient. However, the electric discharge was seen in the backbone standing muscle of he thoracic vertebra surroundings at the time of passive rotatory movement.The muscle electric discharge was seen in the left backbone muscle at the time of passive right rotation. In a normal person, the torque curve painted a sine curve at the time of passive rotation. Torque worked in the opposite direction of rotation, when knees is between -50 degrees to 0 degree at the time of passive left rotation. When knees is between 0 degree to 50 degrees torque worked toward rotation. In reverse rotation, the torque curve painted a reverse sine curve. In a parkinsonian patient, the torque curve painted a trapezoid at the time of rotation. In a parkinsonian patient, torque worked toward rotation, when knees are between -50 degrees to 0 degree at the time of passive left rotation. When knees are between 0 degree to 50 degrees torque worked in the opposite direction of rotation. In a parkinsonian patient at the time of the biggest passive rotation the significant correlation between the muscle electric discharge and torque value was admitted. The coefficient of correlation become -0.891 at the time of, the biggest left (50 degrees) rotation and become 0.831 at the time of, the biggest right(-50 degrees)rotation.

The torque value was measured twice to 10 times with 1 time of measuring.When it expresses about the distribution of the measured value, the coefficient of variation shows 2.123~19.07 in a normal person in 50 degrees rotation and shows 3.193~27.22 in a parkinsonian patient.The significant difference was not admitted with 1% of significant standard with Mann-Whitney's U test, as open for more than 1 week with 8 normal person and measured.

DISCUSSION

It was conceivable that in the following facts by the measuring of a normal person in the supine position, namely,voluntary right rotation results through the means that the right backbone standing muscle contracts and left rotation results through the means that the left backbone standing muscle contracts.The muscle electric discharge was not admitted to any muscles at the time of passive rotation,when the normal person is relaxed.The electric discharge was seen in the same muscle as a normal person at the time of voluntary rotation,in the parkinsonian patient.However, the muscle electric discharge that is not admitted by the normal person at the time of passive rotation, was admitted.The abnormal muscle electric discharge was admitted in the thoracic vertebra backbone standing muscle of the opposite side at the time of voluntary rotation.The abnormal muscle electric discharge was seen,in the right backbone standing muscle,in the left backbone standing muscle with passive left rotation with passive right rotation namely.This abnormal muscle electric discharge through according to rigidity of the body trunk.

CONCLUSION

Measuring it repeatedly by using,dynamometer the torque value,was correlating with an abnormal muscle electric discharge.The validity was proved from these.Even the reproducibility is admitted also,and even the accuracy of the torque value was confirmed.The reliability was proved from these.

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P-206

Distribution of Muscle Fiber Conduction Velocity on M. Biceps Brachii Using Surface Array Electrodes and the Model of Generation

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INTRODUCTION

The muscle fiber conduction velocity (MFCV) is propagation velocity of interference wave due to a group of muscle fiber action potentials. The MFCV is used to evaluate the muscular disorder and the muscular fatigue. In generally, it has been considered that MFCV is constant at the locations of the muscle. But the values of the MFCVs were measured in the locations expect for the innervation zone (end-plate) and the ends of muscle (tendon), or the distance between the electrodes used was too wider (i.e., more than 10 mm). Therefore, there is a low accuracy in the past studies of the MFCV. Recently, "array electrodes" were developed as a new method for the measurement of the MFCV. The MFCVs were measured at the region including the end-plate and the tendon with the use of array electrodes that inter-electrode distance was less than 10 mm. These values depended on the locations of the muscle detecting the action potentials. Particularly, MFCVs in the region of the end-plate and the tendon were faster than those in the other regions. Although the factors of changing of the MFCVs were explained by hypotheses and models, a uniform agreement have not been obtained yet.

The aim of the study is to investigate the distribution of the MFCV in m. biceps brachii. To begin with the factor of changing of MFCV was declared according to the past studies, and the hypothesis was examined by the factors. Next the numerical model of MFCV was formulated based on the obtained hypothesis, which were obtained by the application of electromagnetic theory. The model was formulated to elucidate an electric phenomenon in the muscle.

METHODS

For the formulation of the model, an experimental result to compare with the model is shown in the Fig. 1. Subjects were twelve healthy males, aged 22-23 years. Subject sat on a chair and performed the isometric contraction at 20% of maximum voluntary contraction (MVC), and the elbow was maintained at right angle. The values of MFCV were evaluated from the motor unit action potentials detected by array electrodes at five different zones on m. biceps brachii, and MFCV was estimated by using the averaging method. Surface array electrodes were composed of six stainless steel wires, with a diameter 1 mm, a length 10 mm, and the inter-electrode distance was 5 mm.

The model expressed the relation between an electric field due to the current source I_m at end-plate and the velocity of the electric charge q in the muscle considered as the volume conductor. The electric field $E(r)$ at some position r in the volume conductor measured from the end-plate was evaluated by Gauss' theorem with both the current source I_m at the end-plate and the conductivity of volume conductor $\sigma(r)$ as in equation (1). The velocity of electric charge, which was taken as the MFCV, was in proportional to $E(r)$ with the mobility $\mu(r)$ in the volume conductor. Since it was regarded that the conductivity of the muscular tissue was larger than that of the tendon tissue, the ratio $\sigma(r)/\mu(r)$ denoted electric property of the conductor was assumed to depend on Gaussian function. For the experimental result as shown in Fig.1, two conditions, which the MFCV was the minimum at the relative middle point between the end-plate and the tendon, i.e., $x=1/2$, and the value of the MFCV at $x=1/2$ was about 4.0m/s, were used to make the model equation fit to the experimental results. Using above the ratio and the two conditions, the model for the muscle fiber direction x was evaluated in equation (2). Where b was fitting parameter with the range $1/4 < b < 1/2$. This model was called "electric field model".

$$\bar{E}(r)=\frac{I_m}{4\pi\sigma(r)}\frac{\bar{r}}{r^3} \quad (1), \qquad MFCV(x)=\frac{4b}{x^2+b-(1/2)^2}\exp\left\{\frac{x^2-(1/2)^2}{b}\right\} \quad (2)$$

RESULTS and DISCUSSION

The simulated result of the MFCV was evaluated in Fig. 2. In the figure, the parameter b is taken to be 0.30 to fit most the experimental result. The MFCVs evaluated by the model were in good agreement with the experiment values. This agreement was better than that in the other models; that is, the model with the use of the idea by Schneider et al. (1991) and the model of Li and Sakamoto (1996). The idea by Schneider et al., however, suggested the importance of the consideration of heterogeneous tissues in the muscle that caused the variation of MFCV.

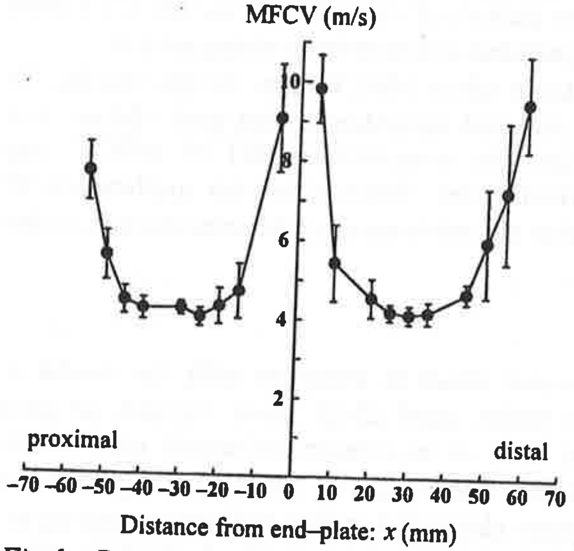

Fig.1: Distribution of MFCV during 20% MVC in m. biceps brachii for twelve subjects.

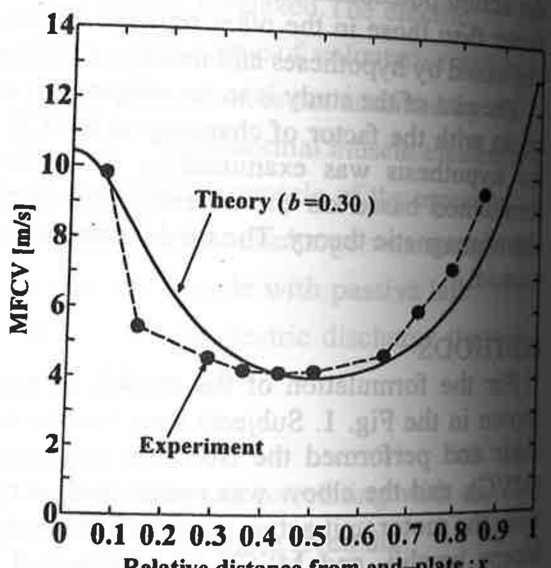

Fig. 2: Relation between theoretical curve and experimental values.

CONCLUSION

The numerical model (i.e., electric field model) that represents the distribution of the MFCV in m. biceps brachii is formulated with the use of the Gauss' theorem in electromagnetic theory. The resultant curve according to the model is in good agreement with the experimental result. It is important to consider the electric property in the muscle.

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P-207

Neurophysiological effect of the devised therapeutic foot sole on equinovarus foot of hemiparetic patient

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INTRODUCTION

We applied our devised sole plate which give light pressure on the outsole for correcting the mild equinovarus foot resulted from cerebrovascular accident. The purpose of this study is to confirm availability of this sole plate. Therefore, we investigated the muscle activity change between the tibialis anterior muscle (TA) and the gastrocnemius muscle when wearing the sole plate.

METHODS

Twelve hemiparetic patients were recruited for this study. All subjects manifested mild equinovarus foot. Surface EMG recordings were performed in both at rest by delivering electrical stimulation to the outsole (a train electrical pulses was applied to activate high threshold slow conducting fibers) and when subjects were stood comfortably wearing the sole plates.

RESULTS

Appling pressure to the outsole (S1 nerve supply) produced significant increment of muscle activity of TA in all subjects. On the other hand, gastrocnemius decreased its activity. The changes mentioned above were confined to the affected side in all subjects. Moreover, giving pressure on the other parts of the sole showed no significant changes.

DISCUSSION

Both of giving pressure using the sole plate and electrical train pulses have certain similarities regarding the increment of TA activity. In the previous study, the increment of TA muscle contraction elicited by giving electrical stimulation was resulted from the dominance of withdrawal reflex. Therefore, it is concluded that withdrawal reflex contributes to the efficacy of the sole plate for correcting the hemiparetic patient's equinovarus foot.

CONCLUSION

In this study, we confirmed that our devised sole plate is available for correcting equinovarus foot of hemiparetic patient.

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P-208

Analyses of surface electromyographic findings of isometric contraction of the vastus lateralis, the vastus medialis and the rectus femoris

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PURPOSE

Clarification of the pathogenesis of knee disorders requires a full undestanding of the mechanism of muscular activities in articulatory movements. Somemuscular activities contribute to a single articulatory movement, and it is necessary to evaluate the differing levels among these muscular activities.The relationship between amount of electric discharge of muscles and an articulatory torque can presented as equation curve.The electric potential on an electromyogram is useful in examining this relationship. The purpose of this study was to develop a method to determine the levels of differringmuscular activities by utilizing power equiation.

SUBJECTS

Fifty-six healthy subjects, 24 males and 32 females of 19-30 years of age (group mean age 22.5 yrs),who have no history of orthopedic surgery in their knees, participated in this study.

METHODS

Subjects were asked to take a supine position on a couch hanging down both legs, with their pelvic fixed by an aluminum-made frame and with their lower limbs below the surface of the couch. After making sure that their knees and lower limbs will not rotate, their lower part of the right leg was fixed to the resistance arm of a CYBEX II Plus Isokinetic Dynamometer, with surface bipolar electrodes attached to the Vastus medialis(VM) , the Vastus lateralis (VL) and the rectus femoris(RF) 10 mm apart . Electromyograms were taken into a personal computer at asampling time of 1 msec for analytical process. The subjects, whose extended knees were fixed at the angle of 90° , were asked to push the arm of the CYBEX in the direction of knee extension. The electromyograms were recorded while isometric contraction in the knee extension. At the same time, the electromyograms of the output torque in knee extension were also recorded, and the subjects were asked to keep watching the monitor of the testing machine and to make successively maximum torque outputs of 20%, 40%, 60% and 80%. Each output was maintained for about 2 seconds in order not to make a rapid increase. It took 12 seconds for recording all of the outputs.

In analytical process, a root mean square (RMS) at a unit of 100 msec was obtained from the electromyogram data, and the relation between the RMS and the output torqu of both VL, VM and RF of each subject was applied to the equation of $y=ax^b$ (x: the output torqu, y: RMS):**power equiation**. As for the value of the coefficient b in the equation, ANOVA and multiple compartison were conducted among VL, VM and RF. The significant level was 5 %. The SPSS for windows was used in statistical procedure.

RESULTS

1) Proportion of variance in Approximate Curve

The mean proportion of varianc in the approximate equation showing the relation between the output torque in knee extension and VM RMS in all the subjects was 0.72 (SD: 0.14). As for the VL, the mean proportion of variance was 0.74 (SD:0.13)and RF was0.69(SD:0.12) .

2) Difference between the Mean Value of the Coefficient *b* in VM,VL and RF

The two coefficients, a and b, in the equation $y=ax^b$ canbe obtained by applying to the equation the relation between the output torque in knee extension and the RMS in each of the subjects in each of the muscles. The coefficient a shows the inclination of the curve and the coefficient b shows the depth or the height. The inclination that the coefficient a showed was apt to change influenced by the condition at the time of the recording of electromyograms while the coefficient b was not subject to the same condition. Further analysis was conducted by utilizing this characteristic of the coefficient *b*. Difference in coefficient *b* among VM,VL and RF were analyzed by using coefficient *b* as a dependent variable . As a result, VM averaged 0. 87 (SD:0..32) ,VL averaged 0.88 (SD: 0.28) and RFaveraged 0.61 (SD: 0.22), showing a significant difference between RF and other 2 muscles(VM , VL).

DISCUSSION

The two coefficients, ***(a)*** and ***(b)*** can be obtained by applying the corelation between the two variables, ***x*** and ***y*** to the equation mentioned above. The coefficient ***(a)*** represents the curve inclination and the coefficient ***(b)*** represents the depth or the height. An approximate line forms a straight line nota curve,in the case of ***b=1***. In the case of ***0<b<1***, the line forms a convex curve and the coefficient ***y*** dose not increase in pararell with the increase of the coefficient ***x***. The tendency is observed increase of the coefficient ***y*** decline gradually.On the contrary, in the case of ***b>1***, the line forms a concave curve, and there is tendency that the increase of the coefficienty rose sharply with the increase of the coefficient ***x***.Further analysis of this tendency of the coefficient ***b*** led to findings that the mean coefficient for VM to be 0.87,VL,0.88 and that for RF,0.61. There was a significant difference between RF and other 2 muscles(VM and VL).Observations of the mean values reveal that 3 muscles present upward convex curves and that the curve for RF is more upward curved than VM and VL. Thus , the curve for RF tends to reach the uppermost limit at the lower torque, as compare to the curve for VM and VL . These observations suggest that the activities of VM , VL and RF are not similar .It can be concluded the newly developed methods (using **power equiation**) can be appied in differetation the activity levels among some musclar activuties.

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Essential Factor to Produce Faster Step Initiation

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INTRODUCTION

In a initiation of the polyarticulated unstable standing movement, the first detectable sign for the movement is not always the primary movement and it's synergies, but other activities which precede the onset of those intended primary ones[1,2,3,4].

To know the essential factor to produce faster step initiation, electrical and mechanical activities in the anticipatory and executive phases were analyzed.

METHODS

On the force platform, seven healthy adults performed a single step forward from static upright standing as fast as possible with their own spontaneous pace. The electromyographic (EMG) activity of the lower limb muscles, the ground reaction force, the moment components about the XYZ axes, the hip angle, and the ground contact of the foot sole were recorded simultaneously. The digitized data were processed to measure through an interactive program.

RESULTS

The first active sign of the EMG change is not the sartorius of the moving limb (SARm), one of the primary synergies, but the tibialis anterior of the supporting (TAs) and the moving (TAm) limbs, and the first mechanical change do not occur in the joint angle change of the intended hip flexion movement but occur in the backward share force (BSF) of the horizontal component in the reaction force.

There was significantly and negatively correlation between the step time and the respective duration (DUR) of the anticipatory EMG activity in the TAs and in the TAm, while no significant correlation between the step time and the amplitude (AMP) of that EMG activity was observed. Also, signifcant corelationship between the anticipatory BSF and the step time. There was no significant correlation between the step time and neither the DUR nor the AMP of the EMG activity in the SARm.

DISCUSSION

In forward and backward directions, the platform is pressed down and backward by ankle dorsi flexion when the tibialis anterior of both limbs contract, then, the forces given to the platform has horizontal components. That is, the horizontal components of the ground reaction force produce forward propulsive force for the step initiation.

This mean that the functional role of the anticipatory contraction in these ankle dorsi flexors are not a compensation to postural perturbation mentioned previously[11] but the active trigger for propeling the body forward during step initiation.

CONCLUSION

These results obtained in this experiment suggest that not the executive component but the anticipatory one, and not the amplitude but the duration of the anticipatory EMG activity of both ankle dorsi flexors produce primarily shorter movement time in the step initiation.

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P-210

Muscle Fiber Conduction Velocity Estimated through an Inverse Problem Analysis of Surface EMG

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INTRODUCTION

Muscle fiber conduction velocity (MFCV) is usually estimated from a time shift between two surface EMG signals[1]. This method is only applicable to EMG signals that propagate linearly with recording positions along the muscle fibers. If muscle fibers are not long enough or the skin and fat tissues are too thick, linear propagation is not observable[2]. To overcome this problem, a method of an inverse problem analysis was developed.

METHODS

Twelve channels of surface EMG were detected by using a surface electrode array with 5.0 mm contact pitch. A model of surface EMG generation was developed, which included MFCV, the position of innervation zones and the depth of muscle fibers as variable parameters. Once these parameters were given, synthesized EMG wave forms were calculated so that they fit to the measured EMG as much as possible. These parameters were then systematically changed to find the optimal values.

RESULTS

Fig. 1(A) shows the wave form of EMGs recorded from the biceps brachii of a healthy adult subject under 50% of the maximal voluntary contraction. In the regions apart from the source of motor unit action potentials (MUAPs), linear propagation was observed. Fig. 1(B) shows MFCV and the correlation coefficient calculated by the cross-correlation method. Fig. 2(A) shows the synthesized EMG that best fit to the measured signals. Two innervation zones were assumed. The wave forms agreed well with the measured one. The difference was 20.3% of the signal power. MFCV and the correlation coefficient were also calculated for the synthesized EMG (Fig. 2(B)). The MFCV estimated by the inverse problem analysis was 3.74 m/s, which was the same as the MFCV obtained by the cross-correlation method applied to the signals detected at positions distant from the innervation zones.

DISCUSSION

When MUAPs arise at the motor endplates, the surface potentials appear around the innervation zones according to the volume conduction. In the regions apart from the innervation zones, MUAPs approach from distant positions and the surface potential changes gradually. In this region signals detected with a surface electrode array show identical wave forms and a time shift linearly changed with the recording positions. This clear propagation is not observed around the innervation zones.

CONCLUSION

MFCV was estimated by the inverse problem analysis of multichannel surface EMGs. This method is applicable to small muscle, in which it is difficult to detect linear propagation of MUAPs.

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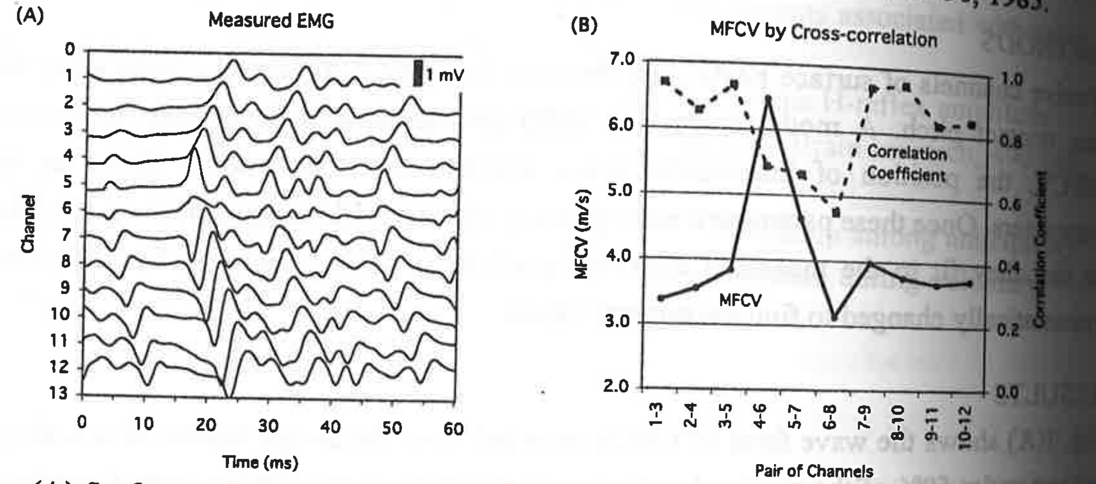

Fig. 1 (A) Surface EMGs detected with a linear surface electrode array. (B) MFCV and the correlation coefficient calculated by the cross-correlation method.

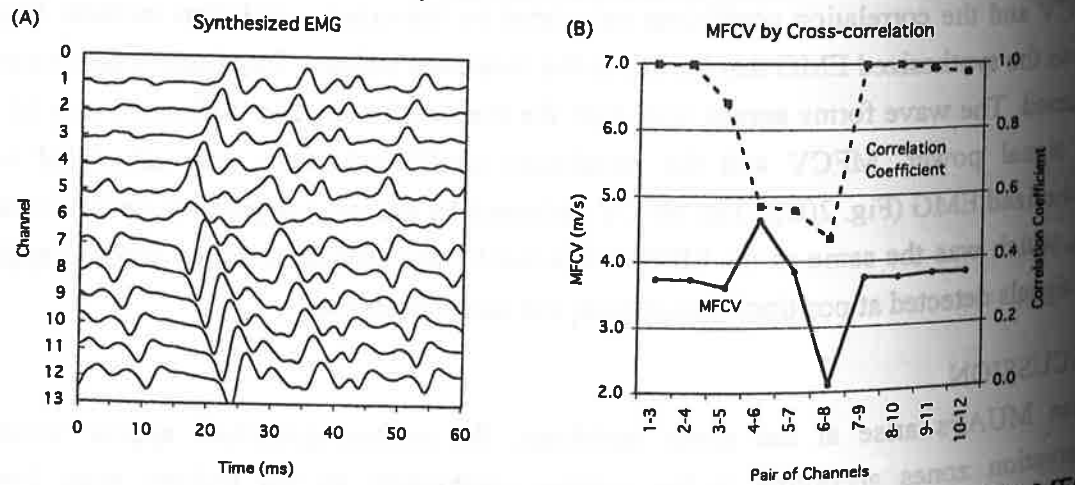

Fig. 2 (A) Synthesized EMG that best fit to the measured signals in Fig. 1(A). (B) MFCV and the correlation coefficient for the synthesized EMG.

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Habituation Process and Rail Effect in Treadmill Walking: An EMG Study of the Ankle Antagonist Pairs in Normal and Hemiparetic Subjects

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INTRODUCTION

In rehabilitation clinics, gait training on treadmill is widely accepted for convenience [1, 2]. However, on the account of appropriate restoration of gait pattern, similarity of treadmill walking and overground locomotion has been a debatable issue [2]. This study using the EMG linear envelope (LE) and variance ratio (VR) of consecutive strides to quantify the habituation process and effect of rail support of the ankle joint for normal subjects and hemiplegic patients during treadmill walking. Our results indicated that 1). habituated behavior was notable in the calf group but not in the pretibial group during treadmill walking. 2). control consistency of the ankle antagonist pairs could better be improved with rail support.

METHODS

Twelve normal adults and one-side involved hemiparetic patients, unfamiliar with treadmill walking or training, participated in the habituation experiment. In floor walking, all normal subjects walked on a 10m walkway at their comfortable speeds for 5 controlled trials. In treadmill walking, the subjects took the walking trials on a motor-driven treadmill for 12 minutes. The hemiparetic subjects repeated the trials similar to the normal subjects except that minimal support on rail for successive 7-minutes' treadmill walking was allowed for safety sake. On the account of rail effect for treadmill walking, we recruited eight additional normal adults to participate the rail effect test. All healthy adults performed treadmill walking with rail support in the same manner as hemiparetic patients except an additional 7-minutes non-rail treadmill walking. EMG LE and VR of the pretibial and calf groups with rail support and without rail-support trials were compared for both patient and healthy groups.

RESULTS

For all healthy subjects regardless of dominant or non-dominant side, VR of the pretibial group could never reach below habituation threshold (95% confidence interval of VR in floor walking) prior to the end of walking trial. In contrast, the majority of healthy subjects on treadmill were finally able to contract calf muscles consistently across strides with low VR within 95% confidence interval of VR in floor walking. In the light of EMG VR, our results strongly suggested that rail support was a significant factor of reducing activation variability of the ankle muscle during human locomotion ($p<0.05$). For normal subjects, EMG LE of the calf muscle during treadmill walking without rail support seemed less phasic, including decrease in normalized peak amplitude and earlier activation of main phasic activity. Interestingly, calf phasic activity during treadmill walking rendered in phase with that during floor walking if rail support was provided. In hemiparetic subjects, significant phasic patterns of the ankle muscles were noted during treadmill walking with rail support. However, these finding were not typical because of intra-subject and inter-subject variations.

DISCUSSION

The habituation process of the ankle muscles for naïve subjects on treadmill is possibly due to the forward momentum imposed by the constantly mobilized belt. Concerning the VR trends of the two muscle groups, we suggest the adaptation mechanisms for the calf and pretibial muscle groups were different. Next, lateral stability provided by rail support was likely to result in lower EMG VR [3]. Notable change of EMG patterns of the ankle muscles might be correspondent to reduction in postural reaction.

CONCLUSION

Our results showed that the habituation process and rail effect on treadmill could involve in evolutional motor reorganization. This fact should not be neglected, and warrants cautious interpretation for EMG data and other biomechanics parameters recorded on treadmill walking.

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P-212

Control in Motor Units of Lower Extremity Muscles in Swing Phase during Fast, Free and Slow Walking Speeds

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INTRODUCTION

We investigated changes in median power frequency (MdPF), integrated electromyography (IEMG), its rate of partial frequency zone to whole zone in right lower extremity muscles during swing phase at fast, free and slow walking speeds in normal adults. We also examined a control of the recruitment and firing rate of motor units in those muscles for swing phase during different walking speeds.

METHODS

Ten healthy volunteers without signs of neuromuscular disorders (4 men and 6 women), ranging in age from 22 to 38 (mean 30) years participated in the study.

Using a digital metronome, the subjects were requested to walk on level ground for a distance of fifteen meters at three different walking speeds ; fast (1.69 m/s), free (1.2 m/s), and slow (0.69 m/s).

The muscles we chose for this study were the right vastus lateralis (VL) and medial hamstrings (MH). A pair of Ag-AgCl surface electrodes, one-centimeter in diameter (Nihon Koden, co, Japan) in a bipolar lead system were applied over the central belly of each muscle. They were placed parallel to the muscle fibers two centimeters apart and secured to the skin by a piece of tape. Analog signals from the electrodes were converted to digital signals and stored in a PC card by means of an 8 channel PC card recorder (Teac DR-C2 ; Teac, co, Japan). Signals taken at a sampling time of 0.2 ms were analyzed using a new method in a computer program called "MemCalc" [1].

The mean MdPFs, IEMG values and its rates of partial frequency zone to whole zone of the VL and MH were compared among three different walking speeds.

RESULTS

In zone for the whole frequency from 20 to 1000 Hz, the mean IEMG values of the VL and MH for early stance phase were significantly greater with increased walking speed. In the zone of high frequency (70 to 200 Hz), the mean rate of MH for swing phase was significantly greater with increased walking speed. But VL was no significant difference in above frequency zone. In high frequency zone (200 to 1000 Hz), the mean rate of VL for swing phase was significantly lower with increased walking speed. In low frequency zone (20 to 40 Hz) the mean rate of VL for swing phase tended to be greater with increased walking speed.

DISCUSSION

It was considered that the MH for swing phase was selectively controlled to recruit the larger motor units in fast-twitch muscle fibers with increased walking speed, because in high frequency zone the rate of IEMG value of that muscle for swing phase was significantly greater with increased walking speed. Contrary to this, the VL was selectively controlled to recruit the smaller motor units in slow-twitch muscle fibers with increased walking speed, because in the high frequency zone the rate of IEMG value of the VL for swing phase was lower and in the low frequency zone that for swing phase tended to be greater with increased walking speed.

CONCLUSIONS

In conclusion, the different motor controls for each muscle were delicately performed for swing phase during different walking speed.

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The Mechanical Efficiency of Walking and Its Clinical Applicability

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INTRODUCTION

During normal gait, an exchange takes place between the potential energy (PE) of the human body's center of gravity (COG) and the kinetic energy (KE) of the COG in order to minimize the amount of work needed for, and to optimize the mechanical efficiency of walking. The percentage work of the COG saved by this energy exchange is thought to provide a direct measure of the mechanical efficiency of walking. This ratio can therefore be used as a good index for evaluating pathological gait and the effectiveness of various treatments.

The study presented here was undertaken to examine the proportion of energy which can be saved by the exchange between potential and kinetic energy in normal gait and to demonstrate the clinical application of this index.

METHODS

The subjects were 12 healthy females (mean age: 23.1years) and 12 healthy males (mean age: 26.9 years) and 2 patients (Case 1: a 65-year-old man with Charcot-Marie-Tooth disease; Case 2: a 43-year-old woman with hip disorders). The subjects were instructed to walk on a path, equipped with two force platforms, at a comfortable pace on more than 5 occasions. Additionally, Case 1 was instructed to walk with a bracing ankle-foot orthosis (AFO) on both legs, and Case 2 with a 2-kg load in the right hand. For each subject, the data selected for analysis were taken from the 3 sessions in which the subject's feet contacted the force platforms most appropriately. The data obtained from the marker position by means of a synchronized three-dimensional measurement technique provided the mean forward velocity during one gait cycle. The sampling rates were 240 Hz for the force platform data and 60 Hz for the three-dimensional data. The following are the major gait parameters that were calculated:

1) time-distance factors: gait cycle(sec.), gait velocity (m/min.), cadence, and stride length;
2) three dimensional acceleration, velocity, and displacement of COG;
3) PE, KE and total energy (TE) of COG versus time;
4) Energy Exchange Rate (EER) = $1 - |\triangle TE| / (|\triangle PE| + |\triangle KE|)$.

This means that EER represents the energy exchange between PE and KE in relation to the sum of work necessary to change PE and KE of COG. EER was obtained for 1) in terms of time, 2) during each gait phase (one gait cycle was divided into four phases of two single support periods and two double support periods), 3) throughout the gait cycle.

RESULTS

The EER in each period of the gait of healthy individuals was similar for the male group and the female group. It was higher during the single support period than during double support period. The mean EER throughout the gait cycle was 63.9±6.7% for males and 63.0 ±5.6% for females.

In Case 1, the mean EER throughout the gait cycle was 49.7% when no appliance was used and rose to 57.9% when an AFO was used. The use of an AFO led to a particularly marked improvement in the EER during the single support period. In Case 2, the mean EER throughout the gait cycle was relatively high (58.8%), but the EER during the right single support period was slightly lower than that for healthy individuals. When this patient carried a 2-kg load in her right hand, the mean EER throughout the gait cycle improved to 68.5%, and the improvement was particularly marked during the right single support period.

DISCUSSION

These results suggest that in healthy individuals, a very large portion of the work needed to walk is obtained from energy exchange, and that the energy exchange rate is higher during the single support period than during the double support period.

Analysis of EER revealed that the EER of each patient was lower than that of healthy individuals and that the EERs of these patients were improved by the use of appliances. When evaluating the efficiency of gait, EER is expected to serve as a useful indicator, since it allows an overall evaluation of gait for all phases and it provides concrete information concerning the problematic gait phase and the severity of the problem.

CONCLUTION

EER is a useful equation for determining walking efficiency. This parameter was considered to be a good index for evaluating the mechanical efficiency of walking.

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Effect of load and carrying position on the electromyographic activity of gluteus medius in unilateral Standing

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INTRODUCTION

The major function of gluteus medius muscle is to maintain a level pelvis in frontal plane during unilateral standing.in standing on one leg which occurs with every step, 85% of body weight must be balanced by the hip abductors , specially gluteus medius around femoral head , forming a first-class lever system.since the lever arm of the weight is longer than the lever arm of the muscle , so gluteus medius is at a mechanical disadvantage and must produce a force greater than 85% of body weight to maintain equilibrium.

Biomechanically, magnitude of joint reaction force can be decreased by shifting weight over the supporting leg, thus decreasing the force requirements of the gluteus medius to mach the torque acting at the hip axis, and thereby decreasing the joint compression force.

Two factors that influence on the amounts of activity of gluteus medius and hip compression force are carrying position of the hands (ipsilaterally or contralaterally to a test hip) and load size.the main purpose of this study is to determine through surface E.M.G , the relative amounts of gluteus medius electrical activity produced during unilateral standing and when subjects carry load sizes of 2kg, 5kg and 10kg , ipsilateral and contralateral to the test hip.we expected the contralateral carrying position would result in higher E.MG from the gluteus medius muscle during unilateral standing than would the ipsilateral carrying position and heavier loads demands higher E.MG activity from gluteus medius muscle.E.MG activity of gluteus medius was used as an indication of the relative amount of myogenic hip compression force.

Applied objective of the study is to advise people about optimal load sizes for carrying and carrying position to decrease joint force , thus preventing hip degenerative disease or disease progress.

Method

In this quasiexperimental study, 10 cllege students (all men) volunteered to participate in the study.test leg randomly was chosen.application of the electrode assembly was preceded by through cleaning the skin with alcohol.we applied the electrode assembly perpendicular to the muscle fiber direction at a point two fingerwidth down the lateral illiac crest. Electrodes were fixed with adhesive tape.electrical activity resulting from

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active hip abduction verified electrode placement is over the muscle.subjects performed unilateral standing with no external load that served as a baesline measurement of the influence of external load on the activity of the muscle.then we measured load influence of 2kg, 5kg, and 10kg, ipsilateral and contralateral to the test hip..

Results , discussion and conclusion will be sent later , before 2000/feb/20.

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Upgrade of low-cost technology for accurate analysis of foot-ankle dynamics

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INTRODUCTION

Plantar pressure and ground reaction force measurements are largely used in gait analysis to characterise normal and abnormal function of the human foot. The combination of these data together provides a more exhaustive, detailed and accurate view of foot loading during activities than traditional measurement systems alone do. A prototype system of a piezo-dynamometric platform has been already realised by the authors and widely described elsewhere [1]. Briefly, it consists in the superimposition of a pressure platform onto a force platform and in their synchronisation. The device allows the measurement of pressure distribution, global ground reaction force (GRF) and local vertical GRF component, and the estimation of local shear GRF components. The system is effective when there is need for specific foot subareas loading or the biomechanics of foot minor joints to be accurately described; this is particularly attractive both in biomechanic research or in clinical context.
For the measurement to be reliable, however, accurate synchronisation is essential between the two instruments. In the already realised prototype it was achieved by means of a dedicated PC-card and a specific, but now obsolete, operating system. In the present paper a new solution is proposed in order to render the whole system more robust and transportable, with respect to the commercial PCs and operating systems, and thus available at low cost.

DESCRIPTION OF THE ACQUISITION SYSTEM

The dedicated PC-card, which managed the old prototype of the integrated platform, handled a specific hardware interrupt to transfer data from the pressure platform memory to the PC RAM every 10 ms. The interrupt had the highest priority, since the operating system (MS-DOS™) allowed the masking of the remaining interrupts, and the "real-time" transfer of data was assured. The main drawbacks of using that PC-card with that operating system were its cost, a limited range of port addresses and interrupts, the conflicts with other PC-cards like common video or audio cards. Most important, the real challenge posed to real-time data acquisition by the presently available operating systems is the latency of the CPU response due to their intrinsic multitasking nature. This means that a fixed sampling rate can be no longer guaranteed with the technique based on the interrupt handling, unless of complex and expensive modifications. A common solution for this problem is to use data acquisition cards, with huge quantity of on-board memory, acting like a FIFO. This assures that no data are lost even though the CPU is not available for the whole sampling period. This solution is quite expensive and prevents effective synchronisation with other measurement devices, which is essential to manage our integrated piezo-dynamometric platform.
To overcome such strong restrictions, we designed and built a stand-alone card with a 16-bit CPU on-board, which acts like a software FIFO. It allows to: i) read pressure and force data from the integrated platform at the exact sampling rate with negligible jitter; ii) concurrently transfer them to the PC RAM or hard memory through the standard parallel port commonly available on PCs; iii) exactly and easily synchronise several devices. A block diagram of the board and the system is drawn in Figure 1. The parallel port is used in 8-bit bi-directional mode: in forward mode (from PC to board) it carries commands like start acquisition, stop acquisition, inquire status, etc.; in backward mode (form board to PC) it carries the acquired

data at a transfer rate up to 200 kB/s. The platform port is used to read data from the integrated platform; since it can be located quite far from the device, the port has been equipped with high-current line-drivers in order to maintain signal integrity.

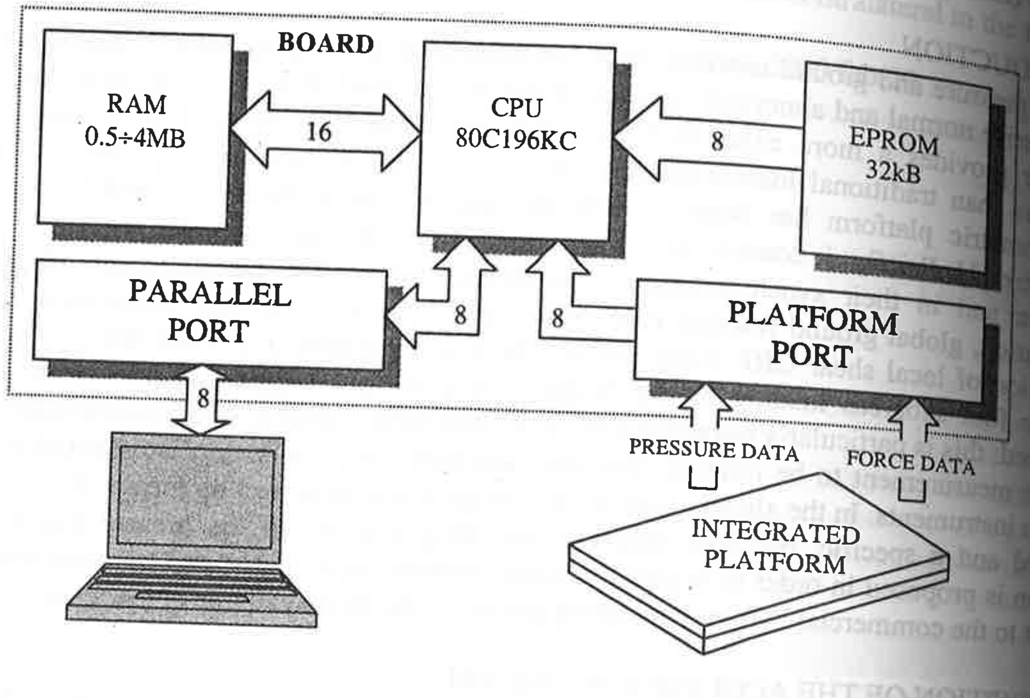

Fig. 1 – Block diagram of the system

DISCUSSION AND CONCLUSIONS

The external hardware solution here presented has been implemented at a very low cost and applied to the previously assembled piezo-dynamometric platform. At the selected sampling rate (100 Hz), and for standard gait analysis experiments, the speed of the parallel connection is adequate to transfer almost all the data within each sampling period. The on-board memory is instead widely used in postural analysis, where there is a greater amount of data to transfer during each sampling period; the memory capacity (4MB maximum) is enough to guarantee continuous data collection for at least 60 s, even at 100 Hz sampling rate.
The new solution allows our integrated platform to be used with present operating systems and portable PCs without any lack of accuracy. We used a prototype of the device in different clinical and biomechanical environments, and we found it effective for the complete dynamic characterisation of the whole foot and of some foot subareas of specific interest [2].

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P-216

Effects of bilateral upper-limb exercise on trunk muscles activity.

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INTRODUCTION

In order to maintain posture, compensatory muscle activities of trunk muscles against upper-limb movements are required. However, there are few data describing trunk muscle activities with different types of upper-limb movements. The purpose of this study was to examine the effect of bilateral upper-limb movements on trunk muscles activities, especially effect of postures, effect of direction of movement, and effect of hand grip position.

METHOD

Ten healthy adult volunteers (5 female and 5 male, aged 26.2 ± 8.7 years old) participated in this study. Muscle activities were recorded from the rectus abdominis, the obliquus externus abdominis, the trapezius, the latissimus dorsi, and the erector spinae via Neuropack 8 electro-myography (Nihonkoden Inc, Japan). After reducing skin impedance, two recording electrodes were attached on little distal to the middle of target muscle with 1.5 cm intervals. EMG was normalized by isometric maximum voluntary contraction of each muscles. Subjects were asked to perform three upper-limb movements with assist of MOFLEX functional exercise machine (PROXOMED Inc. Germany). This equipment enables subjects to move eccentrically and concentrically with constant speed with variable resistance. The speed of the movement was set at 0.3 m /sec. After subject felt comfortable with the movement, EMG was recorded at the sampling rate of 2000 Hz for 5 seconds. The three movements consist of pull-down at standing position, pull-up at standing position, and pull-down at sitting position. The width between grips was changed to 15 cm, 60 cm, 75 cm, and 100 cm for the third movement. Mean and standard deviation of each muscle activity (%MVC) during six conditions were calculated. Data exceeding two standard deviations was removed from the analysis.

RESULTS

During pull-down at standing position, the rectus abdominis and the obliquus externus abdominis showed more than 30% of MVC. The trapezius and the muscles spinae showed 20% or more muscle activities for pull-up movement at standing position. Especially the trapezius indicated more than 50% of muscle activity during pull-up movement. For pull-down at sitting position, muscle activity represented similar to the first movement, but muscle activity of the latissimus dorsi increased depending on increase of hand width, whereas muscle activity of the rectus abdomimus decreased. The greater the hand width showed the greater the muscle activity.

DISCUSSION

Effect of posture: During pull-down movement, both rectus abdominis and obliquus externus abdominis showed high activity, although the standing position revealed higher activities than the sitting position. Elector spinae also increased activity in standing position, so that we believe that standing position requires more muscle activity to maintain posture against upper-limb activity.

Effect of movement direction: In comparison of pull-up and pull-down at standing position, pull-down required more muscle activities on the rectus abdominis and the obliquus externus abdominis, whereas pull-up required muscle activities on the elector spinae and the latissimus dorsi. Both front muscles and back muscles showed muscle activity in both pull-up and pull-down movement, back muscles are dominant during pull-up movement, and front muscles are dominant in pull-down movement.

Effect of handgrip width: As the distance of each hand increased, greater the latissimus dorsi activity and less rectus abdomimus activity were observed. We believe that in order to pulled down the functional bar, isometric contraction will be required in the direction of adduction and internal rotation movement simultaneously with shoulder joint extension movement.

Application for clinical setting: Both pull-down and pull-up showed muscle activity in back muscles, but the activity was higher in the pull-up movement, so that pull-up movement can be used for the advanced stage of back muscle treatment, and pull-down exercise should be used from the earlier stage. Movement in standing position can be also applicable in the advanced stage, since the standing position requires more activity to stabilize pelvis. To control activity in abdominal muscles, the position of handgrip can be used.

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TIME-FREQUENCY ANALYSIS OF THE EMG SIGNALS: INVESTIGATIONS ON HEEL STRIKE TRANSIENT

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INTRODUCTION

During heel strike, the leg landing on the ground is exposed to repetitive impulsive loads. Heel Strike Transient (HST) is referred in literature as a "resulting irregularity in the ground reaction forces"[1] related to such a loading. In general, it has been observed in the Vertical component of Ground Reaction Forces (GRF): in our previous paper [2], we have verified its happening by correlation with some irregularities observed in the Antero Posterior component of GRF. Since the HST seems can be dangerous even if small,[1], and since it is related to the aetiology of the low back pain, osteoarthritis and to the possible damage of the endo-prostheses, we are trying to explain the HST presence. For this purpose we analysed the EMG signals of some muscular groups to identify possible strategies aimed at reducing or preventing the HST.

METHODS

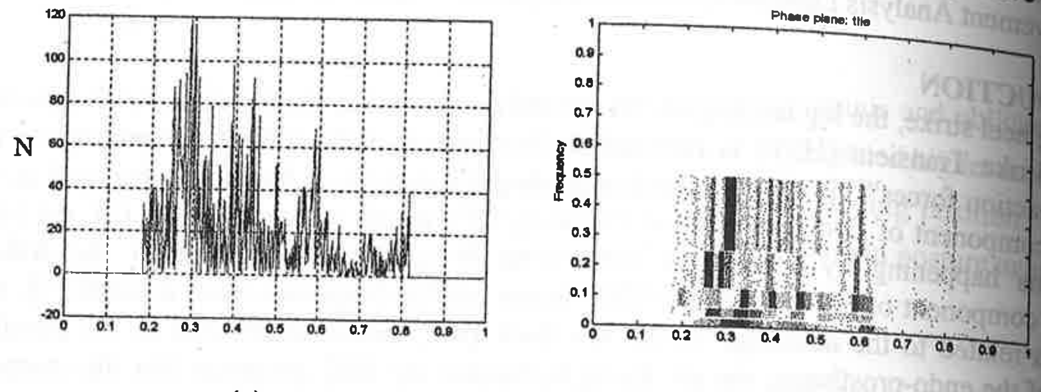
The EMG activity of rectus femoris, tibialis anterior and hamstrings muscles of the leg striking on the ground has been analysed. Five total knee replacement subjects and five normal subjects have been examined. The data have been collected at 500 Hz sampling frequency during a gait analysis test. Zero-padding has been used for data processing (1024 samples needed). The EMG signal has been full wave rectified and then processed using wavelet transform. The mother wavelet used has been the fourth order Daubechies wavelet. The structure implemented is a filter bank, being the wavelet basis function conceived as the impulse response of a filter [3]. The outputs of the wavelet transform, are named expansion coefficients. They can be put on tables, useful for quantitative analysis. The information content present in the coefficient's amplitudes can be shown as a picture by means of the values of a specified *energy function*. In such a picture named "tile representation", the darkness of each tile correspond to the value of the energy associated to the relative expansion coefficient [3].

RESULTS

Our analysis has been devoted to identify the activation patterns of muscular groups before and after the heel strike. The tile representation allowed us to have information on the temporal activation and at the same time, on the frequency content of such an activation [4]. The time-frequency distribution of the muscles examined provides insight on the types of fibers (slow and/or fast) recruited particularly before and during loading response period. The tile representation shown in the figure 1, related to rectus femoris, reveals the recruitment after heel strike of fast and at lower intensity of slow fibers

DISCUSSION

Our preliminary study seems to agree with results present in literature [4] and reveals the activation of both types of the fibers during heel strike. Generally slow fibers are dominant during terminal swing. This period of activity, preparing the knee and the leg for the next heel strike, it is sometime followed by high frequency fast fibers recruitment. We are performing more accurate observations of the tile representation. Particularly, we are investigating the possible co-activation of agonist-antagonist muscles aimed at reducing the speed of the leg striking the ground and at modifying the intensity of the impulsive loading.



(a) (b)

Fig.1: (a) Surface Emg of Rectus femoris during a gait cicle, (b) tile representation of the signal

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Effect of current source distribution on the inverse analysis solution of surface EMG

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INTRODUCTION

In the inverse analysis study of surface EMG [1], we estimated the depth and intensity of equivalent current dipoles regarded as active muscle fibers. The estimated depth varied proportionally with the estimated intensity. This relationship may be caused by the distribution of muscle fibers. We therefore studied the possible bias in the estimation of the inverse analysis with a numerical simulation of surface EMG.

METHODS

Measurement of surface EMG and inverse analysis

Surface EMG was measured by positioning a 16-channel electrode array on the biceps brachii of three male subjects during a static contraction. The depth and intensity of equivalent current sources were estimated for 46 motor unit action potentials (MUAPs) extracted by averaging the surface EMG [1].

Numerical experiment

Surface potentials of single motor units (MUs) were simulated numerically. Each MU consisted of one hundred current sources distributed uniformly and randomly over a circular territory. Under 4 conditions indicated in Fig. 2, we produced 50 distribution patterns of current sources. Each current source had an intensity of 0.05 nAm. We then estimated the depth and intensity of a single equivalent current dipole from the surface potentials calculated from these distributions.

RESULTS

The depth and intensity of equivalent current dipoles estimated from the measured surface EMG varied proportionally to each other (Fig.1). The results of the numerical simulation were similar to the actually estimated ones except for the condition of 1.5 mm radius and 2.5 mm depth (Fig.2).

DISCUSSION

In actual muscles, the territory of MUs is independent of the depth. The proportional relationships between the estimated depth and intensity of MUs can therefore be a bias in the inverse analysis process. MUs estimated to be located at shallow positions with lower intensities may have some muscle fibers near the skin surface, whereas deeply estimated MUs with higher intensities do not have such fibers. MUs at shallow positions with higher intensities do not exist in actual muscles. If an intensity of current sources is uniform among different MUs, the depth of motor unit can be corrected to actual values by removing the effect of this bias in the inverse analysis.

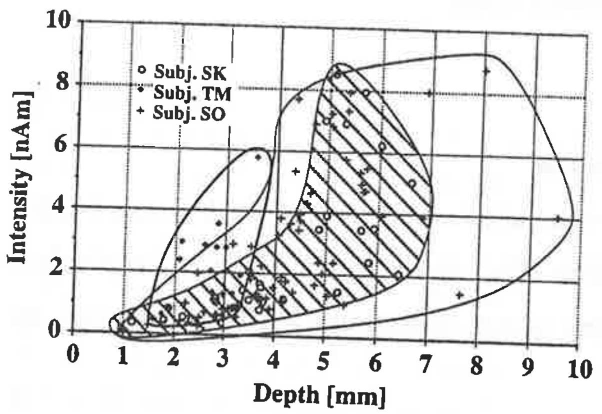

Fig. 1 The results of the inverse analysis of surface EMG.

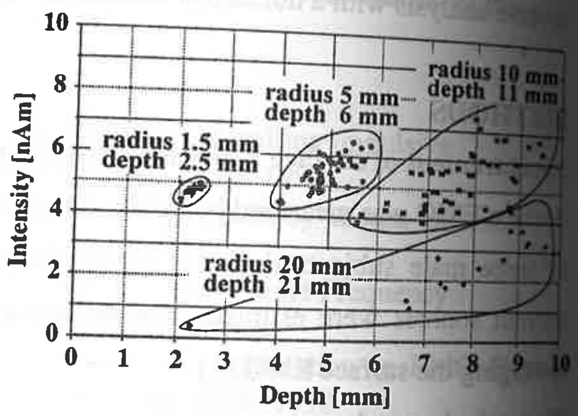

Fig. 2 The results of the numerical simulation.

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P-219

Age-related Changes in the Conduction Velocity and Spectral Variables of Myoelectric Signals Detected from the Tibialis Anterior with Surface Electrode Array

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INTRODUCTION

Age related decline of the motor performance might be caused by the senile change not only in the respiro-circulatory and nervous systems but also in the skeletal muscles. Morpho-functional features of human muscles are conventionally evaluated by using the tissue biopsy or intramuscular EMG, which are invasive. Recent advances in surface EMG studies have introduced potential utility of the spectral profile and conduction velocity (CV) of myoelectric signals noninvasively derived from muscles, for detecting their metabolic conditions. We attempted to identify the age-related changes in these EMG variables by comparing the data of young and elderly people.

METHODS

Ninety-nine healthy female subjects (24 were 20s, 75 were 50-70 years old) perticipated in this study. They sat on a chair with the hip and knee joints flexed 90 degrees, and requested to perform isometric dorsi-flexion with a maximal voluntary effort for 5 seconds. Myoelectric signals were picked up from the tibialis anterior muscle by means of a surface electrode array consisting of 4 stainless steal contacts spaced at 5mm intervals. The signals were led bipolarly in 3channels from the neibouring contacts, recorded on a magnetic tape, and digitized at a rate of 5kHz.

Cross correlation coefficients(CC) between each pair of channels were calculated, and the pair which yielded the highest correlation was selected. MFCV was computed from the inter-contact distance(5mm) and the time shift giving the maximal value of cross correlation. The median frequency (MDF) was calculated from the myoelectric signals of the middle channel.

RESULTS AND DISCUSSION

Fig. 1 shows the mean±SD of the CC, MFCV and MDF for each age group. Overall mean of CC is as high as 0.89, and CV is 4.88 which is close to the values reported in previous studies. These results suggest that the propagation of myoelectric signals were appropriately picked up in the present study. One-way ANOVA revealed that difference between the age groups was significant in MFCV whereas insignificant in MDF. Multiple comparisons indicated that MFCV was significantly higher in 20's of age group than in 60's and 70's of age group.

The most likely factor causing these age-related decline of MFCV may be the selective atrophy of FT fibers in the elderly. It has been well documented that there exists a significant correlation between MFCV and % FT fibers in the vastus lateralis muscle. Another potential reason is the age-related difference, if any, in the motor unit firing rate. MFCV has been reported to be positively related with the rate. Possibility of the influence of muscle temperature may not be excluded. Further research including additional data collection is needed to determine the causality.

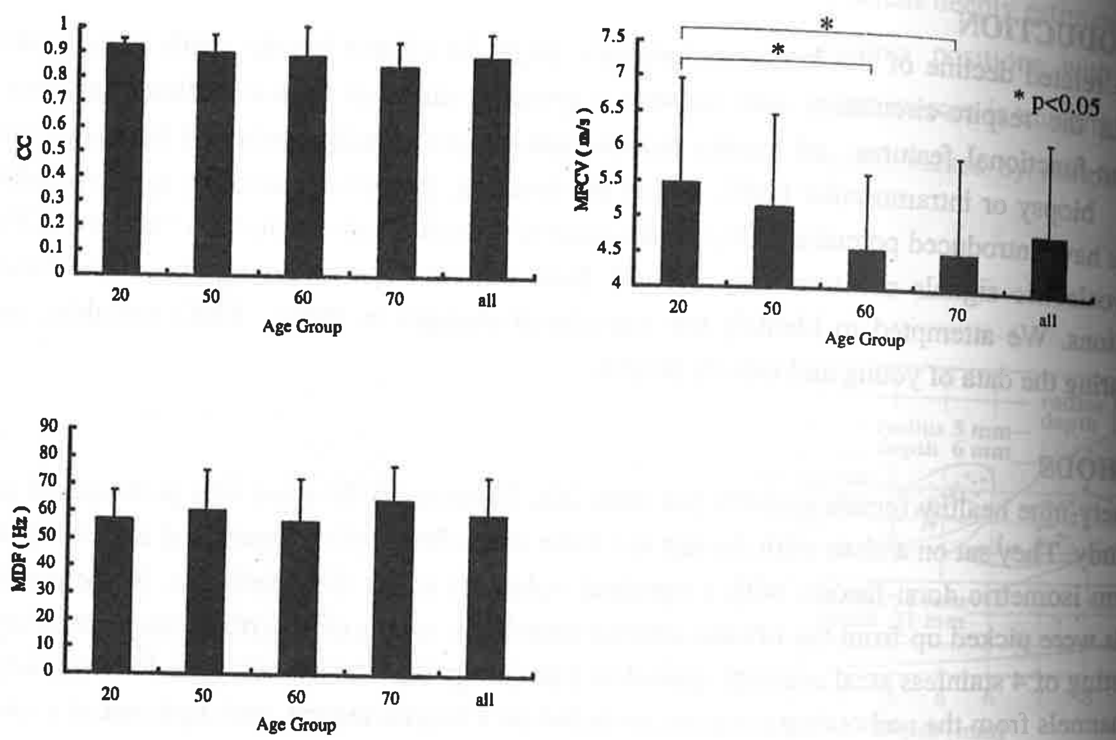

Figure 1. Age-related changes in CC , MFCV and MDF calculated from myoelectric signals detected from the tibialis anterior with surface electrode array.

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P-220

FINE WIRE EMG OF THE CERVICAL MUSCLES IN THE DIAGNOSTIC OF WHIPLASH INJURIES

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Introduction: One problem of whiplash injuries is most of all the diagnostic objectivity of the pain symptoms. The radiological diagnose is mainly morphologically orientated. Such a morphological damage, however, cannot be proofed in many cases, shows itself in pains and functional limitation. The kinesiological EMG correlates the electrical muscle activity with the range of motion, torque and other dynamic parameters. The literature does not know any kinesiological study of the cervical muscles.

Aim of the study: Demonstration of muscular dysfunction of neck muscles in the course of fresh whiplash injuries and with patients showing late whiplash syndrome.

Patients and methods: In our study participated 30 healthy volunteers, 25 patients with fresh spinal whiplash injuries and 40 patients with a pain history of at least 6 months after a whiplash injury. The patients were examined clinically a standardized pain report was taken and a fine wire EMG examination was done. All patients with fresh whiplash injuries were seen a second time after 8 weeks. Patients with a pain history of more than 6 months were divided by a pain score in those without or only moderate pain (n=11) and those with pain (n=29). EMG signal was recorded while the patients/controls performed three motion cycles of right/left rotation and flexion/extension. The EMG can be described by determination of the amplitude and their temporal relation to motion related events.

Results: All volunteers showed an increase of the electrical amplitude during contraction and a decrease of the potential during muscle flexion. The volunteers represent an excellent comparison because of very low variations.

4 of 25 patients with fresh whiplash injuries showed a normal EMG. All 4 did not have any pain after more than 8 weeks. 21 patients with fresh whiplash injuries showed pathological EMG. 4 of them still showed pain and limitation of motion as well as a pathological EMG after 8 weeks. 16 patients had no more pain after 8 weeks and showed a normal EMG. The EMG of 1 patient could not be used for reasons of motion artifacts.

In the group of patients with a pain history of at least 6 months 38 patients (95 %) could be classified correctly in groups with and without or moderate pain by the help of the EMG ($p<0,001$).

Conclusion: The kinesiological EMG can objectively classify a damage or dysfunction of the cervical muscles. The technique can be useful for follow up examinations and for expertise jobs.

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The Contribution of Grouping Discharges in Surface EMG to its Spectrum Change

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INTRODUCTION

The spectrum of surface EMG is often compressed to lower frequency(EMG slowing) during fatiguing contractions. The EMG slowing is sometimes absent in bipolar EMG although it is clear in monopolar EMG(1). The difference of the EMG slowing between the lead methods is related with the grouping discharges on surface EMG in this report.

METHODS

Static contractions were performed in knee extension at 3, 8 and 15%MVC for seven subjects and in elbow flexion at 10 and 40%MVC for nine subjects. Surface EMGs were recorded from vastus lateralis in the knee extension and from biceps brachii in the elbow flexion by monopolar and bipolar leads. One of the bipolar electrodes was used as that of the monopolar EMG. A reference and a ground electrode were placed over the anterior surface of the tibia in the knee extension and over the dorsum of the forearm in the elbow flexion. The contractions were usually continued for 60, 30 and 5 minutes in 3, 8 and 15%MVC of the knee extension and for 40 and two minutes in 10 and 40%MVC of the elbow flexion respectively.

Relative power in 8-20Hz was used for the index of the EMG slowing. Averaged waves classified by amplitude(AWCA) were calculated as follows. Peaks on EMG were used as the origin of the averaging. In this paper, 'the origin' means the peak point for the averaging. A positive peak is a turning point from an increase to a decrease of positive recorded potential. A negative peak is an upside-down peak in negative potential. The contractions were divided equally into five or 10 parts. Ten averaged waves were calculated for each part according to the amplitude of the peak: five amplitude levels for the negative and positive peaks. Level 1 was lowest and level 5 was highest. The amplitude levels were decided from the amplitude distribution of EMG in the start of the contractions. The length of the averaged wave was 128msec. AWCAs of bipolar EMG were calculated with own peaks. AWCAs of monopolar EMG were calculated with the peaks of the bipolar EMG, that is, the averaging was synchronized with the bipolar EMG's. Since monopolar EMGs were recorded as the relative potentials from a reference electrode with AC amplifiers, negatively large potentials show high activity, positively large potential shows low activity.

RESULTS

In monopolar AWCA, a high activity part followed the origin of low amplitude levels and a low activity part followed the origin of high levels. The parts after the origins seemed to change with the time of the contractions. Correlation coefficients were calculated between every point of AWCAs and relative power in 8-20Hz and were called R-AWCA(Fig.1). The R-AWCAs between 15 and 30 msec after the origin were low in the low levels and were high in the high levels. This shows the rate of low frequency components of EMG increased if the activity level during 15-30 msec after small peaks increased and/or the activity level after large peaks decreased. The alternation of low and high activity levels, grouping discharges, in the cycle of 30 to 60 msec caused the EMG slowing.

DISCUSSION

Fig.2 shows raw EMG where the rate of low frequency components was largely different between bipolar and monopolar EMG. Apparent grouping discharges are seen in both of the EMGs. In the monopolar EMG, the potential was negatively high at high activity parts and was positively high at low activity parts. In the bipolar EMG, the average potential was zero at any activity levels although the amplitude was different between high and low activity parts. If the wave is symmetry against the zero potential level, the cycle of the grouping discharge would not be analyzed as its cycle in bipolar EMG. The difference in the EMG slowing between the lead methods must be caused by the difference in the detection ability of the cycle of the grouping discharges.

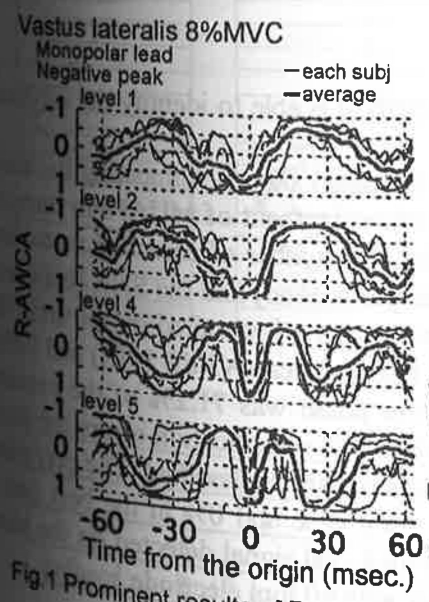

Fig.1 Prominent results of R-AWCA

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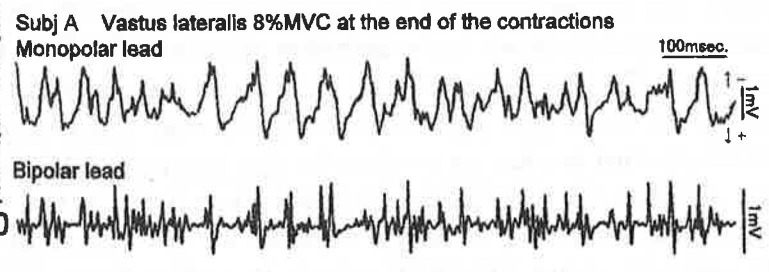

Fig.2 An example of grouping discharges

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SURFACE EMG DECOMPOSITION: PRELIMINARY RESULTS

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INTRODUCTION

It is purpose of this work to address the issue of surface EMG decomposition by spatial filtering and spatial sampling techniques, using linear electrode arrays and array processing methods, for the detection and classification of motor unit action potentials (MUAPs) and for the identification of the constituent MUAP trains. Recent works related to the study of single MUAPs have demonstrated the possibility of detecting and tracking a few MUAPs during an isometric sustained contraction (1,2).

METHODS

Linear electrode arrays detect surface EMG in a number of equally spaced locations, along the muscle length and provide a indication of the motor unit innervation and termination zones, and propagation velocity. MUAP detection and extraction is performed with the Wavelet technique and combine the information provided by the electrode arrays working in the spatio-temporal domain. Extraction is made by identifying the firing time for each MUAP and tracking its propagation towards the tendon zones. Each identified MUAP is extracted in the spatio-temporal domain to preserve the information useful to recognize and classify it by meansof the innervation zone position, fiber length and conduction velocity. MUAP classification in clusters (Motor Units) is obtained using a multi-channel neural network based on a ART2 model (3). It consists of several networks that work in parallel, one for each channel. Each network performs the classification on the basis of the MUAP morphology detected on the corresponding channel. The results from each network are integrated with the others to identify the specific motor unit.

RESULTS

Preliminary tests with simulated and real signals show that the method is able to identify the recurrence of contributions of the same MU during a contraction.

The system performances have been evaluated using computer simulated signals, comparing the known number of classes with the estimated one and verifying the correct assignment of MUAPs to their own classes. We have created signals of different complexity, varying the number of recruited motor units (between 5 and 8), the firing frequency (between 5 and 30 pulses per second) and the SNR (between ∞ and 3dB). The system seems to be able to correctly identify the number of recruited motor units. The percentage of true positives in the detection phase was 70.1% in the worst case (3 dB SNR) and 92% in the best one. The percentage of true positives in the classification phase was 71.2% of the extracted MUAPs in the worst case and 93.5% in the best one. The detection and classification errors are due to superpositions that are not yet resolved so that overlapped MUAPs remain unclassified. The percentage of false positives for the classification phase was 3.5% in the worst case and 0% in the best one. In Fig.1 an application of the technique is shown for a two seconds long real signal detected on the biceps brachii muscle at about 20% MVC using a 16 contact linear array with 10 mm electrode spacing.

DISCUSSION & CONCLUSIONS

We have proposed an automatic technique for signal segmentation and classification of action potentials which, although does not yet permit to give reliable information about firing patterns due to superpositions, constitutes a useful tool for a) the identification of the innervation zones and estimation of the length of the fibers of the active MUs detected by surface electrodes, b) the extraction of MUAPs morphologies, c) the detection of MUAPs at different contraction levels, opening interesting perspectives for investigation of the central motor control. The resolution of the superposition issue will increase the system performance in the near future.

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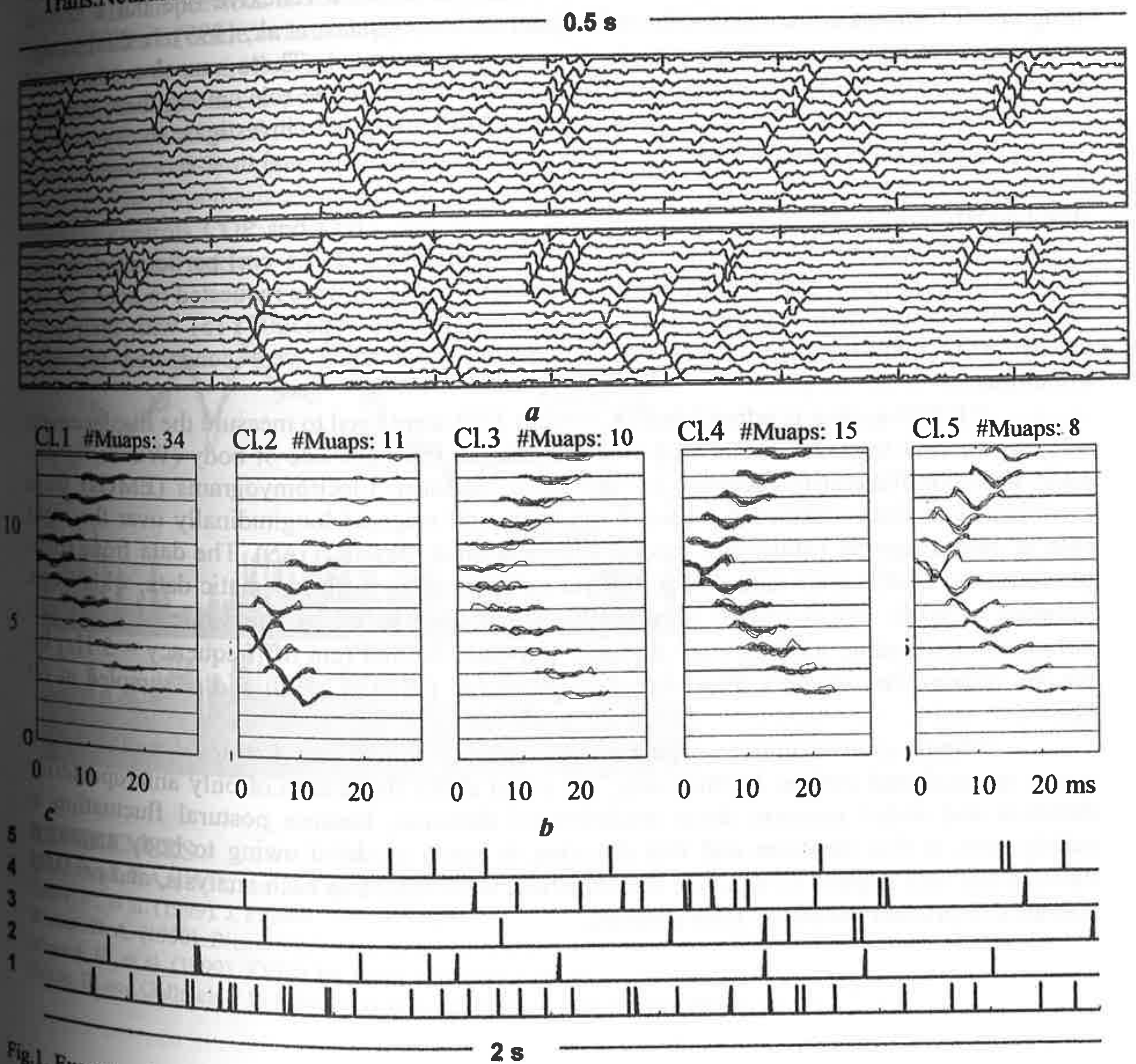

Fig.1. Example of application to a two seconds signal detected with double differential technique from the biceps brachii during an isometric contraction at about 20% MVC level. (*a*) Two EMG segments of 0.5s each. (b) Signatures of the identified motor units. c) Fring patterns (without superpositions).

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Synergistic strategy among ankle extensors during human quiet standing

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INTRODUCTION

Human quiet standing (QS) is often modeled as an inverted pendulum rotating around the ankle joint. According to this scheme, because the center of gravity (COG) is located in front of the ankle joint, the agonist of the movement during QS is considered to be ankle extensors. The classical study introduced the concept of the stretch reflex strategy where shift of COG constantly stimulated stretch afferents of ankle extensors that then contracted reflexively (Hellebrandt, 1938). However, a recent study indicated that EMG activity of lateral gastrocnemius muscle precedes COG and the center of pressure (COP), and suggested that the modulation pattern of this muscle is not a reflexive one but a central program of feedforward control of the ankle joint stiffness (Gatev, et al., 1999). In their study, another ankle extensor, soleus muscle, was not investigated. These muscles consist of different fiber types (Saltin and Gollnick, 1983), and therefore the role among these muscles may be expected to be different. So the purpose of this study is to investigate the synergistic strategy among ankle extensors during QS by way of the statistical and time-series analysis.

METHOD

Five healthy subjects (age 28.2–2.2 years; height 172–7.1 cm) participated in this study. All the subjects gave written informed consent. Subjects were requested to keep QS for about 30 seconds with barefoot on force platform (Kisler, Type5007Y15) with their eyes opened (EO condition) or closed (EC condition). Five trials were conducted for each condition.

VICON system (Oxford Metrics, system 370) were used to measure the displacement of COG by four segment model with five markers on the right side of body (Winter, 1990). COP was simultaneously recorded by the force platform. Electromyograms (EMGs) were recorded by surface electrodes placed 2 cm apart and oriented longitudinally over the right side of soleus muscle (SOL) and medial gastrocnemius muscle (GAS). The data from force platform and EMGs were sampled at 480 Hz synchronously with kinematic data, which was sampled at 60Hz. After EMGs were rectified and normalized by the value of maximum voluntary contraction, all data were digitally low-pass filtered (cut off frequency = 5 Hz) by the 4th ordered Butterworth filter with zero phase lag (Winter, 1990) and re-sampled at 60 Hz.

Tibialis anterior muscle, which was also recorded, was very low-level, and therefore it was not analyzed further. In this study, we noted about fluctuation of only anteroposterior direction and didn't mention about mediolateral direction, because postural fluctuation is mainly seen in this direction and this direction is easily modeled owing to body anatomy. Paired t-test was applied to evaluate the statistical significance in each analysis, and $p < 0.05$ was used to prevent excessive false positive.

RESULT and DISCUSSION

The following results concerning difference between GAS and SOL were obtained:
1) The average amplitude of GAS tended to be larger during EC than during EO (p=0.05, not significant), but that of SOL was not different between conditions (p=0.08).
2) The standard deviation (SD), which can be regarded as a measure of fluctuation, of GAS was larger during EC than during EO, but SDs were not different between conditions in SOL.
3) The coefficient of variation, which is the normalized SD by the average value and should be used to compare SDs on different average values, was larger on GAS than in SOL during both conditions.
4) The correlation coefficient (CC), which was obtained as the peak value in the correlation function, against COP was larger in GAS than in SOL during both conditions.
5) CC against the velocity of COG was larger in GAS than in SOL during EC.

It is usually said that the length of COP is longer during EC than during EO, and this may also be true in this study. Both of this result and the results 1, 2, 3) suggest that large fluctuation of GAS during EC causes large fluctuation of COP during the same condition.

In the previous studies (Gatev, et al., 1999; Masani, et al., 1999), it was reported that the activities of ankle extensors precede the fluctuation of COP and COG, and this suggests that posture is controlled by ankle extensors with feedforward manner, not with reflexive manner. And also in our previous study (Masani, et al., 1999), the fluctuation may be derived from the fluctuation of the velocity of COG and it may be the control parameter of posture. The result 4) and 5) suggest that GAS is more important to control posture than SOL.

The hypothesized scheme of postural control is presented from these result; GAS actively controls COP and COG, and SOL is activated rather tonically only to enhance the stiffness around ankle.

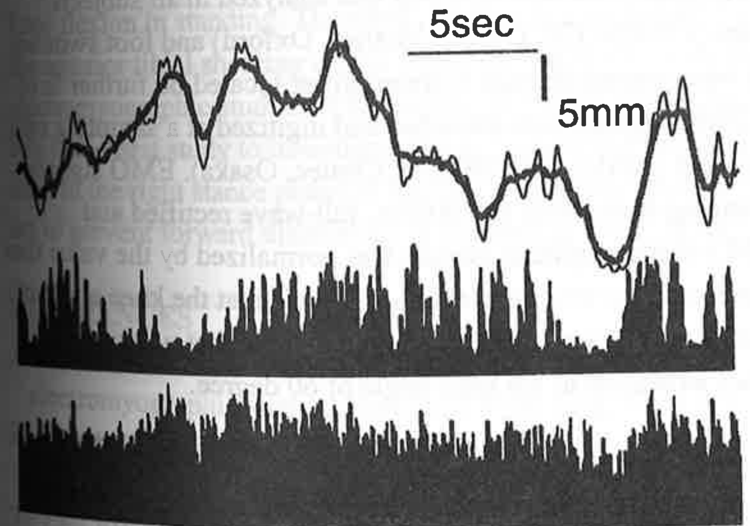

Fig. Example of typical recording from one trial during EC condition
From bottom to top: activity of soleus muscle (SOL), activity of gastrocnemius muscle (GAS), fluctuation of center of pressure (COP) (thin line) and fluctuation of center of gravity (COG) (thick line). GAS actives phasically and seems similar to COP, while SOL seems to active tonically more independent to COP.

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EMG activity of the popliteus muscle during standing and descending a step

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INTRODUCTION: Among human muscles, the popliteus is unique in structure, having an intimate relationship to an articular meniscus and an inversion of its fleshy and tendinous attachment[1]. It was postulated by several investigators that this muscle acts as an internal rotator of the tibia on the femur and as a retractor of the lateral meniscus during flexion of the knee[1, 2, 3, 4]. In the present study, we recorded EMG activities of the popliteus muscle during standing at several knee angles and during descending a step.

METHODS: Eight normal volunteers (8 male, aged from 21 to 36 years) participated in this study. The subjects had no previous problems in their thigh muscles or knee joints. Informed consent was obtained from all subjects. Bipolar fine wire electrodes were inserted into the right popliteus muscle, and electrical stimulation was used to confirm the location of the electrode. The diameter of the wire was 75 μ m, and each electrode tip was bared for about 2mm. Each inter-tip distance was set at 5mm. Also, EMG activity of the vastus lateralis muscle was picked up with bipolar surface electrode. All subjects performed four standing tests and two descending tests. They held standing position at the knee angles of 0, 30, 60 and 90 degrees and descended one-step staircase with a riser height of 20 cm from their right lower limb and from their left lower limb. Descending a step was analyzed in all subjects using a 3-D motion analysis system (VICON 370, Oxford Metrics, Oxford) and foot switches on the heel and toe. EMG signals were passed through a preamplifier located no further 5cm from the point of electrodes. The EMG signals were recorded and digitized at a sampling rate of 2500Hz using a 12bit A/D converter (AD12-16U (98) EH, Contec, Osaka). EMG signals were filtered using a bandwidth ranging from 10Hz to 1000Hz, full-wave rectified and averaged. While the smoothed EMG of the popliteus muscle was normalized by the value that was obtained during the maximum isometric internal rotation of the tibia at the knee angle of 90 degree, that of the vastus lateralis muscle was normalized by the value that was obtained during the maximum isometric knee extension at the knee angle of 60 degree.

RESULTS: The EMG activities of the popliteus and vastus lateralis muscles were increased significantly with an increase in the knee angle during standing (Table 1). During descending a step, the popliteus muscle showed some activities in both swing and stance phases (Fig. 1). In right swing phase of the descent from the right leg, the activity of the popliteus muscle increased gradually as the activity of the vastus lateralis muscle increased. The peak activity of the popliteus muscle showed about

Table1. %EMG of the popliteus and VL during flexed knee stance

	Popliteus		VL	
Knee angle	Mean	S.E	Mean	S.E
0	8.6%	6.4%	2.9%	1.1%
30	16.6%	6.8%	36.8%	5.8%
60	38.4%	9.6%	55.1%	6.6%
90	42.0%	8.9%	70.0%	6.3%

50% maximum EMG at the right stance phase of the descent from the left side leg. In this point, the activity of the vastus lateralis muscle also showed peak activity. Descending from the left leg, the activity in the popliteus muscle showed obviously for almost 70% of the right swing phase and then decreased quickly.

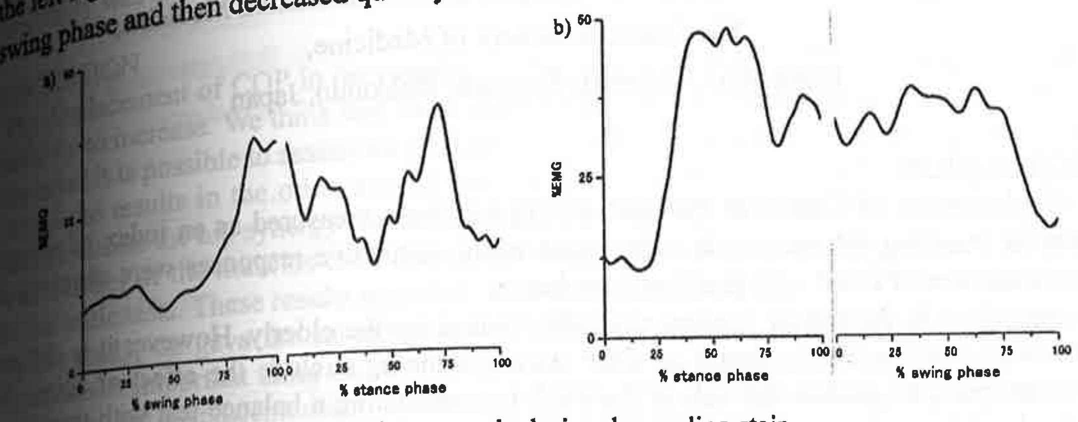

Fig. 1. %EMG of the popliteus muscle during descending stair.
a: descent from right side lower limb; b: descent from left side lower limb

DISCUSSION: Previously, the popliteus has been described as acting continuously to assist the posterior cruciate ligament in preventing forward dislocation of the femur on the tibia during flexed knee stance[1]. However, Yack et al.[5] indicated that there is actually an increase in anterior displacement of the tibia with increasing knee flexion in standing. In our study, the EMG activities of the popliteus and the vastus lateralis muscles increased with the increase of knee flexion in standing. Therefore, it was considered that the popliteus muscle acted to limit the anterior tibial shearing on the femur during flexed knee stance[6]. Although, electromyographic studies of the popliteus muscle have been reported by several authors[1,2,4,6], this is the first study to investigate the activity of the popliteus muscle during descending a step. In the right stance phase of the descent from left lower limb, the popliteus muscle may act to prevent forward dislocation of the tibia as same as the standing with the knee flexed.

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Measurement of Center of Pressure after forward translation in healthy subjects

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INTRODUCTION

The displacement of Center of Pressure (COP) has been measured as an index of postural stability in standing. Moreover, in subsequent study, corrective responses were observed by the measurement of COP with platform translation.

It is important to predict or prevent the falls, caused by the elderly. However it is difficult that the value of the displacement of COP during standing exclude the effect of aging. We have been trying to predict the risk of their fall by conducting a balance test with translation stimuli. In this study, we investigated the change of the trace of COP after forward translations for the healthy subjects.

METHODS

Twenty-six (thirteen males and thirteen females) young healthy subjects (24.8 ± 2.74 yrs, 166.5 ± 9.25 cm, 60.0 ± 11.48 kg, mean ± SD) and twenty (ten males and ten females) elderly healthy subjects (65.4 ± 3.62 yrs, 159.4 ± 7.80 cm, 58.6 ± 7.98 kg, mean ± SD) with no history of neuromuscular disorders volunteered for this investigation. Each subject was fully informed about the possible risks and nature of the experiment and signed the informed consent.

Each subject then stood barefoot on the three dimensional force plate of the platform, with feet parallel on natural, and gazed at a target, a circle 20 [mm] in diameter for thirty seconds. First, all subjects were measured in quiet standing with eyes open and with eyes closed.

As to forward translation stimuli, the time took 0.15 [s], and the displacement were 3.75, 7.50, 10.00, 15.00, 20.00, 30.00 [mm]. These six trials were carried out at random, and COP data after stimuli were recorded.

For COP recording, the three dimensional force plate of the platform (G6100, Anima, Japan) was located in the well-lighted room. The device consists of 2 computers and force plate, control box, and switch for giving translation. The data of COP was collected by the computer through the analog to digital convertor at 50 [Hz].

For electromyography (EMG) recording, surface electrodes were secured to the skin over the belly of the eight muscles (gluteus maximus, rectus femoris, biceps femoris, tibialis anterior, soleus, gastrocnemius, abductor hallucis, extensor digitorum brevis). The data of EMG was collected by means of the electroencephalograph (DAE-2110, NIHON KOHDEN CORPORATION, Japan) at 1 [kHz].

RESULTS

In the static tests, all subjects were nothing to report about Romberg sign.

In the dynamic tests, that is, the measurement of COP with forward translation, the analysis of only Y-direction (anterior – posterior) about COP is presented here (Figure 1). In the translation displacement from 3.75 to 15.00[mm], sway of COP showed a tendency to

increase. Whereas in the other stimuli between 20.00 and 30.00 [mm], the results varied greatly. The elderly group showed larger sway than the young group on the whole.

In the result of EMG of the static tests, the number of the muscles used during standing in the elderly was more than in the young.

DISCUSSION

The displacement of COP in the translation displacement from 3.75 to 15.00[mm] showed a tendency to increase. We think that these results indicate the ankle synergy stabilizes the body. Moreover it is possible to assess the postural ability for individuals by means of these tests. While the results in the other stimuli between 20.00 and 30.00 [mm] varied greatly. Those results indicate the hip synergy and/or the ankle synergy stabilizes the body.

The number of the muscles used during standing in the elderly was more than in the young for the static tests. These results may indicate the effect of aging for the postural stability.

In this study, we gave the subjects relatively small stimuli. Because we thought that safety was the most important thing and that the tests had not to impose a burden for the subjects. As the results, the displacements of COP in the elderly were significantly greater than in the young.

In conclusion, these results indicated that the individual ability of posture control might have been assessed by means of measuring sway of the center of gravity after translation stimuli.

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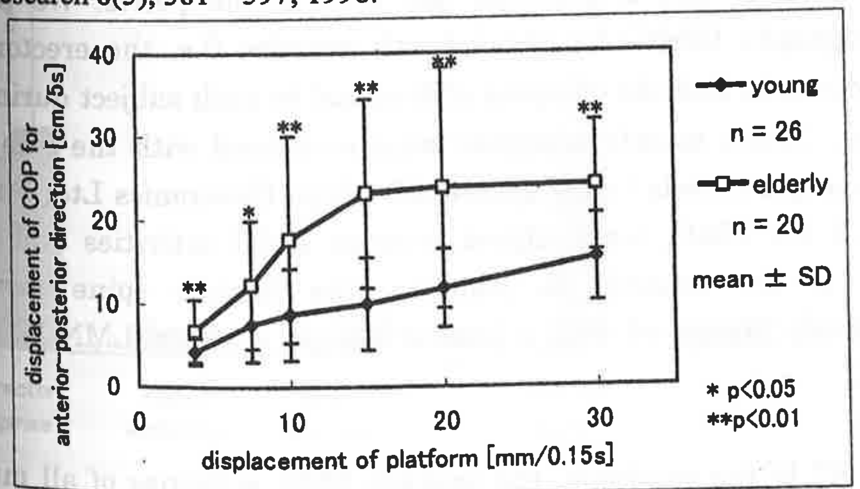

Figure 1 Displacement of COP for anterior-posterior direction after forward translation. The significant differences were approved by Mann-Whitney's U test.

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The effect of pelvic inclination on trunk muscle activities and lumber spine movement during a repeated lifting task

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INTRODUCTION

A lifting task exposes the lumbar spine to an excessive force. Therefore, the lifting task frequently leads to low back injuries. It is important to establish a lifting technique without producing a low back problem. Some previous studies have indicated that a squat lifting technique with an anterior tilt of the pelvis dominantly uses leg muscles and that this lifting technique is safe for the lumbar spine. However, these studies analyzed trunk muscle activities or lumbar spine movement only at a single performance. Therefore, it has remained unknown that a pelvic inclination affects trunk muscle activities and lumbar spine motion during a repeated lifting performance. The purpose of this study is to examine the effect of pelvic inclination on trunk muscle activities and lumbar spine movement during a repeated lifting task.

METHODS

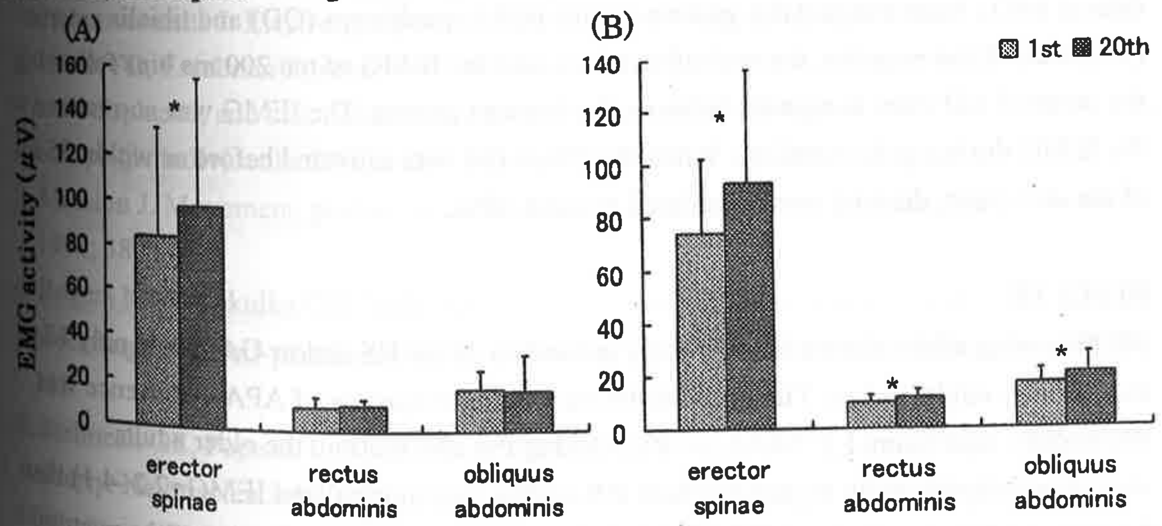
Twelve healthy male volunteers were involved in this study. The age of the subjects was 24.3 ± 3.7 years old (mean ± SD). Each subject lifted a 10-kg weight at the preferred rate for 20 cycles in the following two conditions: an anterior tilt (AT) and a posterior tilt (PT) of the pelvis. We performed an electromyography (EMG) for three trunk muscles (i.e. the erector spinae, the rectus abdominis, and the obliquus abdominis) in each subject during a repeated lifting task. Trunk muscle activities were measured with the sampling rate of 2000 Hz using a muscle tester (ME3000P, Mega Electronics Ltd, Finland). From the data of the EMG, we analyzed average EMG activities and mean power frequency of the muscle. In addition, the lumbar spine movement was simultaneously measured with a lumbar motion monitor (LMN II, Chattanooga Inc, U.S.A).

RESULTS

(1) In the AT lifting condition, the average EMG activities of all muscle groups significantly increased from the 1st to the 20th cycle ($p<0.01$). On the other hand, the average EMG activities of the rectus abdominis, and the obliquus abdominis did not change during a repeated lifting, while the erector spinae significantly increased ($p<0.01$, Fig. 1). (2) The mean power frequency of the erector spinae at and the rectus abdominis significantly decreased from the 1st to the 20th cycle in the AT lifting condition ($p<0.05$), although that of only the erector spinae significantly decreased ($p<0.01$). (3) Regarding the lumbar movement, there were no significant differences of any parameters between the 1st and the 20th cycles in the AT condition. In the PT condition, the ranges of lumbar motion in the direction of flexion-extension significantly decreased from the 1st to the 20th cycle ($p<0.05$).

DISCCUSSION

In the present study, the results of the average EMG activities demonstrated that the AT lifting style (i.e a squat lifting technique) produces not only muscle activities of the erector spinae but also those of the rectus abdominis, and the obliquus abdominis during a repeated lifting task, although the PT lifting style produces only muscle activities of the erector spinae during a repeated task. In addition, the power frequency data suggested that the AT lifting style induces the fatigue of the rectus abdominis, but the PT lifting style does not. These findings have indicated that the AT lifting style activates the abdominal muscle group during a repeated lifting task. The muscle activities of the abdominal muscle group are considered to be beneficial for the protection of a low back injury. Therefore, the squat lifting technique may decrease the risk of a low back injury.



*p<0.01

Figure 1. Average EMG analysis. (A) PT lifting style, (B) AT lifting style

P-227

Postural Muscle Control Prior To and During Arm Raising in Young and Older Adults

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INTRODUCTION

Anticipatory postural adjustments (APA), including the activation of the leg muscles, have been observed to occur prior to arm raising in standing subjects and were believed to set the body into a status that would minimize the postural imbalance induced by the upcoming limb movement (1,2,3). Failure to prepare the body in advance may result in greater postural disturbances such that greater muscular effort would be needed to maintain equilibrium after the initiation of the arm movement. Older adults have been shown to show less frequent or delayed APA (4,5,6) and therefore may need to modify their postural muscle activation during the ongoing arm motion. The purpose of this study was to reveal how the postural muscle control for the ongoing arm motion would be affected by APA. It was hypothesized that age-related impairment in APA would be accompanied by changes in postural muscle activation during the arm motion.

METHODS

Seventeen young and 17 older adults with no known history of neuromuscular or musculoskeletal disorders participated in the study. The subjects stood on a force platform and were asked to raise both arms simultaneously to 90° flexion as fast as possible upon a "go" command. Surface electrodes were placed on the muscle belly of the right anterior deltoid (AD), hamstrings (HS), gastrocnemius (GA), quadriceps (QD) and tibialis anterior (TA). For all the muscles, the activation onset, and the IEMG of ten 200 ms bins following the onset of AD were compared between the two age groups. The IEMG was normalized to the IEMG during quiet standing. When the HS or GA was activated before or within 25 ms of the AD onset, the trial was considered to have APA.

RESULTS

All the young adults showed anticipatory activation of the HS and/or GA, while only 13 of the 17 older adults did so. The group difference in the frequency of APA occurrence was statistically significant (χ^2=4.55, p<.05). During the arm motion, the older adults maintained significantly higher levels of HS contraction (normalized IEMG=2.2~4.1) than the young adults (normalized IEMG=1.7~2.2). The mean onset latencies of the postural muscle APA did not show significant group differences. For the anterior leg muscles, typically the TA and QD remained silent or with minimal activation prior to and during the arm motion, and did not show significant group differences.

DISCUSSION

The hypothesis of this study was supported by the findings that less frequent activation of the postural muscles prior to the arm motion was accompanied by greater HS IEMG during the arm motion in older adults. The young adults invariably showed APA and required less postural muscle effort. It seems that in the absence of APA, greater postural effort was employed by the older adults in order to maintain standing equilibrium while the arm was accelerating. The higher level of HS contraction could create a backward rotation of the body to counteract the forward rotation induced by the arm acceleration. Thus, lack of APA needs to be compensated for by greater postural muscle activation after the initiation of the arm movement.

CONCLUSION

Less frequent activation of anticipatory postural adjustments in older adults was accompanied by greater hamstrings IEMG during the arm acceleration. The control of postural muscle for the ongoing arm raising movement was affected by the presence or absence of postural preparation prior to the movement initiation.

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P-228

DISSOCIATION OF THE OBJECTIVE SENSORY EXAMINATIONS AND THE ELECTROPHYSIOLOGICAL FINDINGS IN PERIPHERAL NERVE DAMAGE

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INTRODUCTION

Entrapment neuropathy is a commonly encountered disease. The objective sensory examination and the electrophysiological study are often performed for the diagnosis. These assisting tests are also useful for evaluating the effect of the treatment. We have tried to assess the dissociation between these tests with searching for the better clinical application.

METHODS

In 73 hands with carpal tunnel syndrome, we examined the static two point discrimination (2PD) and the touch threshold using Semmes-Weinstein Monofilamment (SW) at the pulp of their index finger. M-wave of the abductor pollicis brevis muscle and sensory nerve action potential (SNAP) of the index finger were elicited by an electrical stimulation to the median nerve at the wrist.

And we had measured these parameters in 20 normal subjects to define our normal values.

In 6 healthy volunteers, these tests and somatosensory evoked potential (SEP) were also recorded during ischemia induced by a pneumatic tourniquet 1) at their forearm.

RESULTS

According to our normal data (Figure 1), 5mm of 2PD and the blue filament of SW were defined as normal range, 4.4 ms of the terminal latency (TL) of the M-wave, 5.7 mV of the amplitude of the M-wave and 47 m/s of the sensory nerve conduction velocity (SCV) were calculated as our normal limit (±2.5 standard deviations from the mean). And we analyzed the cases in whom SNAP was not evoked in this setting.

In carpal tunnel syndromes, the false negative cases were observed in 74% by 2PD, 37% by SW, 18% by TL, 27% by the amplitude of the M-wave and 3% by SCV. In 64% SNAPs were evoked. In half of the cases with reduced amplitude of these action potentials, they could recognized the 2PD and SW of the normal range (Table 2).

After 20 minutes ischemia, the SNAP (Figure 1) was almost disappeared, while the 2PD, SW and cortical SEP (Figure 2) were normally recorded.

Table 1 ; Our normal data (N=20)

2PD ; All subjects recognized 5 mm	
SW ; All subjects recognized blue filament	
TL of M-wave ; 3.2±0.5 ms	Amplitude of M-wave 12.9±2.9 mV
SCV ; 59±5 m/s	Amplitude of SNAP : 49±21 μV

Table 2 ; The percentages of the cases with normal 2PD and SW in whom the amplitude of the action potentials were reduced.

	M-wave (N=53)	SNAP (N=26)
2PD	60 %	54 %
SW	42 %	19 %

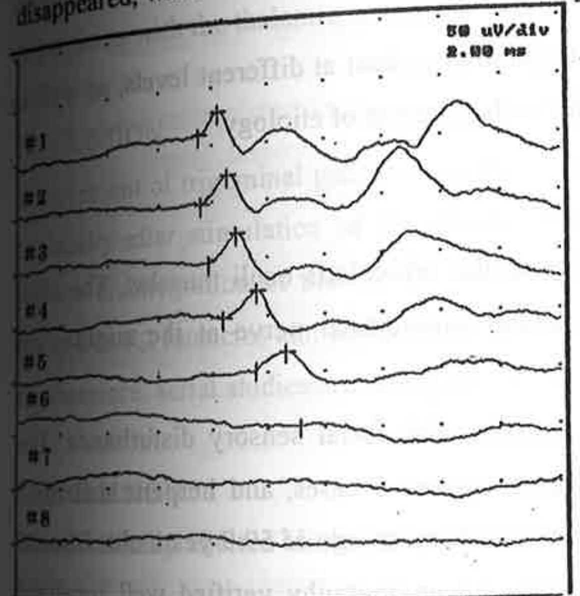

Figure 1 ; SNAP by elbow stimulation
#1 was recorded before ischemia of the forearm
After 20minutes (#6), SNAP was almost disappeared, while 2PD and SW were normal.

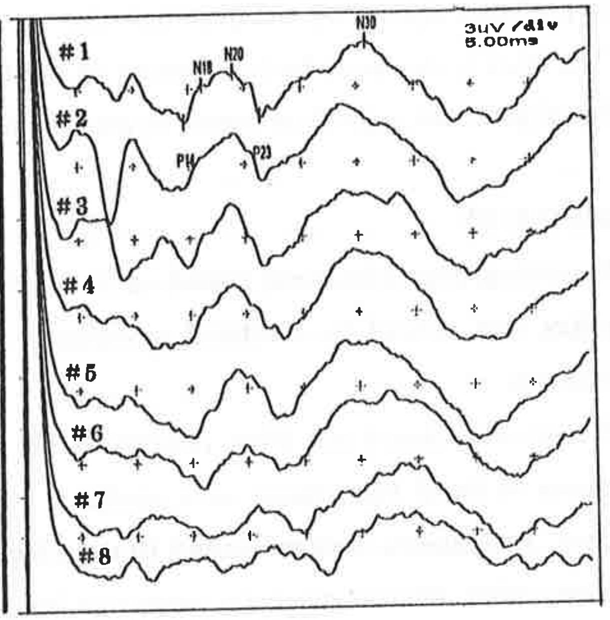

Figure 2 ; SEP by wrist stimulation
#2-#8 were after ischmia, at every 4 minutes
After 28 minutes (#8), N20 and N30 were recorded, while 2PD and SW were abnormal.

DISCUSSION

Mild damage with segmental demyelination depressed the nerve conduction velocity. Functions of the recognition are preserved in moderate axonal damage with the cancellation of the occlusion in the synaptic connection 2).

CONCLUSION

For the mild cases of the entrapment neuropathy, the electrophysiological study is more suitable than the objective sensory test.

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P-229

Quantitative Evaluation of Facial Hypesthesia by Electrical Blink Reflex

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INTRODUCTION

Senosry disturbance is difficult to assess objectively. Somatosensory evoked potential is useful in quantitative evaluation for the sensory disturbance in the limbs. However, it is not applicable to the face. Therefore, it is still an open question how to evaluate facial hypesthesia objectively and quantitatively.

The blink reflex provides information on the trigeminal system at different levels, as well as facial paralysis, regardless central or peripheral involvement as of etiology.

METHODS

Recording electrodes were placed on both sides of the orbicularis oculi muscles. The blink reflex was evoked by electrical stimulation of the supraorbital nerve at the supraorbital foramen.

We serially carried out blink reflexes in 20 patients with facial sensory disturbance. The causes of facial hypesthesia were strokes 13 cases, tumors 5 cases, and herpetic neuritis 2 cases. Ten patients were males and 10 were females with mean age of 59.9 years old. Clinical examination, nuclear magnetic resonance imaging, and angiography verified well localized unilateral lesion in the cerebrum or brainstem. Of the 20 patients, one patient had cerebral sensory cortex lesion over the right parietal area, 6 thalamic lesions, 6 brainstem lesions, and 7 trigeminal lesions. All patients complained of facial numbness with pin-prick, temperature and touch sensation.

RESULTS

Twelve out of all 13 patients with strokes showed normal R1. Stimulation of the affected face disclosed small R2 EMG activity in all 12 patients, regardless of pathoanatomical lesions. The latency of R2 was delayed in 9 patients. Three patients with thalamic lesions had only attenuation of R2 EMG activity without latency delay. Prolongation of R2 latency was rather prominent in the patients with brainstem lesions. In contrast, stimulation of the normal face evoked normal R2 components bilaterally in 10 of 12 patients. The other 2 patients with midbrain lesions disclosed delayed R2 latency at the stimulation of the intact as well as the involved face.

In contrast, the other 7 patients with peripheral trigeminal lesions showed significant delay or deminution of R1 and/or R2 components on the affected side. One patient with pontine stroke lesion showing facial palsy as well as facial hypesthesia disclosed lack of R1 and bilateral R2 prolongation at stimulation of the affected face.

With clinical improvement, R2 EMG activity was getting bigger and R2 latency was shorter in a year follow-up term. A smaller response indicated more complete sensory loss, and stimulation of an anesthetic part of the face failed to elicit any response at all, especially for the patients with the thalamic lesion.

DISCUSSION

Involvement of trigeminal pathway causes an afferent pattern with delays or diminution of R2 bilaterally after stimulation of the affected side. In the peripheral lesions, R1 abnormality reflects disintegration of the nerve conduction along the reflex pathways. Measurement of R1 and/or R2 latencies and EMG areas is objective and quantitative in the facial hypesthesia. Furthermore, serial studies are indispensable to the prognosis.

CONCLUSION

The electrically elicited blink reflex provides a means of quantitating facial sensation.

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P-230

The Relation between the High Intensity Area on MRI and the Motor Conduction

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INTRODUCTION

In the mophorogic study, the hihg intensity area on MRI demonstrated the edema or hyperamia in the white matter of the cord. But in few report the motor conduction were measred in man.

METHODS

38 hands of nineteen cervical myelopathy patients were measured. The cathode surface electrode were placed on the muscle of the Biceps Brachii (BC), the Triceps Brachii(TC) and Abductor Pollicis Brevis(APB) muscle. Following per cutneous electric stimulation of the median nerve at wrist, M-wave and F-wave were recoded. Peripheral latency (PL) was caculated accoding to Kimua's formula. In the BC and TC muscle, PL was obtained by (the onset latency of the tendon reflex)/2. Motor evoked potential(MEP) following transcutaneous and cervical electromagnetic stimulation was recoded from the same electrodes on BC, TC and APB. The Central Motor Conduction time (CMCT) and the latency from the anterior horn cell to the rootlet (AHL) was calculated. Nine teen patients were divided into five group according to the level of the high intensity area on MRI; C3/4 level proup (three cases), C4/5 level group (two cases), C5/6 level group (seven cases), mutiple level group (two cases) and no high intensity area group (five cases).

RESULTS

AHL demonstrated no relationship with the level of the T2 high intensity area. The difference between the CMCT of BC and the CMCT of APB was 1.7±0.5ms in the C3/4 level proup, 8.5 ±0.5ms in the C4/5 level proup, 4.7±2.9ms in the C5/6 level proup, 4.8±9.6ms in the multiple level proup and 1.6±1.4ms in the no high intensity area group. The CMCT was significantly elongated at the T2 high intensity area.

DISCUSSION

In chronic compression myelopathy patients, the T2 high intensity area demonstrated the damage of the long tract in the white matter more than that of the anterior horn cells in the gray matter.

CONCLUSION

The T2 high intensity area demonstrated high relationship with the CMCT.

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P-231

P300 and Mismatch Negativity in Parkinson's Disease

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INTRODUCTION

In our previous study[1,2], P300 was measured in patients with Parkinson's disease while anti-parkinsonism medications were discontinued. In the present study, P300 and mismatch negativity were measured in patients with Parkinson's disease while anti-parkinsonism medications were continued.

METHODS

We studied 8 patients (mean age: 60.8 years old) with Parkinson's disease and 8 age-matched healthy controls with their informed consents. P300 and mismatch negativity were measured according to the guideline of the Japan Society of Electroencephalography and Electromyography[3] with a Neuropack Σ evoked potential recorder (Nihon Kohden, Tokyo, Japan). An oddball stimulus paradigm was employed for P300 examination in which subjects kept a running mental count of rare target tone pips (p=0.2, 2,000 Hz) interspersed against a background of more frequent nontarget tone pops (p=0.8, 1,000 Hz). Thirty responses to rare tones were averaged and two averages were obtained to ensure reproducibility. The N100 and N200 latencies and amplitudes were measured at Fz, and the P200 latency and amplitude were measured at Cz and the P300 latency and amplitude were measured at Pz. For recording mismatch negativity, subjects were instructed to read a book and ignore the sounds which consisted of rare tones (p=0.1, 1,100 Hz) and frequent tones (p=0.9, 1,000 Hz) applied randomly. One hundred responses to rare tones were averaged and subtraction of the response to frequent tones from the response to rare tones was performed. The latency and amplitude of mismatch negativity was measured at Fz.

RESULTS

Figure 1 shows actual records of P300 examination. The latency of P300 was significantly longer in the Parkinson's disease group than in the healthy control group. The latency of mismatch negativity did not show any significant difference between the two goups.

DISCUSSION

We reported that in Parkinson's disease with Hoehn and Yahr stages II and III, the prolongation of P300 latency is seen even in the absence of dementia and is improved by L-DOPA[2].

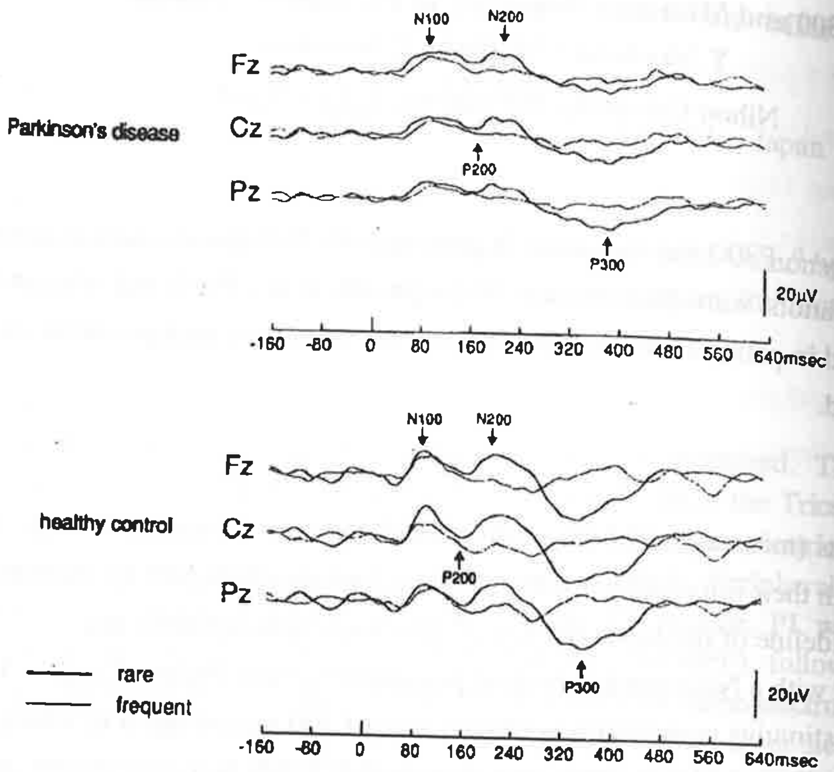

Figure 1. P300 in a patient with Parkinson's disease and in a healthy control. Compared with the healthy control, the patient with Parkinson's disease showed a prolongation of P300 latency.

The present study suggests that P300 may be abnormal even if the patients with Parkinson's disease take oral anti-parkinsonism medication.

CONCLUSION

P300 may be abnormal in patients with Parkinson's disease who are on anti-parkinsonism medication.

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Event-related Potentials (P300, Mismatch Negativity) in Diabetes Mellitus

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INTRODUCTION

In our previous study[1,2], P300 was measured in patients with diabetes mellitus. We measured P300 and mismatch negativity in patients with diabetes mellitus in the present study.

METHODS

We studied 10 patients with non-insulin-dependent diabetes mellitus who did not show any abnormality on head magnetic resonance imaging (mean age 57.2 years) and on 8 age-matched healthy controls. P300 and mismatch negativity were measured according to the guideline of the Japan Society of Electroencephalography and Electromyography[3] with a Neuropack Σ evoked potential recorder (Nihon Kohden, Tokyo, Japan). An oddball stimulus paradigm was employed for P300 examination in which subjects kept a running mental count of rare target tone pips (p=0.2, 2,000 Hz) interspersed against a background of more frequent nontarget tone pops (p=0.8, 1,000 Hz). The N100 and N200 latencies and amplitudes were measured at Fz, the P200 latency and amplitude were measured at Cz, and the P300 latency and amplitude were measured at Pz. For recording mismatch negativity, subjects were instructed to read a book and ignore the sounds which consisted of rare tones (p=0.1, 1,100 Hz) and frequent tones (p=0.9, 1,000 Hz) applied randomly. One hundred responses to rare tones were averaged and subtraction of the response to frequent tones from the response to rare tones was performed. The latency and amplitude of mismatch negativity were measured at Fz.

RESULTS

Figure 1 shows actual records of P300 examination. The latencies of N200 and P300 were significantly longer, and the amplitudes of N200 and P300 were significantly smaller in the diabetes mellitus group than in the healthy control group. The latency and amplitude of mismatch negativity did not show any significant difference between the two groups.

DISCUSSION

N200 and P300 have been reported to be an index of cognitive function, and cognitive functions have been reported to be decreased in patients with diabetes mellitus[2]. The present study suggests that P300 examination may be abnormal in diabetes mellitus without abnormality on head magnetic resonance imaging.

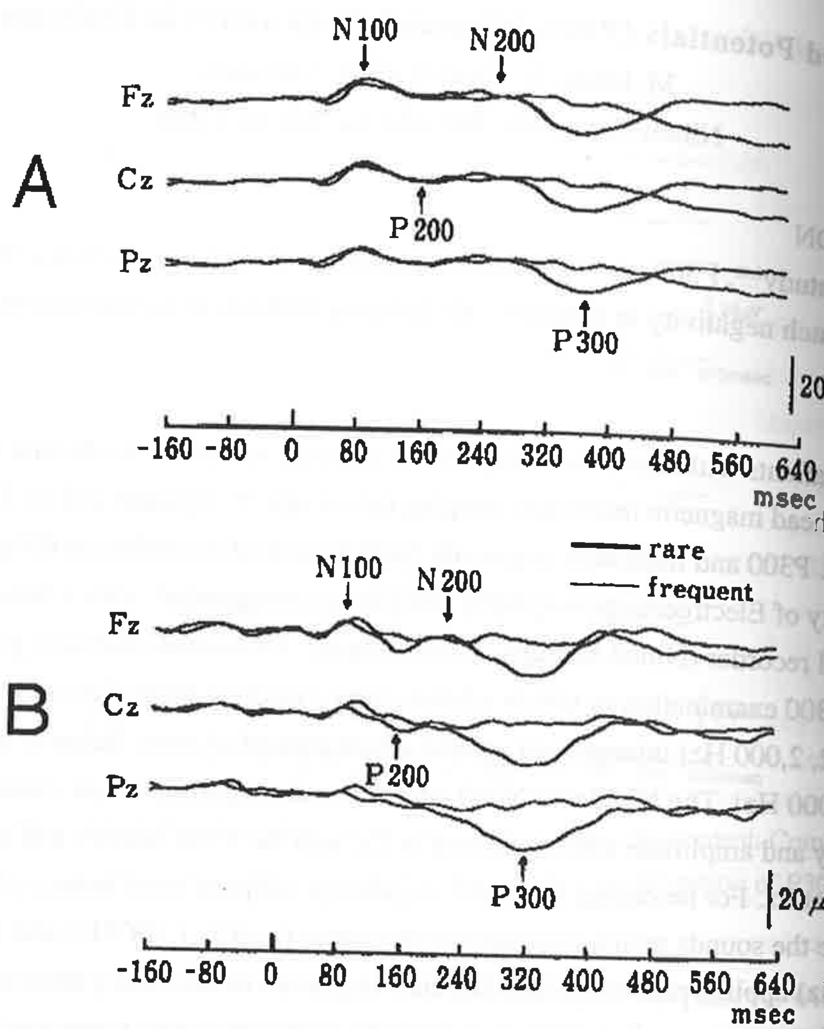

Figure 1. P300 in a patient with diabetes mellitus (A) and in a healthy control (B). Compared with the healthy control, the patient with diabetes mellitus showed prolonged latencies and decreased amplitudes of N200 and P300.

CONCLUSION

P300 may be abnormal in patients with non-insulin-dependent diabetes mellitus.

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P-233

Soleus H-reflex response to vestibular stimulation by horizontal linear acceleration

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INTRODUCTION

It has been demonstrated that the amplitude of soleus H-reflex is continuously depressed during upright standing[1-2]. Although it was speculated that this phenomenon may be occurred by the tonic labyrinthine reflex, the role played by the vestibular inputs on the postural modulation of H-reflex has not been well known. The purpose of this study was to clarify the effects of vestibular (otolith) stimulation on the excitability of soleus motoneuron pool.

METHODS

Subjects were 11 healthy male volunteer aged 21-32. None of them had a past history of auditory or vestibular disorders. The Human Research Committee of the Research Institute of Environmental Medicine, Nagoya University, had approved the experimental protocol and procedures. The informed consent was obtained from every subject before the measurement. Subjects were seated in the experimental chair setting in the capsule of a linear accelerator (SLED). The angles between the head and body, of hip, knee and ankle joints were held by straps or footplates. Furthermore, they were blindfolded to remove the visual input. The SLED under magnetic levitation was driven by cables connected to a servo-controlled motor. The SLED moved the step acceleration (rectangular G-loading mode) at a constant amplitude of 14 m. Subjects were exposed to three different G-load levels of 0.1 G, 0.2 G and 0.3 G. The soleus H reflex was evoked by stimulating the tibial nerve in the popliteal fossa at 500 ms and 3500 ms after the G-load. Square stimulus pulses of 1 msec were applied with intensity adjusted to evoke an H-reflex of approximately 40 % (range from 30 to 50 % among subjects) of the maximum M response.

RESULTS

There were no tonic EMG activities in soleus and tibialis anterior during G-loading. In the results of two-way (acceleration × elapsed time) repeated measures ANOVA, the interaction was significant ($p<0.01$). The amplitude of H-reflex decreased compared with the control value at 500 ms in every G-loading condition (Fig.1). The H-reflex in the 0.3 G condition

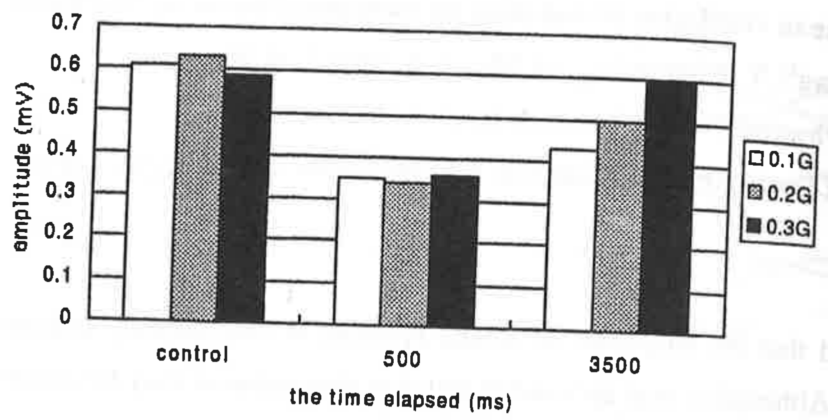

Fig.1 Changes in amplitude of H-reflex responses to vestibular stimulation

recovered to the control level at 3500 ms, but they were remained depressed in the 0.1G and the 0.2 G.

DISCCUSION

Results of the present study suggested that the vestibular (otolith) stimulation by horizontal linear acceleration inhibited the soleus motoneuron excitability. The sensory inputs originated from the utriculus are transmitted mainly to the lateral vestibular nucleus of Deiters and thence to the lumbar and sacral spinal cord via the lateral vestibulo-spinal tract (LVST). During sudden fall, the tendon jerk and the H-reflex have been facilitated in the calf muscles about 80 msec from onset of fall[3]. Vestibular caloric or electrical stimulation, activating the semicircular canals, also induced facilitatory effects on the soleus motoneurones excitability[4]. These studies had investigated the dynamic short-latency EMG responses within only 100 ms after the vestibular stimulation, while the longer larency response was observed in the present study. Our results suggested that the facilitation of soleus motoneuron excitability would be followed by depression during the vestibular stimulation.

CONCLUSION

The present findings suggested that the vestibular (otolith) inputs must be important for modulation in the excitability of soleus motoneuron pool during upright standing.

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P-234

The Gate Analysis of Rheumatic Patients by Force Plate and F-scan

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INTRODUCTION

Rheumatoid Arthritis (RA) is whole body disease with multiple arthritis and it is much possibility that the tumble by gait disturbance causes the secondary disabilities. We analyzed the gait pattern of RA patients quantitatively by the force plate and F-scan.

SUBJECTS

Subjects were 19 RA patients who admitted in the rehabilitation ward of HOKKAIDO University Hospital and 3 controls. The 19 RA patients could gait independently and aged 40~78 years(average 63.6±12.0).

METHODS

We analyzed their gait pattern of 3 times among 5 seconds by the force plate (ANIMA Co.) and F-scan (Tekscan Co.) at the same time. The F-scan can analyze the pressure of the foot bottom with the passage of time. We compared the 19 RA patients and 3 controls.

RESULTS

In the data of force plate, the parameters of 3 controls were small SD, showed the similar patterns. Though, the parameters of RA patients showed large SD and various patterns. The vertical force of the controls showed two peaks but the vertical force of RA patients did not showed it. The forward-backward force and the gait speed of RA patients were smaller than the controls significantly.

In the data of F-scan, the plantar pressure of the forefoot of the controls was bigger than the RA patients at the toe off, significantly. The ratio of plantar pressure (heel/fore foot) at the toe off was 0 in the controls. But, the ratio of plantar pressure of RA patients showed about 20%.

CONCLUSIONS

The arthritis were shown at the whole lower extremity in RA patients, the replacement ratio of the artificial joint is higher in the progressive case. In this study, the characteristics of the gate in RA patients were shown the small impact at the heel contact and the small driving force at the toe off. It is considered that the characteristics were caused by the joints disorder and the weakness in the lower extremities. The method of the gate analysis by the force plate and F-scan is not suitable for evaluation of the each joint function by multiple arthritis in RA patients. But it is suggested that this method is useful for the evaluation of the gait as the coordinative movement by plural joints.

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P-235

GAIT DISTURBANCE AFTER CORPUS CALLOSUM INJURY

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SUMMARY

We experienced a patient with rare type of gait disturbance after corpus callosum injury. Her gait motion was like skipping only right side. By shoulder flexion, her gait became faster and better. Some tests including motor evoked potentials and positron emission tomography were performed. But we didn't recognized any abnormality. Gait disturbance after corpus callosum injury like this patient was not papered in the past.

INTRODUCTION

After corpus callosum injury, clinical features were characterized by left ideomotor apraxia, construction apraxia, and left agraphia. Gait disturbance was rarely shown. In 1995, Giroud et al described gait disturbance due to corpus callosum injury in which the patients used a wide based with their feet rooted to the ground, and demonstrated gait of shuffling with short steps and freezing, with no arm swing, and slight extension of the trunks.

We experienced a patient with other type of gait disturbance after corpus callosum injury.

CASE REPORT

A 39-year-old female admitted the Hokkaido University Hospital on September 1999, suffering from gait disturbance. She was given a diagnosis of arterio-venous malformation (AVM) at left posterior lobe and mid to posterior portion of corpus callosum at 22 years old and underwent the first operation of AVM. At 34 years old, she underwent the second operation because of the residual AVM. Although she showed right hemineglect and short-term memory disturbance immediately after operation, she did not disclose gait disturbance except that she complained slight weakness of the left leg. Gait disturbance appeared one year after operation with the weakness of the right leg recovered, and admitted our hospital at 39 years old.

Neurological examinations on admission demonstrated slight superficial and deep sensory disturbance at the right side of her body. However, she did not show abnormality of muscle power, deep tendon reflexes, or autonomic functions. She could walk alone without any help. But gait motion was very characteristic like skipping only at right side. During the short stance phase of the right leg, the right shoulder joint kept extending against her intention. At swing phase of the right leg, the hip and knee joints demonstrated overflexion. The center of pressure was backside of her body compared to normal position at walking.

About higher cortical function on admission, she demonstrated right hemineglect and short memory disturbance. Classical symptoms of disconnection syndrome (left ideomotor apraxia, construction apraxia and left agraphia) were not recognized. Psychological high cortical tests performed by senior psychologist, disclosed 94 of total IQ, 106 of VIQ, and 80 of PIQ in Wechsler adult intelligent scale revised (WAIS-R), and 87 points in Wechsler Memory Quotient. Benton Visual Retention Test also showed normal range. All Blood chemistries were within normal range.

In Brain MRI, T1 weighted images showed low intensity lesions in the left posterior lobe, the left interhemispheric parietal lobe, and the mid to posterior portion of corpus callosum. T2 weighted images demonstrated them as high intensity lesions, representating resection area and inter-operating contusion.

Nerve conduction studies of the right median, ulnar, tibial, peroneal and sural nerve, showed normal range in all components; conduction velocity, distal latency, amplitude and F-wave latency. Motor evoked potential (MEP), measured by a round coil, of the bilateral abductor pollicis brevis, abductor digiti minimi, adductor hallusis, tibialis anterior and deltoid demonstrated normal latency and normal amplitude.

Figure 2 showed the results of analysis of gait by force platform. The duration of stance phase were shorter (0.45s) at right side than that of left side (0.70s). The vertical force showed two peaks at both side. But the shape of two peaks was deeper at right leg than that of left leg. The gait motion showed like a skipping only at right side. Figure 3 showed the result of analysis of gait by force plate at walking by flexion of her shoulder joint. By flexion of right shoulder joint, gait motion were improved remarkably and showed no laterality of the duration of stance phase. The duration of stance phase was almost same at both sides. The stance phase of left leg became shorter and lateral force of left side became bigger than Figure 2.

Functional brain mapping measured by $H_2{}^{15}O$ Positron Emission Tomography (PET) demonstrated normal activations on the contralateral primary sensorimotor area in hand grasping task, but did not demonstrate clear activations in ankle planter-dorsi flexion task. (Figure 4).

CONCLUSIONS

We reported a patient showing very rare gait disturbance after corpus callosum injury. Gait motion showed very characteristic. Giroud et al. described gait disturbance due to corpus callosum injury in 1995. He described the patients used a wide based with their feet rooted to the ground, and demonstrated gait of shuffling with short steps and freezing, with no arm swing, and slight extension of the trunks. This patient's gait may include alien hand sign.

When she walked, her right upper extremity moved back side and her lower extremity moved to overflexion at hip and knee joints without her intention The alien hand sign almost recognized at left side of patients. But some patients showed alien hand sign at right side. It was difficult to find the patients with gait disturbance and corpus callosum injury. Gait disturbance like this patient after corpus callosum injury was not shown in the past.

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Figure 1 Brain MRI (T2WI: axial, saggital, coronal)

Figure 2 The result of analysis of gait by force platform at normal walking.
The dotted line is force of right leg. The continuous line is force of left leg.
Upper figure show vertical force. Medium figure show progressional (forward and backward) force. Lower figure show lateral force.

The duration of stance phase on right leg was 0.45s. That of left side was 0.70s. The laterality of stance phase was remarkable. The vertical force showed two peaks. The shape of two peaks was deeper at right leg than that of left leg.

Figure 3 The result of analysis of gait by force platform at flexioning her right shoulder. The duration of stance phase was almost same at both side. Stance phase of left leg became shorter than that of Figure 2. The shape of two peaks in vertical force became more similar to normal pattern than that of Figure 2.

Figure 4 Upper figure: PET, task of grasping

Activation of bilateral inside of frontal lobe was recognized.

Lower figure: PET, task of ankle flexion-extention

Activation was not clear..

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The effect of rhythmic sound stimulation for gait of Parkinson disease

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Introduction

Patients with Parkinson disease (PD) often fall down because of festination and frozen gait. We investigated about falling in 325 patients with PD in Hokkaido. Our data showed that 85.9% of PD had gait disturbance and 78.0% of PD had imbalance during gait. About 80.0% of PD fell down at least once a year in one year. More serious PD had more in falling. Goldberg told the hypothesis of the two pattern of voluntary movement and the gait disturbance of PD was classified by this hypothesis into the external movement in evoked the gait by external stimuli. In generally, PD patients tend to become easy in gait by using external visual and auditory cue. Then, we developed the aid of gait supporting by rhythmical sounds as the auditory cue.

Methods

The subjects were 17 patients with PD (5 males and 12 females, age in average: 66.1±7.5 years). In the Hoehn and Yahr Classification of Disability, stage Ⅱ of PD was 3 patients, stageⅢ was 13 patients and stageⅣ was 1 patient.

We evaluated the effects by the "aid of gait" for gait disturbance of PD. The "aid of gait" is light (300g) and handy type. They can switch on it easily by patient himself. The "aid of gait" can be changed in nature of rhythmical sound, speed of rhythm and numbers of repeat. PD patients walked with the "aid of gait" and were measured time and steps for 10m gait, and the surface EMG of tibialis anterior muscle(TA) and soleus muscle, and were asked subjective feeling.

Results

The surface EMG during gait showed that the surface EMG of TA became two phasic wave during gait with the "aid of gait" using rhythmical sound and she could have the effective toe off. Steps of 10m gait became smaller and 1 stride time became standerdizing by auditory cue in severe gait disturbance of PD. They mentioned that rhythmical sound by using this new device made their gait to be easy subjectively.

Conclusion

We developed the handy "aid of gait" for PD patients using auditory cue. Their subjective symptoms and gait improved by this aid. This hypothesis of the effects of rhythmical sound is supposed that auditory cue influenced external evoked voluntary movement by the circuit of cerebellum and premotor area.

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Effects of Repetitive Passive Range-of-Motion Exercise on the Gait of Spastic Patients

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INTRODUCTION

We have developed a motor-driven range-of-motion exercise machine for hip and knee joints, which can memorize and replay exactly the same exercise as the therapists teach. We named it Therapeutic Exercise Machine (TEM). We previously reported the hip joint torque and the electromyographic activity of the hamstrings in spastic patients decreased significantly during the repetitive passive range-of-motion (RPROM) exercise. The purpose of this study was to investigate the effects of RPROM exercise on the hip joint torque and the gait of the spastic patients.

METHODS

Ten hemiplegic patients, eight secondary to stroke and 2 to traumatic brain injury, participated in this study. All patients could walk, even though their gait pattern was spastic, for more than 3 min by themselves with or without walking aids. Muscle tone was markedly increased in all patients.

The hemiplegic leg of the patients was mounted on TEM, and the therapist taught the motion of Straight Leg Raising (SLR) exercise once to the TEM. The motion path was memorized by the machine. SLR exercise was done 30 times. Each SLR cycle takes 15 sec. The load torque of patients' hip joint were monitored by force sensor. The hip torque had a peak at the maximum flexion of the hip. The simple linear regression for the peak torque of the joint vs. the number of times of the SLR exercise was statistically analyzed.

Gait speed (m/min.), stride length (m), energy consumption (mlO_2/kg/min.), and energy cost (mlO_2/kg/m) were measured before and after the exercise. Measurement was done during 3 min. of continuous walk at the speed comfortable for the patient. The energy consumption was determined from the average values for the last 1 min. of walk. These values were statistically analyzed by the t-test. Ten normal subjects were included as age-matched controls, in whom only the gait was measured.

RESULTS

Averaged peak torque of the hip joint of patients was significantly decreased ($p<0.05$) with the exercise. The gait speed and stride length after the exercise increased significantly ($p<0.05$). The energy consumption of the patients did not different significantly between those before and after the exercise, Table: Summary of results

(mean ± SD)	Hip joint torque (Nm)	Gait speed (m/min.)	Stride length (m)	Energy consumption ($mlO_2/kg/min.$)	Energy cost ($mlO_2/kg/m$)
Spastic patients					
Before the exercise	19.9 ± 7.4	21.6 ± 13.2	0.63 ± 0.26	10.07 ± 5.29	0.61 ± 0.41
After the exercise	17.1 ± 6.5	25.7 ± 16.3	0.75 ± 0.30	9.87 ± 6.00	0.45 ± 0.28
Control subjects	—	57.8 ± 14.8	0.60 ± 0.08	9.00 ± 3.10	0.18 ± 0.08

although decrease in the energy consumption after the exercise was observed. The energy cost of the patients was decreased significantly ($p<0.05$). The mean energy cost of the controls was lower than that of the patients. Both hip joint torque and energy cost decreased after the exercise in all patients.

DISCUSSION

Our results show that after the RPROM exercise, the hip joint torque values decreased significantly, the gait speed and stride length increased significantly. The energy cost also decreased after the RPROM exercise significantly. The results suggest that extension of the knee joint was enhanced at the swing phase of gait by decreased of muscle tone and/or connective tissue resistance, and the stride length thus increased. That's why the energy cost of gait decreased after the RPROM exercise.

CONCLUSION

1. We examined the effects of RPROM exercise on the gait of spastic patients using our machine.
2. The hip joint torque in the spastic patients decreased significantly with RPROM exercise.
3. The gait speed and stride length increased significantly and the energy cost decreased significantly after the RPROM exercise.
4. The results were attributable to decreased muscle tone and/or connective tissue resistance of the hamstrings by the RPROM exercise..

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The Effect of Jogging on P300 Event Related Potentials

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INTRODUCTION

Physical exercise has beneficial effects not only on cardiovascular system and fat metabolism, and also directly effect the cognitive process[1]. The P300 event related potentials can be considered as a manifestation of CNS activity involved with the processing of cognition. Jogging is one of the most popular sports and is very easy to keep going everyday. Jogging effects on cognition process may be important for older adults to have comfortable and meaningful lives. We studied the effect of physical exercise on cognitive processes by measuring the P300 event related-potential (ERP) after jogging.

METHODS

Seven well-trained joggers were enrolled in this study and the P300 potentials using auditory oddball paradigm. All subjects were male ranging in age from 29 years old to 44 years old (mean 34.6±4.7 years old). All subjects were well-trained joggers who run regularly. Subjects were instructed to run at a comfortable and self-paced cadence for thirty minutes (about 5km). In ERP experiment, the stimulus sequence was random and subjects were asked to mentally count the total number of target stimuli. The active recording electrodes were placed at Fz, Cz and Pz and linked earlobes were used as the reference. ERPs were measured before jogging and post-exercise ERP measurements begun approximately 10 minutes after the completion of jogging.

RESULTS

Six of seven subjects showed an increase in the amplitude of the P300 at Cz after exercise relative to pre-exercise amplitudes. The mean amplitude of P300 significantly increased from 11.0± 6.0μV pre-exercise to 14.1± 6.1μV post-exercise ($p<0.01$). The mean amplitude of the P300 also increased significantly at Pz from 11.8± 5.3μV pre-exercise to 14.4± 5.6μV post-exercise ($p<0.01$). The amplitude of the P300 significantly increased compared to values recorded before jogging. However, the mean latency of the P300 at Cz was unchanged with mean latencies of 315.8±42.0 ms pre-exercise and 313.3±30.8 ms post-exercise, respectively.

DISCUSION

The results of this study showed that the amplitude of the P300 was significantly increased after jogging compared to baseline data before jogging, while the latency of the P300 was unchanged. Jogging has some effects on P300 amplitude in our study which reflected the activation in cognitive process because the P300 potentials can be considered as a manifestation of CNS activity involved with the processing of cognition. Several reports have suggested that frequent physical exercise may have facilitate on mental performance. Dustman et al[2] studied the P300 component between subjects in good aerobic condition and in poor aerobic condition as determined by evaluating lifestyle and VO2 max and revealed high fit subjects had better neurocognitive and visual sensitivity functioning as well as shorter the P300 latencies compared to low-fit subjects. Similarly, Geisler and Squires[3] showed that the P300 amplitude increased, and latency decreased significantly following 3-5min of moderate exercise using a simple auditory oddball task. These findings have suggested that the P300 potentials can be affected by physiological factors.

CONCLUSION

Our findings suggest that jogging has the effect of facilitating cognitive processes involved in generation of the P300.

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Motor fiber evoked potentials in somatosensory evoked potentials (SSEP)

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INTRODUCTION:

N10 potentials recording at the anterior mid-neck have been shown to be evoked from the anterior root in somatosensory evoked potentials (SSEP) responding to median nerve stimulation.

METHODS:

We studied the change of amplitude in Erb, lateral neck, N10, N13, and N20 potentials by stimulating the median nerve both at the wrist and the fingers.

RESULTS:

The N10 potential was not evoked in any subjects by stimulating fingers, while N10 potential by stimulating wrist were evoked well in all subjects. At submaximal stimulation, the contributions of motor fibers were estimated as about 20 % of their amplitudes in Erb evoked potentials.

DISCUSSION:

The N10 potential was not evoked by stimulating fingers that are supposed to stimulate only sensory fibers, while well evoked N10 potentials by wrist reflect on the motor nerve stimulation.

CONCLUSION:

These results suggest that the N10 potentials recording at the anterior mid-neck are not associated with the sensory fiber contributions, but pure motor fiber evoked potentials. And 20 % of Erb potentials amplitudes is related to motor fibers.

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Spinal cord evoked potential changes due to conduction block: a simplified model using solid angle approximation

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INTRODUCTION

Conduction block probably plays the most important part in producing potentially treatable clinical deficits in compression myelopathies. Clinically, evoked potential studies recording the ascending axonal volley at multiple sites along the spinal cord after epidural stimulation help localize the site of conduction block. For better understanding of the clinically recorded potentials, we analyzed the waveform changes caused by conduction block with the help of a model.

METHODS

We produced a simplified mathematical model based on a square-wave solid-angle analysis (Woodbury, 1965), computing a sequence of potential change in a volume conductor generated by an impulse traveling along a nerve fiber. A conduction block was simulated as a phenomenon in which a depolarization wavefront stops traveling when it reaches a certain point, although the following repolarization wavefront continues to travel until it reaches the same point (Tani et al., 1997). The spinal cord evoked potential (SCEP) was produced as an algebraic sum of simulated nerve fiber action potentials (FAPs).

RESULTS

With a conduction block, simulated FAPs that were normally triphasic showed a positive-negative diphasic wave with reduced negativity at the point of the block. At the points beyond the block, there was an initial-positive wave alone of progressively smaller size with increasing distance from the block. The simulated SCEP showed an abrupt reduction in size of the negative wave and a concomitant augmentation of the initial-positive wave at the point of the block, when all constituent fibers were blocked. This change was accompanied by an increased negative wave caudally and an enhanced monophasic positive wave rostrally.

DISCUSSION

Extrapolating from the concept of phase cancellation (Kimura et al., 1988), a selective reduction in one polarity of FAPs due to conduction block can enhance the other polarity of the SCEP, because physiologic phase cancellation should either be limited or fail to occur. This mechanism can explain the characteristic findings near the site of conduction block.

CONCLUSION

The computer model predicted that localization of the precise site of conduction block can be achieved by demonstrating an abrupt reduction in size of the negative peak and a concomitant augmentation of the initial positive peak.

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Cerebellum May Contribute to Generate Scalp-recorded Cortical Potentials Evoked by Electrical Stimulation of the Median Nerve.

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INTRODUCTION
Scalp-recorded cortical potentials evoked by electrical stimulation of median nerve at the wrist consist of early component N20 and late component N35. To investigate these generators, patients with cortical lesions and cerebellar-brainstem lesions were studied.
METHODS
Electrical stimulation was delivered at the wrist with subthreshold stimulation intensity and 2Hz frequency. Recording electrodes were placed at hand sensory areas with reference electrodes (A1+A2). 200-400 sweeps were averaged, and two waveforms were superimposed.
SUBJECTS
(1) Eight patients with cerebral cortical lesions, 49 – 71 year-old, 5 males and 3 females, were studied, who consist of 3 cases with frontal, 4 with parietal, and 1 with fronto-parietal lesions sparing sensorimotor cortices. (2) Nine patients with cerebello-brainstem lesions, 43-70 year-old, 6 males and 3 females, were studied.
RESULTS
(1) Only 3 patients with localized lesions in the posterior portion of the postcentral gyrus had N20, but absent or markedly reduced N35.
(2) Only 3 patients who had lesions involving inferior cerebellar peduncle had N20 but absent or markedly reduced N35.
DISCUSSION
N20 is generated from Area 3, anterior portion of postcentral gyrus, while N35 from Areas 1-2, posterior portion of postcentral gyrus. Posterior column conveys touch to Area 3 and position /movement sense to Areas 1-2 via VPLc thalamic nucleus. However, 15msec seems to be longer when the distance between Areas 3 and 1-2 is considered. Position/movement senses are also conveyed to cerebellum through spinocerebellar tract via inferior cerebellar peduncle. Although deep cerebellar nuclei inputs to precentral gyrus via superior cerebellar peduncle, an alternative pathway to postcentral gyrus from cerebellum may well explain present results and the latency discrepancy between N20 and N35.
CONCLUSION
Cerebellum may contribute to generate late component N35.

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Effects of bed rest on postural modulation of soleus H-reflex

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INTRODUCTION
It was well known the body sway during standing increases after the bed rest (BR) . This mechanism may be not only orthostatic intolerance but also change in the upright posture control system. Previous studies [1, 5)] have reported that H-reflex of soleus, antigravity muscle, is depressed by postural change from supine position to standing position. This phenomenon was considered as a functionally postural regulation in order to stabilize the feedback loop through the spinal reflex. The purpose of present study was to examine the effect of the BR on the postural modulation of soleus H-reflex.
METHODS
Six healthy male subjects, age 19~32years, underwent continuous bed rest in 6 degree head down tilt position for 20 days. All subjects remained inactive throughout the BR period. Subjects gave their informed consent to the experimental procedures approved by the local ethics committee. The H-reflex in soleus was evoked by stimulating the tibial nerve in the popliteal fossa with constant voltages and duration of 1 msec. The maximal amplitudes of the H-reflex and M-response were obtained from each subject. The H-reflex activity was expressed as a percentage of Hmax to Mmax (HM ratio). The presynaptic inhibition was calculated as the change rate in the level of monosynaptic Ia facilitation on the soleus elicited by a stimulation of heteronymous Ia volley on the quadriceps[3)]. Heteronymous Ia facilitation of the soleus H-reflex was obtained by stimulating the femoral nerve in the femoral triangle with a conditioning intensity (1.2 x MT) in supine position. The test stimulating intensity of soleus muscle was adjusted for give a relative amplitude of 15% to the M-response. The time interval between conditioning and test stimulation which produced the peak facilitation in each subject was used. The level of heteronymous Ia facilitation was expressed as a percentage to the amplitude of soleus H-reflex without conditioning stimulation. During the measurement, the subjects, were fixed on a tilting bed apparatus which can tilt the whole body from supine (tilt angle is 0 degree) to standing (85 degree) posture.

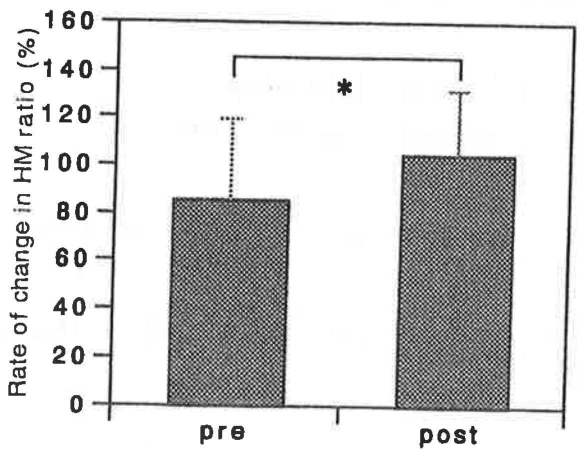

Fig. 1 Rate of change in HM ratio with posture change from spine to standing position before and after the BR. (* : $p < 0.1$)

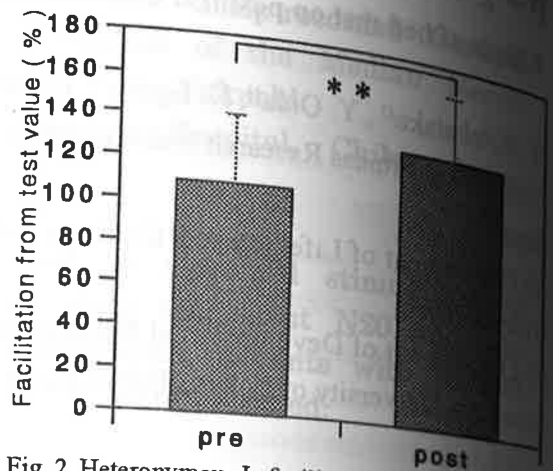

Fig. 2 Heteronymous Ia facilitation in standing before and after the bed rest. (** : $p < 0.01$)

RESULTS

The HM ratio between before and after the BR showed no change in supine. However, the HM ratio in standing appeared to increase after the BR ($p < 0.1$) . The rate of change in HM ratio with the postural change from supine to standing after the BR tended to increase than that before the BR ($p < 0.1$, Fig. 1) . There are no change the heteronymous Ia facilitation in supine between before and after the BR. But the heteronymous Ia facilitation in standing significantly increased after the BR ($p < 0.01$, Fig. 2) .

DISCUSSION

The excitability of soleus motoneuron pool had no effect on the BR. However, there were the previous study which the soleus H-reflex was increased after the BR[2] and opposite result which was decreased after the BR[6]. The present study was not possible to clearly explain these conflicting results. After the BR, the modulation of reflex gain with the postural change was disappeared. It was considered to results from the decrease of presynaptic inhibition[4, 5] during standing after the BR.

CONCLUSION

It was concluded that the postural modulation of soleus H-reflex was disturbed by the inactivity condition during the BR for 20 days.

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Soleus and Gastrocnemius Silent Period with or without Visual Information in Natural Standing and Hemi-Standing by Dominant Leg.

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INTRODUCTION

We had studied about the variation of the soleus silent period during keeping a weight bearing posture among a natural standing, a standing with bilateral knee flexed and hemi-standing by a dominant leg[1]. In those our previous study, the soleus silent period has changed with a postural alteration. Especially, the soleus silent period was most shortened in hemi-standing compared with another standings and we speculated that the soleus silent period was influenced by an amount of bearing the weight and a postural instability, because the amount of bearing the weight to leg was the most in hemi-standing posture and hemi-standing posture was the most unstable posture among those three postures.

In this study, to clarify the effect of a postural instability on central nervous system function using the silent period, we studied the variation of silent period from soleus and gastrocnemius muscles on natural standing and hemi-standing with an opening eyes as the stable condition or with closing eyes as the unstable condition.

METHODS

The subjects were 6 healthy and non-athletic adults, with a mean age of 23.7 +/- 2.5 (21 - 27) years and a mean height of 170.2 +/- 2.5 (167 - 175) cm. Every subject's dominant leg was the right leg. The silent period by single stimulation to tibial nerve at the popliteal fossa was recorded from the dominant side soleus and gastrocnemius muscles during two kinds of standing postures; natural standing and hemi-standing by a dominant leg. The stimulating conditions for recording the silent period were as follows: Intensity; supra-maximum., Duration; 0.2ms., Frequency; 0.5Hz. and Numbers; 30times. The recording electrodes were placed on soleus and gastrocnemius (lateral head) muscles and the reference electrode was put on the ipsilateral Achilles tendon. Sweep time on recording was 200ms. The raw data were amplified with a bandpass between 20 Hz and 2000Hz and averaged 30 times by a Nicolet Viking II e. The silent period was calculated the duration from the artifact due to electrical stimulation to re-starting the electromyographical bursting of tonic muscle contraction under the 200 μV/div on a screen. The postures during recording the silent period were natural standing with opening eyes (POSTURE 1), natural standing with closing eyes (POSTURE 2), hemi-standing by a dominant leg with opening eyes (POSTURE 3) and hemi-standing by a dominant leg with closing eyes (POSTURE 4). To clarify the effect of the postural instability related to opening or closing eyes to the silent period, we compared with the silent period between POSTURE 1 and POSTURE 2 and between POSTURE 3 and POSTURE 4.

RESULTS

The results of this study were demonstrated on the Table.

There were not any significant changes in silent periods from soleus and gastrocnemius muscles with an alteration of postural instability related to visual information on the natural standing and hemi-standing postures.

DISCUSSION

The silent period is the duration of the inhibitory period of muscle contraction detected on electromyography, which is due to electrical stimulation at the innervating nerve during tonic muscle contraction. The silent period has been considered to be the total circuit time from the peripheral nerve stimulus point to the supra-spinal, because the M wave, F wave and Long Latency Reflex (LLR) were recorded during the silent period. The M wave is affected by the peripheral nerve conductive condition and the muscle state. The F wave is influenced by the excitability of the spinal motor neuron. LLR in the lower extremities is affected by the excitability of the spinal cord, brainstem or motor cortex. Therefore, a variation of the silent period may reflect the degree of excitability of the central nervous system.

This study was the preliminary consideration whether the silent period of lower extremity was affected by a postural instability or not. We speculated that if a subject had felt an unstable feeling due to none visual information on standing under the closing eyes condition, the excitability of central nervous system related to silent periods from soleus and gastrocnemius muscles might have changed by an alteration of sensory-motor function in order to keep the postural stability. So, we compared the silent periods from soleus and gastrocnemius muscles on natural standing and hemi-standing by a dominant leg related to opening or closing eyes on the same standing.

As a results of this study, there was no significant change in silent periods from soleus and gastrocnemius muscles with an alteration of postural instability related to visual information on natural standing and hemi-standing by a dominant leg. It was suggested that the excitability of central nervous system, which related to silent periods from soleus and gastrocnemius muscles was not influenced by an alteration of the postural instability related to visual information on natural standing and hemi-standing by a dominant leg in healthy persons.

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Table. Soleus and Gastrocnemius Silent Period with Alteration of Visual Information.(n=6)

	POSTURE 1	POSTURE 2	POSTURE 3	POSTURE 4
Soleus silent period	154.4±12.8	158.7±19.5	136.3±24.9	130.7±21.2
Gastrocnemius silent period	144.3±21.2	148.1±20.3	127.8±22.8	124.7±21.4

(ms)

Average±SD of each condition was shown.
POSTURE 1; Natural standing with opening eyes, POSTURE 2; Natural standing with closing eyes, POSTURE 3; Hemi-standing with opening eyes and POSTURE 4; Hemi-standing with closing eyes.
There was no significant deference in silent periods of soleus and gastrocnemius muscles with or without visual information on the natural standing (POSTURE 1 and 2) and hemi-standing (POSTURE 3 and 4).

P-244

Spinal Neural Function in Different Stretched Positions of Shoulder and Elbow Muscles in Patients with Cerebrovascular Diseases

- F-Wave Study -

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INTRODUCTION

In rehabilitaion medicine, continued stretching has been used for reducing hypertonus and improving voluntary movement in patients with cerebrovascular disease (CVD). Our previous study using the H-reflex had reported that the excitability of spinal neural function in the distal part, the abductor pollicis brevis, of the affected arm was reduced during continued stretching of the proximal part; both shoulder and elbow joints, or all shoulder, elbow and wrist joints[1).]

SUBJECT

The subjects were 20 hemiparesis patients with moderate hypertonus, modified Ashworth scale 2 or 3, caused by CVD. Their mean age was 49.5 years.

METHOD

F-wave during continued stretching for 1 min was recorded from the abductor pollicis brevis after stimulation of the median nerve at the wrist. The methods of continued stretching were follows; relaxation (trial 1), a stretched position with shoulder abduction (trial 2), a stretched position with shoulder abduction and elbow extension (trial 3), and a stretched position with shoulder abduction, elbow extension and wrist extension (trial 4) of the affected arm for 1 min. The intensity of constant current stimulation was 1.2 times to evoke the maximal M-wave, with a stimulus frequency of 0.3 Hz and duration of 0.2 ms, respectively. The F-wave was analyzed for amplitude ratio of F/M (ratio of each maximum amplitude of F and M) and latency.

RESULTS

The amplitude ratio of F/M in trial 2 was the same as that in trial 1. The amplitude ratios of F/M in trials 3 and 4 were significantly lower than that in trial 1. No significant difference was noticed in the latency of each trial.

CONCLUSION

F-wave was a muscle response resulting from 'backfiring' of antidromically activated anterior horn cells. We reported that the amplitude ratio of F/M on the affected side in hemiparesis patients with hypertonus was significantly greater than that in other patients[2]. It is generally said that F-wave, especially amplitude ratio of F/M, is an index of spinal neural function. From this study, it was suggested that the excitability of spinal neural function on the distal part, the abductor pollicis brevis, of the affected arm was reduced during continued stretching of the proximal part; both shoulder and elbow joints, or all shoulder, elbow and wrist joints in hemiparesis patients with moderate hypertonus caused by CVD.

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P-245

AGE RELATED CHANGES ON HUMAN POSTURAL STABILITY

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INTRODUCTION

Postural stability is a multi-component and highly adaptable control process. The high center of gravity of human body (CG) has to be maintained over a relatively small base of support (BOS).(1,2) So, passive stability in man is poor, and hence stability must involve active process as well. The active process of stability is a complex process involving coordinated activities of multiple sensory, motor, and biomechanical components.(2) The limit of stability or the core area (CA) is that area beneath the feet that the subject can use to maintain stability i.e. maximum CG sway without losing balance.(2,3) The resultant relationship of the body segments is reflected by the position of the CG upon the BOS during the upright stance. Therefore, the CG position might be reference to the central nervous system (CNS) in monitoring postural stability.(4) The control of postural upright stance is essentially a matter of either moving the CG relative to the BOS within the CA by using an appropriate compensatory mechanism, or moving the BOS relative to CG (stepping), so as to prevent a fall.(2) Several studies of the CA and displacement of the body CG revealed that it can reflect the degree of postural stability. In addition, it could assess different factors which contribute to the stability.(5,6) The complexity of maintaining the upright stance suggests that there would be a great deal of functional variability within a normal population as a result of individual variation in sensory system, CNS, and biomechanical function.(7) Systemic changes may also occur as a result of development during childhood, as well as, due to the degeneration associated with aging. It would be of clinical significant to identify the nature of any age-related changes on postural stability among normal population.

METHODS

Seventy healthy subjects (33 males, 37 females) were included in the study, their age ranged from 4 - 73 years. They haven't any clinical condition that would affect postural stability. They have been divided into 6 groups. Each group 10 subjects except group II was 20 subjects. The following parameters were studied in each subject, using a gravity board :

- Percentage of CA to BOS area (CA/BOS).
- Percentage of displacement of the vertical projection of body CG from the ideal CG (%CG) in erect posture.
- The symmetry of the CA.
- Height, weight, body mass index (BMI).

RESULTS

- There is a significant positive linear correlation of CA/BOS from young age group to adult ($r = 0.579$, $P<0.001$), which is followed by a significant negative linear correlation from adult to old age ($r = -0.873$, $P<0.001$).
- There is a significant decrease of the posterior segment of the core area among the elderly subjects compared to adults ($F = 6.5$, $P<0.01$).
- Height, weight, BMI, and %CG were statistically insignificant among the studied groups.

DISCUSSION

The significant decrease in the limit of stability among elderly people is suggested to be as they allow themselves a wider mechanical margin of error to compensate for delayed or reduced responses to disturbance of balance.[8] Fujiwara and co-workers in 1982 related this decrease to the decline of calf muscle strength.[9] The decrease of the postural stability among children might be partly related to the immature CNS. Hay pointed out in 1979 that young children (less than 7 years) performing ballistic types of corrections to errors in arm reaching. Around 7 years of age, the children begin relaying on sensory feedback to make more accurate slower movement correction. Children may be changing from a fast ballistic strategy of postural control to a slower accurate sensory monitored strategy.[10] The significant limitation of the posterior segment of the CA among the elderly people means that they depend more on the anterior segment to correct any postural instability. It has been suggested that apprehensive old subjects who are afraid to fall tend to adopt a "stiffened posture" to compensate for their postural deficit.[11] The insignificant %CG among the studied groups might be because the body is not a static mass. It is assumed that the displacement of the body CG can occur without significant decrease of its mechanical stability.

CONCLUSIONS

- Postural stability showed a significant *modulation* with age. The pattern characterized by small CA/BOS among young children, then progressive increase till adulthood and then decrease progressively till elderly people.
- Old people showed a significant decrease of the posterior segment of the CA.
- Height, Body weight, BMI, and % CG were statistically insignificant among the studied different age groups.
- CA seems to be an important index for assessment of human postural stability.

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Free Paper

O-71

An *in vivo* Model of Electromyographic Signal Propagation and Muscle Function

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INTRODUCTION

A new *in vivo* model is described to study the relationship between surface electromyographic (EMG) signal propagation and muscle function. The model was initiated to support research comparing EMG-based measures of muscle impairment with underlying muscle pathophysiology. The *in vivo* technique replaces previous *in vitro* models that were limiting, particularly for studies of muscle fatigue. Specifically, this paper introduces the methods for an *in vivo* protocol in which brief, supra-maximal contractions are evoked at fixed time intervals in a hindlimb muscle of the rat.

METHODS

Female Wistar rats were used to test the model and evaluate the variability of the data for different animals and within repeated trials of the same animal. Under deep anesthesia, the animals were weighed and the right hindlimb was shaved. The motor nerve of the right *tibialis anterior* (TA) muscle (common peroneal nerve) was surgically isolated using a technique published by Crouch (1969). About 3 mm of the common peroneal nerve was carefully freed from the connective tissue. The nerve was then lifted onto a custom bipolar stimulation probe connected to a stimulation unit (Grass S88). The skin and connective tissue fascia covering the TA muscle were incised and removed. The distal tendinous insertion of the TA was isolated and severed from its bony attachment. All other tendinous attachments to the foot were excised. To avoid dryness, both nerve and TA muscle were frequently bathed throughout the experiment with an isotonic saline solution.

The animal was positioned supine on a custom platform where its torso was secured and body temperature maintained. The right knee was fixed in 90° flexion and the ankle maintained in maximal plantar flexion. An adjustable clamp with bilateral bone screws fastened to the femur was used to immobilize the lower limb. The immobilization was critical to prevent artifacts and unreliable data produced by movement of the lower limb with respect to the surface EMG probe during evoked contractions. The distal tendon of the TA muscle was attached to a low-compliance force transducer (Interface, Model MB-10) using Teflon coated wire (Medwire, Sigmund Cohn Corp.) and a clamp.

A micro-manipulator-mounted custom surface EMG probe with 12 pin electrodes (0.5 mm diameter; 2.3 mm inter-electrode distance) was positioned on the surface of the muscle parallel to the muscle fibers. The electrode array allowed to cover the entire length of the TA muscle, including tendinous zones. The active electrode array featured high input impedance voltage followers, which were mounted approximately 3 cm from the detection sites. The electrode connected to a custom multi-channel amplifier with a gain of 250. Custom software on a PC workstation recorded the bipolar EMG signals with a sampling rate of 1024 Hz.

A preliminary sequence determined the supramaximal stimulation voltage and optimal muscle length (l_0), followed by a rest period of 20 min. EMG and force data were then acquired during a series of 0.5 s evoked contractions at supramaximal stimulation (30 pps). Stimulations occurred at 10-minute intervals for 90 minutes followed by 30-minute intervals for up to 3 hours total. The length of the overall procedure was specified to determine whether repeat contractions affect the reliability of the experimental procedure.

At the end of the experiment, both right and left TA muscles were surgically removed, weighed, and frozen at optimal length in isopentane pre-cooled in liquid nitrogen prior to histological and histochemical analysis. Afterwards, the animals were euthanized.

RESULTS

The *in vivo* model allowed the evaluation of EMG signals and force production of rat TA muscle for three consecutive hours. The skeletal muscle fibers of the right TA muscle showed normal morphological aspect in all histological sections. No signals of muscle fiber injury such as fiber disruption, hypercontraction or edema could be found at the end of the measurements. Right and left TA muscles did not show morphological differences. M-wave shape, conduction velocity, EMG amplitude and median frequency changed during the course of the experiment. Nevertheless, the modifications to the EMG signal were consistent with cumulative fatigue resulting from the repeated trials.

DISCUSSION

The *in vivo* model described in this study enabled us to successfully acquire and compare the electromyographic signal, muscle force, and histochemical properties of the rat TA muscle. Only the effect of anesthesia limited time measurements. The technique is compatible with studies requiring data acquisition for periods of several hours. Analyses demonstrated that there was a close association between changes in the EMG and contractile force for repeated evoked potentials during this test period. The slight degradation of the force generating capacity of the muscle can be attributed to the cumulative fatigue effects that were likely present although stimulation duration was minimized and rest periods were provided between stimulation trials.

CONCLUSION

The model allows for an *in vivo* measurement of the influence of muscle impairment on surface EMG signal propagation. Additionally, histochemical analysis allows to assess the underlying pathophysiology responsible for changes in the surface EMG. The model is currently used to study short- and long-term effects of muscle injury (myotoxic and mechanical damage) on the muscle force production for which we will present preliminary data.

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ASSESSMENT OF MUSCLE FATIGUE DURING BIKING

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INTRODUCTION

The spectral analysis of the surface myoelectric signal is widely used to detect and quantify the electrical manifestations of muscle fatigue in isometric and constant force contractions. However, applications to dynamic contractions, as those encountered in most daily activities, are still unusual. The surface myoelectric signal recorded during such contractions is generally nonstationary, thus requiring the availability of proper spectral estimation techniques. During the past five years, we developed several algorithms based on the Cohen class of time-frequency transforms that we used to track the electrical manifestations of muscle fatigue during different kinds of nonstationary muscle contractions. The purpose of this study is to quantify the electrical manifestations of muscle fatigue on a population of young normal subjects cycling on a cycloergometer.

METHODS

Surface myoelectric signals were recorded from a population of 22 healthy volunteers (11 males and 11 females, whose age was 25±3 years) without specific training. After a warming up phase consisting of 5 minutes of stretching, the subjects were asked to carry out 30 minutes of cycling against a constant torque and at a constant velocity. This was set to 50 rpm for female subjects and to 60 rpm for males. SMESs were recorded from rectus femoris, biceps femoris, and gastrocnemius of the dominant leg of the subject. We also recorded the joint angle by means of an angular transducer fixed to the knee. The signals, recorded by single differential active probes, were amplified, bandpass limited between 30Hz and 450Hz, acquired with a sampling rate of 2000Hz, and converted by a 12 bit A/D card.

Signals were recorded during time epochs lasting one minute each and five minutes apart; hence, we recorded seven epochs consisting of approximately 50-60 signal bursts each. By means of a cross time–frequency algorithm we derived the time course of the instantaneous mean frequency (IMNF) of the signal within each activation burst. We verified that the SMESs were cyclostationary over each recording epoch, hence we averaged the IMNF values over the activation bursts to lessen the estimation variability. As usual [1], the electrical manifestations of muscle fatigue were quantified by considering the percent decrement of IMNF during the entire exercise. Finally, by means of a statistical detector recently proposed [2], we derived the activation pattern of our sample population during cycling.

RESULTS

By considering each specific subject and every muscle tested, the decrements of the IMNF during the entire exercise were lower than 3%-5% their initial value. This finding demonstrates that none of the subjects showed clear signs of electrical manifestations of muscle fatigue during this exercise. Studying the group average of the IMNF percent decrement drew the same conclusion.

Figure 1 depicts the mean activation pattern obtained on the entire population. In this figure, black shows the angular interval in which the muscle was active in all the subjects, while gray

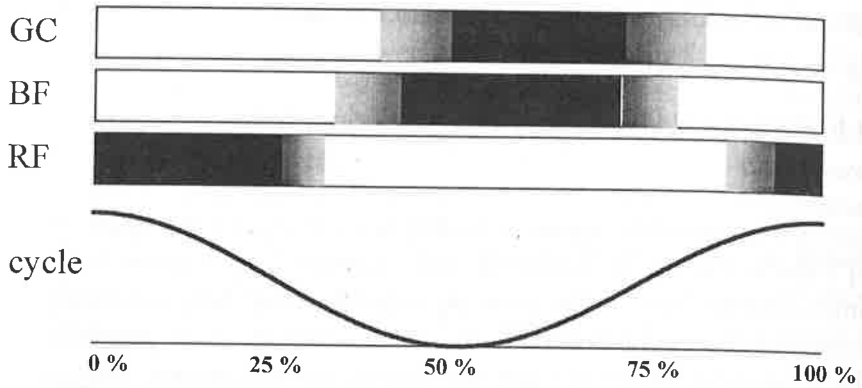

Figure 1 depicts the mean activation pattern obtained on the entire population. In this figure, black shows the angular interval in which the muscle was active in all the subjects, while gray becomes lighter as the percentage of subjects in which the muscle was active at that specific angle decreases. White means that no subject showed muscle activity.

DISCUSSION

The fact that none of the subjects showed electrical manifestations of muscle fatigue may be explained by considering the nature of the exercise. First, the torque produced by each subject during cycling was markedly lower than his/her maximal torque; this supports our initial assumption of considering that cycling a slow–fatiguing exercise. Secondly, as shown by figure 1, during cycling the muscle activity is discontinuous: in fact, each of the three muscles is activated for less than the 40% - 50% of the entire cycle. The two considerations above justify a limited modification of the pH of the interstitial fluid, which in turns explains the absence of detectable modifications of the excitability of the muscle membrane. It follows that the subjective perception of muscle fatigue that all the subjects reported during the exercise must be explained by factors other than membrane properties.

These preliminary findings allowed us to obtain normative data on the behavior of normal subjects during biking with respect to the electrical manifestations of muscle fatigue; this was absolutely necessary prior to extend this study to subjects affected by different kinds of muscular disorders.

CONCLUSION

In this paper, we discuss the electrical manifestations of muscle fatigue of three leg muscles obtained during 30 minutes of cycling on a population of 22 healthy subjects. We estimated the time course of the mean frequency of the SMES by means of a cross time–frequency algorithm and we also obtained the activation patterns of the investigated muscles by applying a statistical detector already described in literature. The main finding is represented by the observation that it is not possible to observe electrical manifestations of muscle fatigue in any subject of our sample population.

In the future we will develop this study as follows: first, we plan to increase the number of normal subjects tested; secondly, we are currently applying nonlinear clustering techniques to the time-frequency distributions of the signal, to detect changes due to muscle fatigue that are not evident applying the usual techniques; finally, we plan to extend this research to subjects affected by different kinds of muscular diseases.

REFERENCE

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Comparison of the Effects of Active and Passive Recovery on the Intracellular Events Detected by ^{31}P-Magnetic Resonance Spectroscopy

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INTRODUCTION

It has been reported that moderate muscular exercise during the recovery period (active recovery) allows faster lactate removal compared with the resting condition (passive recovery), therefore, active recovery is considered to be effective for recovering from muscle fatigue (1). However, the effects of the active recovery on intracellular events have yet to be clarified. ^{31}P-MRS allows no-invasive and real-time measurement of working muscle intracellular energy metabolism *in vivo* (2, 3). Thus, the purpose of this study was to investigate the effect of active recovery on intracellular events using ^{31}P-MRS.

METHODS

Seven healthy men participated in this study. Each subject was asked to place his right forearm on a surface coil in a superconducting magnet, so that the intracellular events in the wrist flexor muscles could be monitored throughout the experiment by the ^{31}P-MRS system (BEM 250/ 80, Otsuka Electronics, Japan). Exercise consisted of wrist flexions using an isokinetic ergometer. Prior to the experiment, each subject was instructed to exert the maximum voluntary effort in wrist flexion to measure the maximum voluntary contraction (MVC).

Following a 2-min-rest, the subject was asked to performe intense muscle exercises. During the exercise period, the subject flexed the wrist joint at 60%MVC load in the isokinetic manner (30 degrees per second) every two seconds until the intracellular pH decreased to approximately 6.4. After the exercise period, the subject had a recovery period for 10min. During the recovery period, the subject was placed under two kinds of recovery conditions; one was passive recovery and the other was active recovery. For the active recovery, the subject was asked to continue the exercise at lower level of power output in a decremental manner. The power output was decreased from 25% to 5%MVC every two min during the active recovery period. MR-spectra were obtained throughout the experiments, and from the spectra the intracellular pH (pHi) and inorganic phosphate to phosphocreatine ratio (Pi/PCr) were calculated as indicators of intracellular events (4). Data were analyzed by one way ANOVA and $p<0.05$ were taken as statistically significant.

RESULTS

Figure 1 shows the changes of the intracellular pH (pHi) during the exercise and recovery period. In case of active recovery (AR), the pHi increased immediately after the exercise period, whereas in that of passive recovery (PR), it still continued the decrease and started to recover 2 min after the exercise period. The pHi in AR reached almost to 6.8 after 5min recovery, whereas it was around 6.4 in case of PR condition. The difference of the pHi from 1 to 7 min between the groups was significant ($p<0.05$). As shown in Figure 2, the Pi/PCr ration in the case of PR decreased quickly to the resting level, while in that of AR the recovery of the Pi/PCr was more gradual. The results indicated that for the active recovery exercise some amount of energy was required.

DISCUSSION

Active recovery, which is called *"cooling down"* or *"warm down"* by athletes, has been considered an effective maneuver to promote recovery from muscle fatigue, since moderate muscular exercise during the recovery period allows faster removal of lactate compared with passive recovery (1). In this study, we used ^{31}P-MRS to evaluate the effects of active recovery on the intracellular events in the exercising muscle. In case of active recovery, the pHi, which decreased to approximately 6.4 after intense muscle exercise, increased rapidly compared to passive recovery, and the difference was significant ($p<0.05$). These results suggest that active recovery may be an adequet maneuver to elicit recovery from intracellular metabolic acidosis, indicated that it was useful on the recovery from the muscular fatigue.

The rapid increase in pHi during the recovery period may be due to a prompt lactate from the intracellular space and/or by increasing the efflux of lactate from the intracellular to the extracellular space. During active recovery, the muscle blood flow increases; thereby the aerobic metabolic pathway for the lactate biochemical removal could be activated. Increased muscle blood flow can promote the intracellular lactate efflux to the extracellular space. Thus, the pHi increased rapidly during active recovery, while pHi increase was slow during passive recovery.

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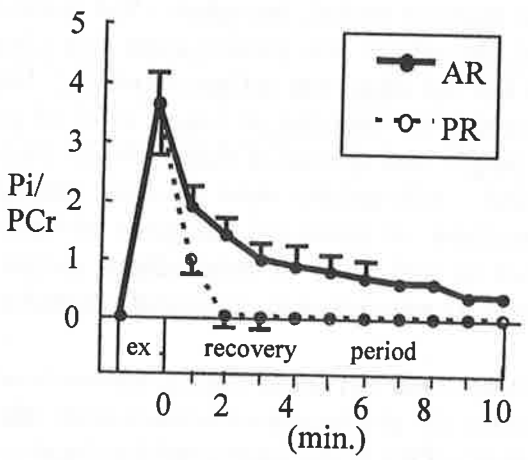

Fig. 1 Time course of Pi/PCr ratio

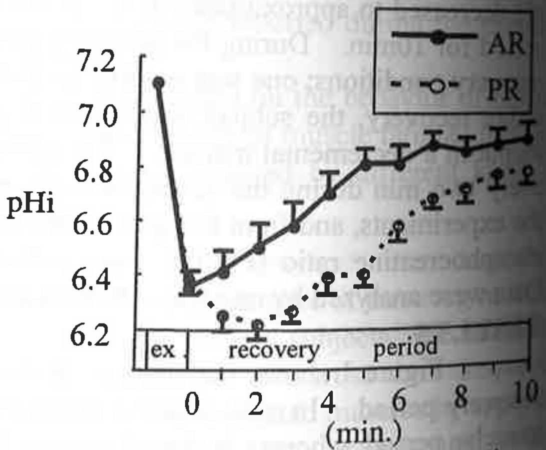

Fig. 2 Time course of pHi

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Effect of Muscle Fiber Length on the Conduction Velocity Distribution Estimation

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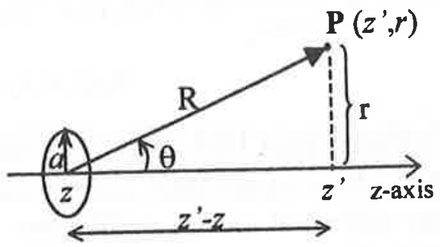
INTRODUCTION

Obtaining a description of the Motor Unit Action Potential (MUAP) at the skin surface is important for applying non-invasive estimation techniques. This paper presents a model that describes innervation and fiber termination effects using volume conductor modelling. Based on the developed model, a Conduction Velocity Distribution (CVD) estimator was assembled and applied to simulated data in order to show how end-effects affect its performance.

MODELING

Surface Extracellular Potential for a Continuous Source



The Legendre polinomial series expansion presented by Plonsey [1, Eq.20] is used in finding the extracellular potential at a point P with Cartesian coordinates (z',r).

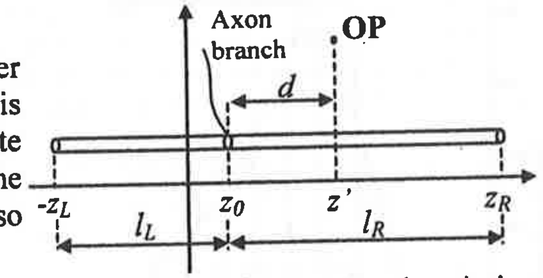
Since the fiber depth r is at least two orders of magnitude greater than the fiber radius a, a good approximation is obtained by using only the 1st term of the series expansion.

The resulting expression given by Eq.1 describes the extracellular potential at point P for a continuous source:

$$V(z',r) = \frac{1}{2}\frac{\sigma_i a^2}{4\sigma_e}\int_{-\infty}^{\infty}\frac{\delta V_m(z)}{\delta z}\frac{(z'-z)dz}{[r^2+(z'-z)^2]^{3/2}} \quad (1),$$

where, $\delta V_m/\delta z$ is the 1st derivative of the transmembrane potential, it is taken as the source,
σ_i & σ_e are the intra & extracellular conductivities, respectively, and
z is the longitudinal distance along the fiber axis.

Surface Single Fiber Action Potential (SSFAP)



The diagram at the right shows a single muscle fiber innervated by an axon branch at point $z = z_0$. It is considered that 2 APs will be travelling in opposite directions towards the left and right terminations. The two-sided source presents a discontinuity at $z = z_o$, so the integral in (1) is divided in two parts.

After changing variables from the spatial (z) to the time (t) domain, the following description is found for the potential at the observation point OP,

$$V(t') = \frac{1}{2}\frac{\sigma_i C^2}{4\sigma_e}\left[\int_0^{t_L} s(t'-t)h(t+d/v)dt + \int_0^{t_R} s(t'-t)h(t-d/v)dt\right] \quad (2),$$

where, $t_L = l_L/v$, $t_R = l_R/v$, $C = a/v$ (constant), v is velocity,

$$s(t) = \frac{\delta V_m(t)}{\delta t}, \text{ and } h(t) = \frac{t}{[(r/v)^2+t^2]^{3/2}}.$$

Making use of the following two definitions

$$h_L(t,d,r,l_L,v) = \begin{cases} 0, & t<0 \\ h(t+d/v), & 0 \le t \le t_L \\ 0, & t>t_L \end{cases},$$

$$h_R(t,d,r,l_R,v) = \begin{cases} 0, & t<0 \\ h(t-d/v), & 0 \le t \le t_R \\ 0, & t>t_R \end{cases},$$

the expression given by (2) can be written in a more compact form as follows

$$V(t) = \frac{1}{2}\frac{\sigma_i C^2}{4\sigma_e} s(t) * [h_L(t,d,r,l_L,v) + h_R(t,d,r,l_R,v)] \quad (3),$$

<u>Surface Motor Unit Action Potential</u>

Since fiber innervation and termination points are dispersed within a MU, the single fiber end-effects are smoothed in the MU signal. However, the following section shows the impact these effects have on the results offered by a CVD estimator proposed in [2].

RESULTS

Figure 1 shows a CVD estimate obtained when the muscle length is properly accounted for in the estimator.

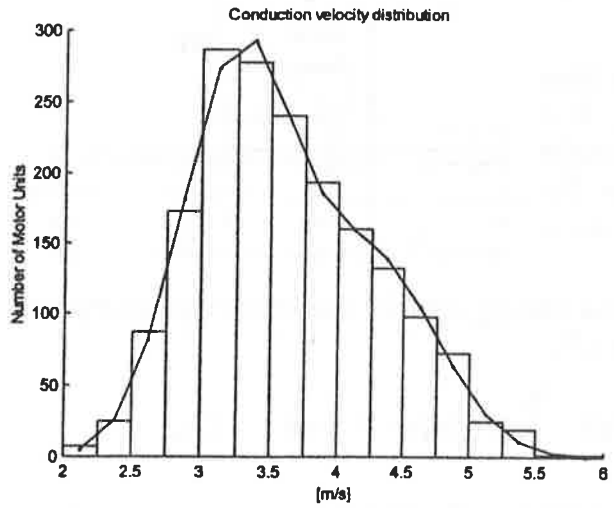


Figure 1. CVD Estimate based on actual fiber lengths

The solid line represents the CVD used to generate the myoelectric signal, which was composed of 1800 active MUs distributed according to a Gaussian pdf over depth. The bar histogram represents the CVD estimate.

Figure 2 shows the results obtained when the estimator assumes that a MU contains nearly infinite length fibers (still including the innervation and fiber termination dispersions within each unit).

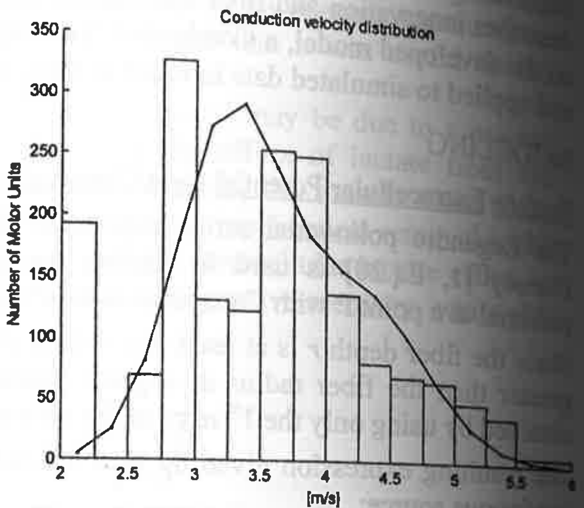


Figure 2. CVD Estimate based on 'infinite' fibers

The muscle length was made as large as 0.5m and 1m. The results for 0.5m and 1m were similar, however the difference between these and the result shown in Figure 1 is significant.

CONCLUSIONS

The present paper presents a description of the surface SFAP generated by a finite muscle fiber in a homogeneous volume conductor. The SFAP modeling is extended to describe the surface MUAP and used to build a CVD estimator. According to the results obtained, it is apparent that the finite length of muscle fibers should not be overlooked when estimating the CVD.

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O-75

In Vivo Force-Length Relationship of Human Tibialis Anterior Muscle

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INTRODUCTION

One of the important properties of a muscle is the force-length property. The muscle's force is largest at certain lengths, i.e., optimum lengths, and decreases at either shorter or longer muscle lengths. The relationships between joint torque and angle of various joints have also been determined in humans as well as in animals. The joint torque-angle relationship can be considered to reflect the muscle's force-length relationship. However, the force-length property is modified before the appearance at the joint by variations in muscle-tendon-skeleton architecture, such as moment arm and pennation angle, during the transmission processes of excursion to angulations and force to torque. In the present study, the fascicle length, pennation angle and moment arm length were determined by ultrasonography to obtain in vivo force-length relationship of human tibialis anterior muscle.

METHODS

Six males participated as subjects in the present study. Their mean±SD age, height, body weight were 26.7±2.6yr, 169.7±6.8cm and 69.8±7.3kg, respectively. Subjects lay supine on a bed with their right feet firmly attached to a footplate of a dynamometer (Myoret RZ-450, asics, Japan). The dynamometer was used to set the ankle joint angle to certain angles (i.e., 130, 120, 110, 100, 90=anatomical position, 80deg). An ultrasonic apparatus (SSD-2000, Aloka, Japan) with 7MHz wave frequency (UST-7.5, Aloka, Japan) was used to obtain a sagital ultrasonic image during resting. The ultrasonic probe was put on the anterior aspect of the lower leg at 40% distal from the popliteus crease. After the acquisition of each image during resting, the subject was asked to develop the maximal voluntary torque (MVC). An ultrasonic image was also obtained during the development of MVC. Two trials were made at each joint angle. These ultrasonic images were stored in an magneto-optic disk using a recording device (MV-50, TEAC, Japan), and then fed into a computer (Power Macintosh G3, Apple, USA). Fascicle lengths and pennation angles were measured using NIH-image (National Institute of Health, USA). These measurements were executed five times on each image, and the mean values among three measurements excluding the largest and the smallest values were calculated. Further, the mean values for the two images at the same joint angle were averaged.

For each subject, the moment arm lengths were calculated using the tendon excursion method (Ito et al., 2000). Briefly, the tendon excursion during dynamic dorsiflexion while developing moderately constant dorsiflexion torque level was measured using the ultrasound apparatus. Using the equation m=dx/da, where m, da and dx represents moment arm, tendon excursion, and changes in joint angle, the moment arm lengths could be calculated. Torque was divided by moment arm to calculate tendon force. In this calculation, it was supposed that the 49.8% of dorsiflexion torque was developed by TA based upon the PCSA ratio reported by Yamaguchi et al. (1990).

A magnetic resonance imaging (MRI) device (0.3T/12.7MHz; AIRIS, HITACHI, Japan) was used to obtain the muscle cross-sectional image of the lower leg. The spin-echo axial-plane imaging was performed with the following variables: repetition time: 820ms, echo time: 20ms, slice thickness: 10mm, interslice gap: 0mm. The anatomical cross-sectional area (ACSA) of the TA was measured by tracing the outline of the muscle on each MR image. The muscle volume was calculated as the sum of all ACSAs multiplied by slice thickness, i.e., 10mm in the present study. The physiological cross-sectional area (PCSA) could be calculated as muscle volume divided by fascicle length and then multiplying the cosine of pennation angle. The isometric stress could be then calculated as tendon force divided by PCSA.

RESULTS and DISCUSSION

The largest moment arm length (39.6±7mm) was found at the anatomical position, and it decreased as the ankle joint was either plantarflexed or dorsiflexed. The maximum dorsiflexion torque was 39.4±4.6Nm at the ankle joint angle of 100deg (Fig.1). The maximum tendon force (527±41N) was found at 120deg despite the fact that the maximum torque was found at 100deg (Fig.2).

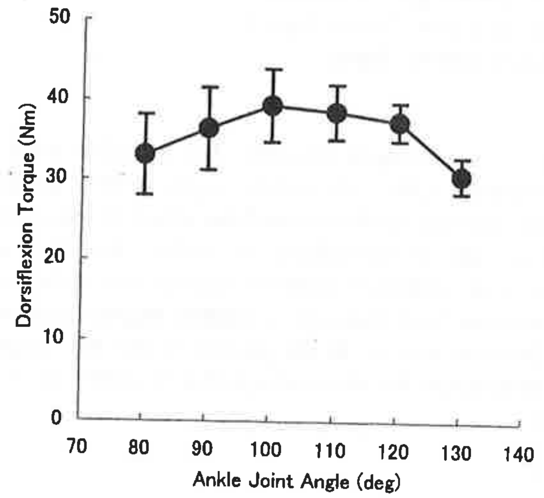

Fig.1 Dorsiflexion torque-joint angle relationship

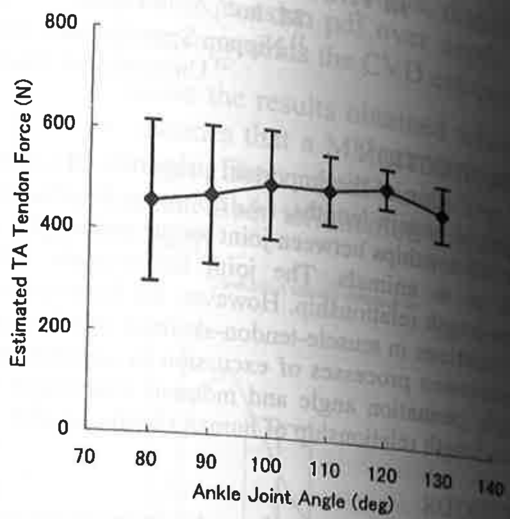

Fig.2 Tendon force-joint angle relationship

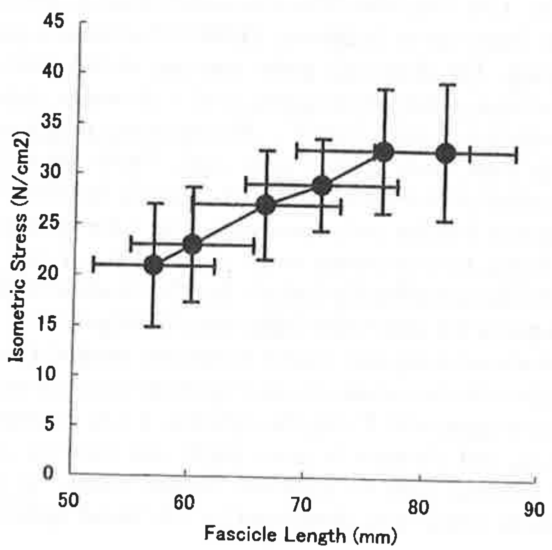

Fig.3 Isometric stress-fascicle length relationship

The mean TA muscle volume was 129,529 ± 17,424mm^3. Fascicle length increased and pennation angle decreased when the ankle angle increased. As the subjects developed MVC, fascicle shortened and pennation angle increased. The physiological cross-sectional area (PCSA) could be calculated from muscle volume, fascicle length and pennation angle at each joint angle. PCSA peaked at the smallest joint angle and decreased as the joint angle increased. When calculated using the resting fascicle length and pennation angle values, PCSA decreased 17.3% on average. Isometric stress, defined as tendon force divided by PCSA, increased as a function of joint angle (21.0 ± 6.1N/cm^2 at 80deg and 32.6 ± 6.8Ncm^2 at 130deg). In Fig.3, the relationship between isometric stress and fascicle length was depicted. The isometric stress was largest at the most plantarflexed position. The TA muscle used only ascending limb and plateau region of its force-length relationship.

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O-76

Muscle Fatigue During Concentric and Eccentric Isokinetic Knee Flexo–Extensions

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INTRODUCTION

The isokinetic exercise is widely used in clinics for training, rehabilitation, and patient follow-up. Generally, the test protocols used consist of series of concentric and eccentric contractions. To our knowledge, at this time studies comparing the electrical manifestations of muscle fatigue typical of the two contraction modalities are missing.

This paper presents the fatigue patterns obtained from four thigh muscles during isokinetic knee flexo-extensions at a joint angular velocity equal to 60°/s, during eccentric and concentric contractions on a population of 16 healthy subjects.

METHODS

The sample population consisted of 16 volunteers (age 29±8 years?) with no history of neurological or orthopedic disorders and without previous experience with the isokinetic exercise. Each subject performed two series of 15 isokinetic knee flexo–extensions, respectively in concentric eccentric modality. In both cases, the angular velocity was set to 60°/s and the range of motion was limited to 80°.

During the exercise, the SMESs were recorded by means of single-differential active probes from four thigh muscles: vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), and biceps femoris (BF). The signals were amplified, bandpass filtered between 30Hz and 450Hz, sampled at 1024 Hz, and converted by a 12 bit A/D card.

The signals were analyzed by means of a cross time–frequency algorithm [2] that allowed for the estimation of the instantaneous mean frequency (IMNF) [1] of the signals. The observation of the time-frequency plot (Choi-Williams distribution) showed that signals were wide sense stationary over each burst in both contraction modalities. The IMNF values were then averaged over the entire range of motion to lessen their variability. We thus obtained 15 IMNF values for each exercise, each of them relative to a specific flexion-extension cycle. Visual inspection of the 15 value series showed that linear regression was an appropriate model and hence we adopted the total percent decrement of the regression line drawn over the 15 values as fatigue index. To obtain group averages, we averaged the percent decrements relative to our 16 subjects for each specific muscle and contraction modality. Statistical analysis was then carried out on the group averages.

RESULTS and DISCUSSION

The group averages of the percent decrements obtained during concentric and eccentric contractions are reported in figures A and B respectively. These results demonstrate that the electrical manifestations of muscle fatigue are higher in concentric than in eccentric modality (paired t-test, $\alpha = 0.05$, $p < 0.004$). However, it is interesting to observe that both the mechanical work produced during the entire exercise and the peak value of the torque measured at the knee joint were higher during eccentric tests (paired t-test, $\alpha = 0.05$, $p < 10^{-3}$), as already showed by other researchers [3].

This apparent contradiction may be explained by assuming that the knee flexors and extensors are more efficient when contracting in eccentric modality than in concentric, even if the latter is generally more common in everyday activities. Some support to our observation comes from the review of Cabri [3], who reported that the consumption of O_2 is lower during eccentric than during concentric contractions producing the same mechanical work. Moreover, by studying the effects of concentric and eccentric training, Higbie [4] hypothesized that the neural activation of muscles during concentric contractions is different from that typical of eccentric contractions.

By comparing the fatigability of different muscles, we observed that the rectus femoris shows the highest fatigue index in both modalities, while vastus lateralis and medialis are more insensitive to the electrical manifestations of muscle fatigue.

CONCLUSION

This paper presents the fatigue patterns of four thigh muscles obtained during a series of 15 isokinetic knee flexion–extension cycles. Statistical analysis demonstrated that every muscle showed lower electrical manifestations of fatigue during eccentric than during concentric contractions, although the mechanical work and peak torque measured at the knee joint were higher. The methodology for the study of the electrical manifestations of muscle fatigue during dynamic contractions that we applied in this study is ready for extensive applications in clinics, to gain a deeper understanding of muscle function in dynamic exercises utilized in rehabilitation and sport training.

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O-77

Muscle Fatigue Evaluation for Longitudinal Assessment of Dystrofic Patients

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INTRODUCTION

In the past decade, several authors demonstrated that the study of the electrical manifestations of muscle fatigue finds ready applications in the assessment of patients suffering from muscle disorders. On the other hand, pathologies that are presently treated only with adjuvant therapy are likely to change dramatically their prognosis in the near future, thanks to the development of new therapeutic approaches. It follows that it is crucial to develop test protocols that are reliable, sensitive, and specific, to allow clinicians to objectively assess and document the conditions of their patients. This consideration motivated a study we undertook to investigate the applicability of muscle fatigue evaluation to children suffering from Duchenne muscular dystrophy.

Duchenne muscular dystrophy (DMD) is a progressive and crippling disease of young males. It is associated with a gradually increasing weakness of the muscles due to the necrosis of muscle fibers, that are progressively replaced by connective tissue. In a previous study, we demonstrated that the electrical manifestations of muscle fatigue are clearly different in normal and pathological children.

This encouraging result suggested us to extend our interest to the longitudinal follow-up of twenty-two Duchenne children enrolled in a pharmacological trial. Our goal was to develop an objective and user independent tool to assess the progression of the disease over several years of observation.

MATERIALS AND METHODS

The pharmacological trial lasted four years. Twenty-two children suffering from Duchenne muscular dystrophy participated in the trial. Each of them was examined before starting the trial and then every two or three months. The children age ranged from four to nine years. At the beginning of the trial all of them were still able to walk without any kind of support.

Each test consisted of two different parts: first, a physician performed the evaluation of the motor performances and of muscle strength following the usual clinical methods; secondly, we assessed the electrical manifestations of muscle fatigue by means of myoelectric signal analysis.

The evaluation of the motor performances was accomplished grading the ability of each child in walking, climbing four steps, standing up from a chair, and performing the Gowers maneuver. Muscle strength was evaluated on the ileopsoas, quadriceps, triceps brachii, and deltoid. It was graded according to the MRC scale.

The muscle fatigue evaluation protocol consisted of the following phases: 1) the determination of the maximal voluntary contraction force (MVC); 2) the execution a voluntary contraction lasting 30s at 80% MVC; 3) the execution of a supramaximal electrically elicited contraction lasting 30s, with a stimulation frequency of 35Hz.

The longitudinal assessment of the disease progression requires the availability of a tool that compares the results of previous tests with those of the last one, thus providing information on the evolution of the clinical status of the patient. Based on the results we obtained by studying the differences between healthy and DMD children, we hypothesized that the percent decrement of the mean frequency (MNF)of the myoelectric signal power spectrum during electrically elicited contractions could have been used to track the progression of the disease. A pilot study demonstrated that it was not able to give reliable indications about the progression rate of the disease by considering only this parameter.

Since the MNF percent decrement alone was not able to describe the progression rate of the disease, we decided to search for an appropriate set of parameters. Due to the heterogeneity and the small size of the sample population, a statistical approach was not applicable. We decided to adopt a multicriteria method called ELECTRE III, because it generally gives good results when applied on small samples and it can handle uncertain and imprecise data.

RESULTS and DISCUSSION

A first interesting finding was that clinical and EMG data must be considered separately. This fact may be explained by observing that these two sets of data show different signs of muscle impairment that commonly may not be seen contemporarily, but that are time shifted of a some months.

The consideration above justifies the development of two different models. First, we formulated a model of the clinical data able to classify the children according to their disease progression rate. The hypothesized model consisted of six criteria: g1) contractile force of quadriceps; g2) contractile force of ileopsoas; g3) contractile force of the upper limbs; g4) walking ability; g5) ability in climbing four steps; g6) ability in performing the Gowers maneuver. By means of this model we were able to classify the patients according to the disease progression rate into three classes: slow, medium, and fast progression rate.

The definition of a possible model based on EMG data was definitively more challenging. By means of several modeling phases we obtained a model consisting of six criteria: g1) the initial value of muscle fiber conduction velocity (CV) measured during the voluntary contraction; g2) the initial value of muscle fiber conduction velocity measured during the stimulated contraction; g3) the percent decrement of MNF during the stimulated contraction; g4) the CV percent decrement during the stimulated contraction; g5) the maximal voluntary contraction torque; g6) the time course of RMS classified by the fuzzy classifier. Based on this model, again we classified our patients in the three classes above. Different classification obtained through the two models was only limited to a few subjects, that were always classified in neighboring classes.

CONCLUSIONS

We developed two different classification models based on a multicriteria procedure to evaluate the progression of Duchenne muscular dystrophy in children enrolled in a pharmacological trial. The first model was based on the clinical assessment usually performed by physicians on patients suffering from this pathology in longitudinal studies. Despite the subjectivity of the evaluations and their dependence on the operator, the model subdivided children in three different classes, corresponding to slow, moderate, and fast progression rate of the pathology. It must be emphasized that, to obtain acceptable results, this approach requires an adequate level of expertise of the physicians involved. The second model was based on objective measurements of some EMG parameters and of the contractile force. This model classified most of the patients as the first model did. This result is relevant to the clinical practice, since it demonstrates that it is possible to classify patients based on objective and user independent data. It follows that this approach guarantees a higher reproducibility of the classification despite the involvement of different operators with various degrees of expertise. This characteristic is of paramount importance in clinics, where reproducible and user independent methods are highly desirable.

O-81

A morpho-kinematic writing analysis in dominant-handhemiparetics: size-related characteristics of writing and motor learning with the non-dominant hand

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INTRODUCTION

Handwriting is considered a sequence of strokes. After long-term practice or the activity of daily writing, each stroke movement becomes ballistic.Shapes of a written character made by the same individual are similar[1] So are kinematic features of pen-tip movement during writing[2] Writing therefore should be evaluated from kinematic and morphological standpoints. The former includes time, velocity, acceleration, and jerk of the pen tip, and the latter are size, line smoothness, and shape variability of the written characters. We reported differences in these parameters between right- and left-hand use in right-handed normal subjects.[3,4] The present study compares those between the right and left in mild right hemiparetics and parametric changes before and after long-term writing practice with the non-dominant hand in severe right hemiplegics in order to show what characeterizes well-acquired writing.

SUBJECTS and METHODS

Nine patients with right hemiparesis due to lacunar stroke participated in experiment 1. All were right-handed. Their grip strength of the right hand was nearly one-half to one-fifth that of the left. They showed no sensory impairment. Using a pen-shaped device, participants wrote a Japanesesyllabary character on a digitizer tablet alternating right and left hands. Participants were instructed to write the character in squares of three different sizes (1x1, 5x5, 15x15 cm) as they normally would write it with aball-point pen.

Several parameters including the time (T), size (S), velocity (V), acceleration (A), jerk (J), shape variability (W), and size-related performance slope index (P) were calculatedfor each writing. T was the time period in which the pen tip touched the tablet. S was the mean distance of the drawn lines from the center of gravity of the written character. W was defined as the mean deviation of the difference in distance from the center between the written character and the corresponding average for each hand and size of the individual writing. P was defined as $\triangle \log S \,/\, (\triangle T^2 + (\triangle \log W)^2\,)^{1/2}$ which was based on Fitts' theory about aimed movemen.[5] It was considered to indicate changes in writing performance according to the writing size. All these parameters were compared between right- and left-hand use.

In experiment 2, two patients with severe right hemiplegia participated. They also were right handed. They had practiced writing with the left hand for3 to 6 months. The above parameters were followed up and their changes were analyzed.

RESULTS

<Experiment 1>

T and the averages of the absolute values of V, A, J, and W increased with writing size (S) for both right and left hand writings in thehemiparetics. The speed (V) became faster as the size (S) became larger. To indicate size-independent parametric fluctuation of V, A, and J, their standard deviations were divided by their averages. They were named V', A', and J', respectively. Parameters T, S, V, V', A', and J' did not differ between right- and left-hand use. Neither did the invariability or accuracy index (S/W).

P differed between the right- and left-hand writings. T andlogW were plotted against logS to analyze the difference in P. Linear relationship was found between these parameters in the right, but the relationship was non-linear in the left hand writing in thehemiparetics.

<Experiment 2>

V increased, W decreased, and S/W increased with writing practice in thehemiplegics, but V', A', and J' did not change even after the practice. P increased to be nearly equal to 1. In other words, the relation between T, logW, and logS became linear after the practice.

DISCUSSION

The handwriting pattern may be generated from a higher-level writing representation acting as a motor program, whereas motor noise derived at a lower level affects the actual output of the program. Motor noise may increase by hemiparesis or ataxia caused by disturbance of the output path even though the motor program is unchanged. On the other hand, the noise in writing done by the non-dominant hand may decrease after long-term practice[6] The present study focuses on this proposition

Writing speed became faster for both right- and left-hand use as character size became larger similarly to published data for the normal subjects[3,4] but the increase in speed was less than that in size. The kinematic parameters indicating speed, acceleration, jerk, and the magnitude of their fluctuation did not differ between right and left hand in contrast to those for the normal subjects[4]. The shape invariability of the written characters (S/W) also did not differ between the right and left in the patients. In other words, writing with the right hand was as poor, both kinematically and morphologically, as that of the left in the hemiparetics.

Fitts[5] introduced a speed-accuracy trade-off rule in which movement time increased proportional to the logarithm of the movement amplitude and was proportional to the logarithm of width of the movement target. This rule may be applicable to well-acquired right hand writing Linear relationship between T, logW, and logS was found for writing with right hand use in right hemiparetics and also with non-dominant hand use when enough writing practice was done with that hand. This finding was identical with that in normal subjects and was considered as a feature of well-acquired handwriting movement.

CONCLUSION

A morpho-kinematic analysis of handwriting was made forhemiparetic individuals to investigate differences between right and left hand use, between different sizes of handwriting Changes in performance by long-term writing practice with the non-dominant hand also were analyzed Neither speed nor variabilityof handwriting differed between right and left hand for the righthemiparetics. Linear relationships between time, logarithm of size, and logarithm ofvariabilty were found in right-hand writing and in well-practiced left-hand writing.

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O-82

An ergonomical study of adjustable beds in hospitals.

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INTRODUCTION

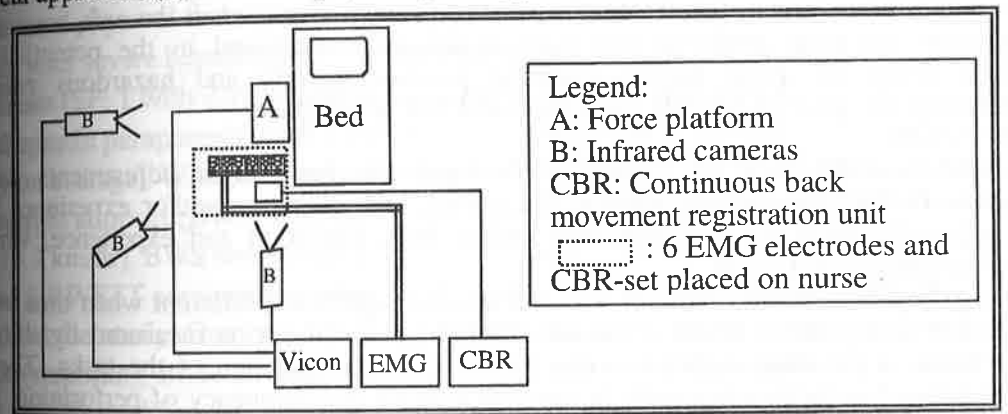
The nursing profession is generally considered as a high-risk profession for developing musculoskeletal disorders in general and low back problems more specifically. The use of more ergonomically designed equipment can be a part in a primary prevention strategy (Zinzen, 1998). The benefits of e.g. patient hoists, patient sliding and rolling boards etc. are already proven but are considered as not practical by the nurses since they demand a/o. more time.

The purpose of this study was to investigate the assumed ergonomical (mechanical, electrophysiological and kinematical) advantages of adjustable beds compared to standard (fixed) beds whilst performing different heavy nursing tasks as defined by Caboor *et al.*, 1997

METHODS

Eighteen nurses, 10 females (mean age 31.0±7.6 year, mean height 166.4±6.3 cm, mean body mass 61.9±5.3 kg) and 8 males (mean age 32.0±7.5 year, mean height 175.2±5.6 cm, mean body mass 75.8±7.1 kg) volunteered for the study. The above mentioned tasks were performed on a standard bed height (51.5 cm) and on a freely chosen height.

Three different research approaches were performed together in a simulated hospital room: (i) a mechanical approach, (ii) an electrophysiological approach and (iii) a kinematic approach.



Schematic view of the test set-up

(i) Mechanical approach: VICON® infrared camera's combined with a Kistler® force platform were used to calculate the joint reaction forces on the L5-S1 joint by means of an inverse dynamic analysis. Next, compressive and shear forces were estimated on the assumption that the L5-S1 moment was generated by a single extensor muscle acting 0.06 m posterior to the center of the disk (de Looze, 1994).

(ii) Electrophysiological approach: A standard electromyographical set-up was used on the M. Erector spinae, the M. Obliquus externus abdominis and the M. Biceps femoris (all on the left and right side). Surface electrode recording was carried out with bar-like active bipolar Ag/AgCl electrodes with a diameter of 15 mm for each electrode (with 8 mm diameter detection area) at an inter electrode distance of 10 mm. The detected electromyographical signal was amplified by an AD 524 amplifier (gain 10) with an input impedance of 10^9 Ω and a CMRR of 90 dB at the level of the electrodes, followed by a preamplifier (gain $50x10^{12}$ Ω, CMRR 85 dB). For digitalization (by a 12 bit Analogue to Digital converter) of the raw EMG signals, the ESPAS-APAS® system used a sampling frequency of 2 kHz to store the data in the computer before further analysis. This may be considered as a low-pass filter of 1 kHz. Signals were full wave rectified, smoothed by a time constant factor of 200 ms. The integrated EMG (IEMG) was considered for a quantitative approach of the signals. Normalization of the signals was performed by using the highest dynamic EMG peak per subject over all the tasks performed.

(iii) Kinematical approach: Spinal motion was continuous measured using an electrogoniometer (Snijders and van Riel, 1987). The recorded parameters of the spinal motion were the changes of

posture (inclination) and the changes of shape (sagital bending, side bending and axial rotation). The range of motion was divided in boundaries of 5° concerning inclination, 5 mm for the bending motions and 2° for axial rotation. The number of entrees and time spent in these boundaries were calculated.
Data used for all analysis were always mean values of at least three trials. Differences in all three approaches between bed-height conditions were determined by the use of appropriate statistics (student-t, ANOVA + post hoc) with $p<0.05$.

RESULTS

The range of bed height adjustments was 6.4 cm and depended on the specific tasks. A high intersubject variation was noticed, however independently of body parameters such as body height. All nurses agreed that the adjustable bed was easy to handle.
(i) Mechanical approach: Spinal compression and shear forces on the L5/S1 segment did not differ in the different bed height conditions. However when the factor time was taken into account and results of the different tasks were combined significant lower compression and shear forces were noticed in the adjusted bed height condition.
(ii) Electrophysiological approach: No differences could been noticed in the muscle intensity under the different bed height conditions.
(iii) Kinematical approach: Considering a variety of variables (torsion, inclination, side bending, maximum amplitude), the range of motion did not significantly change. Only a shift of the time duration histogram is noticed in the direction of the erect and safer position. The number of entrees within boundaries of movement were significantly increased in the safe zone of spinal motion (near the erect position) and were significantly decreased in the potentially health hazardous zones of spinal motion (extreme positions). Safe and hazardous zones were determined on the base of NIOSH guidelines and OWAS results.

DISCUSSION

Remarkable was the lack of correlation between the bed height adjustments and body parameters. Further questioning whether the nurses had education and/or experience in using height adjustable beds revealed that they lacked both education and experience, which may explain this unexpected result.
Except for the EMG results most of the data became significant different when time was taken into account. The positive effect of the adjustable beds could not be measured by the separate nursing tasks. A possible explanation can be found in the selection of the tasks. These tasks were determined as the heaviest tasks in terms of loading and frequency of performing, meaning that the average nurse is performing this rather heavy task quite a lot during a normal working day.
The lack of significant results related to muscular activity may be explained by the fact that the whole study was devised in different tasks with inevitable resting periods (changing test set-up). It may be suggested to measure EMG over a longer period of time to investigate the effects of muscle fatigue in the two bed height conditions.

CONCLUSION

Nursing personnel will benefit by the use of in height adjustable beds since they reduce over a period of time the compressive and shear forces on the L5/S1 segment and reduce the time spent in hazardous zones of the range of motion. It is hypothised that a proper education in the use of these beds will improve the ergonomical benefits.

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O-83

Effect of Body Weight Supported Treadmill Training on Severe Gait Disorders in Neurological Diseases

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INTRODUCTION

Recent studies have shown that body weight supported treadmill training (BWSTT) is effective in improving mobility outcome of patients with spinal cord injury [1-4], stroke [5-7], and moderately affected Parkinson's disease [8,9] (PD). We evaluated functional outcome of BWSTT in severe gait disorders due to various neurological diseases.

METHODS

Eight nonambulatory patients with various neurological diseases (3 males, 5 females, age 25-88 years, 63 ± 8 years, mean ± SEM) who showed no improvement after 1 month of conventional physical therapy (PT) were eligible for BWSTT. They included 3 stroke patients with severe hemiplegia (4 months post stroke on average), 2 patients with spastic paraparesis (SP; 1 with 2 year history of multiple sclerosis, and 1 with 5 year history of familial spastic paraparesis), and 3 patients with advanced PD (Hoehn/Yahr stage 4, 6 year history on average). Written informed consent was obtained from each patient. Degree of body weight support (BWS) was optimized for each patient to tolerate the lowest treadmill speed (0.3 km/hr). BWS was reduced by 10 % when they tolerate 3 km/hr. Each patient received 3 BWSTT sessions per week for 1 month. Medications were not modified throughout the study. Outcome measures included ambulation endurance (m), speed (m/sec), cadence (step/min), stride strength (m), and the Functional Independence Measure (FIM). In stroke and SP, modified Ashworth scale was used for evaluation of spasticity. In PD, Unified Parkinson's Disease Rating Scale (UPDRS) was also used.

RESULTS

After PT there was no improvement in walking endurance (before / after PT = 34 ± 15 / 37 ± 17, mean ± SEM), speed (0.25 ± 0.09 / 0.26 ± 0.10), cadence (66 ± 19 / 66 ± 19), stride length (0.16 ± 0.05 /0.16 ± 0.05), total FIM score (69 ± 12 / 69 ± 12), motor subscore of FIM (46 ± 8 / 46 ± 8), and cognition subscore of FIM (22 ± 4 / 23 ± 4). In the first session of BWSTT, no patient could tolerate the lowest treadmill speed without BWS. Initial BWS was started at -20 to -40 %. After BWSTT, all patients showed improvement in walking endurance (before / after BWSTT = 37 ± 17 / 56 ± 19), speed (0.26 ± 0.10 / 0.40 ± 0.11), cadence (66 ± 19 / 92 ± 13), stride length (0.16 ± 0.05 /0.24 ± 0.04), total FIM score (69 ± 12 / 77 ± 11), and motor subscore of FIM (47 ± 8 / 54 ± 8), but not in cognition subscore of FIM (22 ± 4 / 23 ± 4). Repeated measurements of analysis of variance (ANOVA) showed that there was a significant main effect for time ($p < 0.05$) and a significant interaction ($p < 0.05$) between time and type of therapy (BWSTT vs. PT) in walking endurance, speed, cadence, stride length, total FIM score, and motor subscore of FIM. There was no significant main effect for type of therapy in each measure. Patients with stroke and SP showed no change in spasticity either after PT or BWSTT. In three PD patients, total UPDRS before / after PT was 48 ± 7 / 48 ± 7 and total UPDRS before / after BWSTT was 48 ± 7 / 45 ± 8.

DISCUSSION

This study showed preliminary evidence for the efficacy of BWSTT in improving severe gait disorders regardless of type of disease and type of gait disorder. Of note BWSTT improved chronic gait disorders. Favorable outcome in BWSTT might be attributed to BWS but not to treadmill walking since all patients initially could not tolerate the lowest speed in treadmill walking without BWS. Long-term effect, optimal training program, and mechanism of functional improvement in BWSTT remain undetermined.

CONCLUSIONS

BWSTT compared to PT produced greater improvement in motor performance and ambulation in patients with severe gait disorders due to various neurological diseases.

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Electromyography Patterns of Cerebral Palsy Children in Gait

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INTRODUCTION

During normal gait, the influence of soft tissues other than muscles on joint moment generation is minimal. But in the pathological gait, the influence of soft tissues on joint moments may occur more frequently and more dramatically. This phenomenon can be detected by comparing the EMG and kinetic data.

Sutherland et al. (1993) classified the common gait abnormalities of the knee into four types. In his review, each abnormality was described by physical examination, motion parameters and electromyography (EMG) data. Among these, the EMG data was represented by on/off pattern and did not compare with the kinetic data. The purpose of this study is to identify and classify gait abnormalities of the knee in cerebral palsy (CP) and to compare their differences in EMG liner envelop (LE) among groups as well as kinetic data.

METHODOLOGY

Twenty-three children (mean age are 8.9 y/o) with cerebral palsy were recruited in this study. The Expert Vision™ motion analysis system (Motion Analysis Corp., Santa Rosa, CA) was used to collect marker trajectories. And MLS EMG system was used to collect the muscle-firing signal. Electrodes were placed on gluteus maximus, rectus femoris, biceps femoris, medial gastrocnemius and tibialis anterior. Five trials were sampled for each subject. The sampling rate was 60 HZ for cameras and 1000 HZ for EMG. EMG signal was processed through band-pass filtering, full-wave rectifying and low-pass filter to generate EMG LE. Also magnitude and time normalization is done. The largest value of the EMG signal was defined as 100% peak value. Individual ensemble average, average of three trials, presented the patient EMG data

Based on the kinematic patterns of the knee in sagittal plane, we separated the 46 limbs into four groups, mild knee (n = 17), crouch knee (n = 8), recurvatum knee (n = 14), and jump knee (n = 7). Average of the all patients in the same groups presented the group EMG data.

RESULTS

Tibialis anterior showed larger activation during single limb stance for crouch and jump groups and demonstrated greater firing in terminal swing for recurvatum group. All the abnormal knee groups, except the mild group, demonstrated excessive firing amplitude of gastrocnemius immediately after initial contact. In contrast, the mild group showed slowly increasing firing amplitude, which reached its peak in mid-stance, similar to normal subjects. There were no muscle activities in the swing phase until the terminal swing in four groups.

Except the recurvatum group, the other three groups had notable activities of rectus femoris immediately after initial contact. The crouch group had sustained greater firing in the stance phase, while the jump group had the least activity. The mild group started the firing activity from terminal stance, while the other three groups had delayed onset of firing in mid-swing. All the four groups had the firing activities of biceps femoris in the initial stance and terminal swing. The biceps femoris of the recurvatum group had less activity than the other three groups in the stance phase and an earlier onset of firing in the swing phase. The four groups showed activation of gluteus maximus in terminal swing. Except the recurvatum group, the other three groups reached their peak in initial contact. Jump group fired least during single limb stance. The other three groups had another peaks in initial stance. The activation of crouch group was most aggressive.

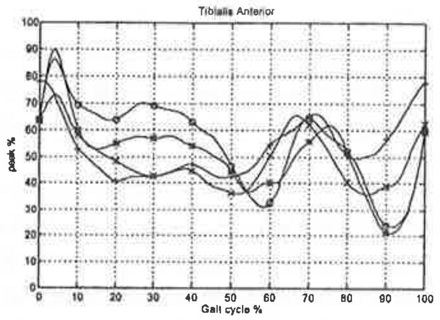

Fig. 1: Mean LE of Tibialis Anterior

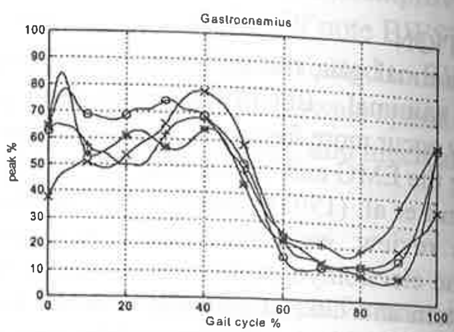

Fig. 2: Mean LE of Gastrocnemius

(o: Crouch, ×: Mild, *: Jump, + : Recurvatum)

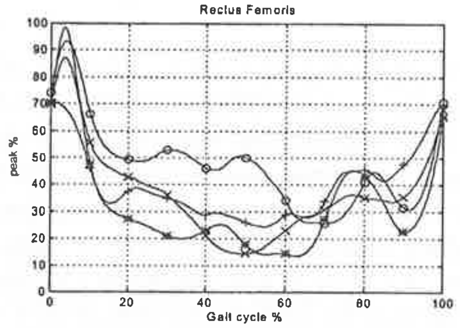

Fig. 3: Mean LE of Rectus Femoris

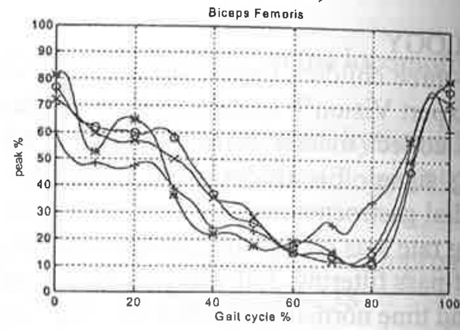

Fig. 4: Mean LE of Biceps of Femoris

(o: Crouch, ×: Mild, *: Jump, + : Recurvatum)

DISCUSSION

In normal situation, the rectus femoris activate for acceleration in terminal stance. Continuous activation will make the knee flexors and extensors co-contracted in mid-swing phase. Final result is knee stiffness and decreased knee motion in swing phase. Except the mild group, the other three groups have this phenomenon. The joint moment pattern is much agreeing with the EMG LE finding. For example, crouch gait demonstrated continuous gastrocnemius firing and the ankle plantarflexor moment is also premature and maintain plateau.

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Some characteristics of the knee muscles activity during ambulation of trans-tibial amputees.

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INTRODUCTION

A good prosthetic fitting accompanied with an excellent physical condition enable trans-tibial (TT) traumatic amputees to freely ambulate during the entire day. Nevertheless, analysis of gait in TT amputees showed conspicuous leg asymmetry, as measured with various gait parameters (1) and the amputated limb of TT amputees is less active in the functions of standing and walking. The reduced activity of the amputated thigh muscles was verified from thigh muscle circumference and strength measurements and from quadriceps muscle biopsy (2).

Gait of healthy subjects is characterized by a high degree of symmetry, especially for step length (ratio: 0.98), stance time (ratio: 0.96) and the double-limb support time (ratio: 0.90). Muscle activity during normal gait also shows that the triceps surei muscle are active from approximately 10 to 50% of the gait cycle (GC) while the tibialis anterior is active during entire swing and until 15% of GC following heel strike (HS). The vasti muscles, mainly active during loading response, begin their activity in terminal swing (90% GC) and cease by the 15% gait cycle point. These muscles reach peak activity at 5% GC. The three two-joint hamstrings muscle are active from mid to terminal swing (75% GC) and until early loading event, at 5% GC following HS. These muscles, mainly active during late swing, act eccentrically to decelerate the passively extending knee (3).

Only scant literature has investigated EMG activity in the lower limbs during locomotion of TT amputee's (4). The present study studied the activity of the muscles controlling the knee joint of the TT amputated leg. We chose to focus our attention on events that antecede and proceed HS, e.g., swing deceleration, initial contact and loading response, since these gait events are known to depend on and require normal muscle strength.

METHODS

Eleven males (mean age 37.4 ±8 years), with trans-tibial traumatic amputation, volunteered to participate in this study. The mean time lapse between the date of amputation to testing was 12.8 ±11.1 years. All prostheses were patellar-tendon-bearing (PTB) with a solid-ankle-cushion-heel (SACH) feet. All subjects were excellent walkers who used their prostheses on a regular basis and were leading an active normal life. Subjects were instructed to ambulate at their most comfortable speed along a 15 meters-long walkway. Time-distance parameters were calculated from foot switches and EMG of the quadriceps and hamstrings was monitored. Time of peak activity of these muscles was determined and expressed in % of GC (commencing from HS = 0% of GC). Since it was not possible to normalize the obtained integrated EMG (iEMG) values, calculated ratios of quadriceps and hamstrings iEMG were determined as follows: 1) Activity of each muscle during the 1st half of stance phase divided by its activity during the 2nd half of swing phase. 2) Activity of each muscle during the 2nd half of stance phase divided by its activity during the 1st half of swing phase.

RESULTS

Timing of muscle peak activity related to HS is given in part A of the Table. A significant difference (*$p<0.05$) was obtained between the hamstrings muscles since this muscle reached peak activity in the amputated leg only at 9.81% ±4.8 of GC (following HS). In parts B and C of the table ratios of quadriceps and hamstrings activities are detailed. Ratios between both leg hamstrings activity are significantly different, because in the amputated leg, during the 1st and 2nd parts of stance phase, this muscle is significantly more active. On the other hand, ratios of quadriceps muscle activity are similar in both legs.

	A) Peak activity (% GC)		B) Stance 1nd half / Swing 2nd half		C) Stance 2nd half / Swing 1nd half	
Muscle:	Amp. leg	Sound leg	Amp.	Sound	Amp.	Sound
Quad.'s	8.84 ±3.6	6.06 ±4.9	3.12	2.92	2.42	3.38
Hamst.'s	9.81 ±4.8*	(-)3.57 ±3.4	3.62*	0.96	6.65*	1.76

DISCCUSION

Full range of motion in all of the lower limb joints is essential for performing normal gait. In TT amputees, the rigid ankle-foot unit impedes the prosthesis user from fluent and normal gait. Kinematic parameters of TT amputee's gait have shown a significant difference between step length (1). A step taken with the sound leg is always shorter since the prosthesis rigid ankle-foot unit lacks, at the end of the 2nd half of stance phase, the necessary dorsi flexion. As a result, the amputee lowers the swinging sound leg earlier and the resulting step is shorter.

In this study it was found that the decelerating sound leg hamstrings, reach peak activity before HS. The deceleration in the amputated leg occurs as well at the end of swing phase but it reaches peak activity only following HS. As a result, the amputated leg hamstrings are almost four times more active during the 1st half of stance in compare with the 2nd half of swing phase. Such a high level of activity is also maintained in the 2nd half of stance, comparison with the 1st half of swing phase. Unlike the hamstrings, the quadriceps in both legs are similarly more active following HS.

CONCLUSION

Relying on the obtained EMG results, it may be that the hamstring muscles in the TT amputated leg are engaged to act as knee stabilizers. Co-contraction of these muscles with the quadriceps, especially during the 1st half of stance phase, compensates for the missing gastrocnemius and for the lack of motion in the rigid ankle-foot prosthetic component.

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0-86

Protas EJ, Cunha I, Henson H, Quresy H, Monga T, Lim PAC. Supported treadmill ambulation training for patients after an acute stroke. School of Physical Therapy, Texas Woman's Univ., and VAMC Rehab. Research & Development Center, Houston, TX

INTRODUCTION. The deleterious effects of strokes make the outcomes of gait training variable. Twenty-five percent (25%) of acute patients who survive 13 weeks after the event can not ambulate, and only 22% of those who had some degree of dependency in gait recovered a normal walking speed (Wade et al 1987). Therefore, the development of new interventions and the modification of existing interventions to improve gait training are necessary. Several reports have suggested that a new gait training strategy using supported treadmill ambulation training (STAT) improves gait with individuals who have walking deficits as a result of a chronic stroke. Few studies have tried this strategy for patients who have had an acute stroke. The purpose of this pilot study was to compare STAT with usual in-patient rehabilitation after an acute stroke. **METHODS. Subjects:** 13 patients (mean age 58.8 yrs, range 44 – 75) who were admitted to the Rehabilitation unit at the VAMC after a recent stroke (mean days since stroke of 16.1, range 8 - 47 days) volunteered to participate in the study. All subjects had significant gait impairments and required gait training. **Procedures.** Each patient was tested on admission to the unit and after approximately 2 to 3 weeks of inpatient rehabilitation. Patients were randomly assigned to either usual gait training (n = 7) or STAT (n = 6). All patients received other appropriate rehabilitation services. The patient's gait speed was tested by asking the patient to walk as fast as possible over a 5 meter walkway. The patient used appropriate assistive devices and was assisted by the physical therapist if necessary. Gait speed was calculated in meters/second by the time to walk 5 meters. Gait endurance was measured by asking the patient to walk back and forth over the walkway as far and fast as possible for a period of 5 minutes. The distance in meters was the gait endurance. The patient was fitted with a facemask attached to a portable gas analyzer (Aerosport KB1-C) prior to the 5-minute walk. The oxygen consumed was continuously recorded by the gas analyzer during the walk. Patients were allowed to stand or sit during the 5-minutes if fatigue occurred. The oxygen costs/meter walked was calculated by the total oxygen consumed in 5 minutes divided by the distance walked. For the STAT, the patient was fitted with a harness and assisted to stand on the treadmill. Body weight support of up to 40% body weight was applied, and the treadmill was started at a very slow speed for 20 minutes/day, 5 days/week. The patient was encouraged to walk with this support and the assistance of the therapist. **Data Analysis.** Since this is a small pilot study, descriptive individual data are presented as well as data for each group. A 2 X 2 design was used with the two factors being group (usual and STAT) and time (pre- and post-). The alpha level was set at 0.05. **RESULTS.** The usual care group by chance had greater gait deficits than the STAT group at baseline. Gait speed improved in both groups (0.12 pre- to 0.27 m/sec post- for the usual care group and 0.35 pre- to 0.57 m/sec post- for the STAT group.) Gait endurance increased for both groups from 17.7 m to 60.7 m for usual care and 81.0 m to 165.8 m for the STAT group. Oxygen costs/meter walked decreased for both groups from 5.15 ml/kg/5min/m to 1.75 ml/kg/5min/m for usual care and 0.86 ml/kg/5min/m to 0.41 ml/kg/5min/m for the STAT group. The gait speed was significantly different between groups ($p = 0.047$) and for time ($p = 0.009$). Gait endurance was also significantly different between the groups ($p = 0.036$) and for time ($p = 0.02$). Oxygen costs/m were not significantly different for group or time. **DISCUSSION.** This pilot study suggests that early gait training using STAT for patients with an acute stroke has merit for improving gait. No adverse reactions were observed from this new intervention. We intend to expand this pilot with a larger sample of patients in a randomized clinical trial.

CONCLUSION. STAT for acute stroke patients offers the opportunity to provide early, specific and effective gait training.

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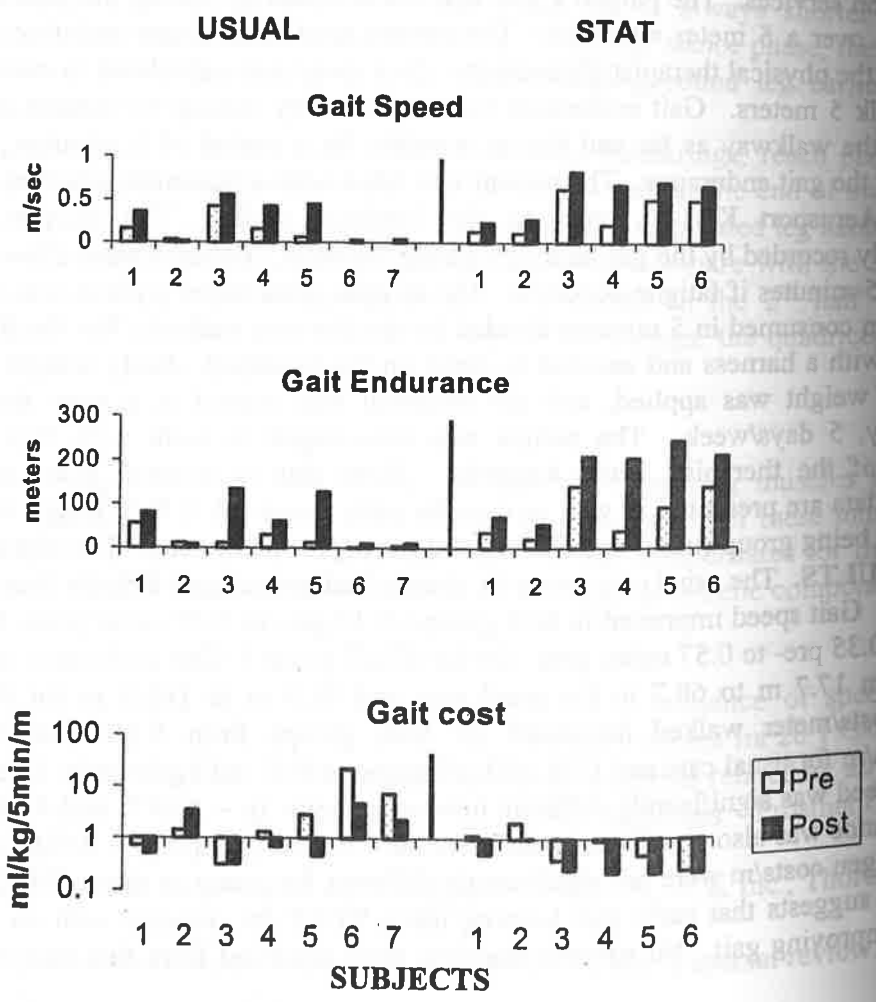

The Importance of Early Rehabilitation in Treatment of Labor Paralysis of Plexus Brachialis and its Role in Prevention of the Undesired Consequences

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INTRODUCTION

We have put the labour paralysis of plexus brachialis in a special group as to the importance of its early discovery and early treatment. It is necessary to diagnose and to start treatment as early as possible in order to reduce or alliviate consequences of the paralyzed upper extremity.

The etiologic moments are based on the existence of regional aplasia, interauterine malposition or delivery trauma Erb-Duchenne is the most frequent from, which appears as a complete one, while the isolated lower Klumpke type is met very rerely in practice. Depending on pathoanatomic substratus, if the neuropraxia, axothemisis, or neirothemisis are concerned, nerv lesion is clinically menifested as well as paralysis or paresis.

METHODS

In the period of the last 10 years we have examined and treated 304 children with paralysis of plexus brachialis caused during delivery. The age of these children ranged between 1 day and 14 years..

Passive position of the involved extremity is dominant in clinical pisture with abdusted and extended arm, pronated hand and forearm and absence of active movements, autstanding hypotonia and areflexion are evident, biceps reflexes, Moro, very often triceps are grasping depending on the lesion level. In diferential diagnosis the attention has to be paid to the possibility of epiphysiolisis existence, acute osteomielitys, obstetric clavicula and humerous fractures, as well as to fat necrosis with paralysis of plaxus brachialis.

The process of physiotherapy consisted of kinesy, electro and thermo therapy, with permanent positioning by Cramer splint till the appearance of active movements and after that it was improvised.

Until 3 weeks of age, physiotherapy consisted of the mild, dosed exercises in all of the three segments, then abducted splint for position correction. After this period of time, electrotherapy treatement was continued with Es ex potential current, bipolary to all the involved segments, with permanent passive exercises, lasting 15 minutes, for 4 to 5 times par day. Mother of such a child was trained, since the first day, to take part in kinesitherapeutic procedures. Intensive electro and kinesitherapy, and also thermoterapy is requered were performed till the appearanace of active movements, and as the child grow its activation was performed through play in different aspects of occupational therapy which was both of recreational and functional caracter.

RESULTS

The treatement results obtained by physiotherapy were better in the group of children in treatement immediately after the birth. The healing was reached in over 80% of the cases with good functional status in the rest of 20%. However, in the greater group which came for treatement at two or more months of age, this percent was about 60%, the improvement was reached in about 20%, and in 10% the results was unsatisgactory, for the children came after 1 or more years of age, with already formed permanent contractures.

DISCUSSION

The lasting of physical treatement depended of the lesion degree. In complete restitution, we have directed the preschool and ending of their grow, for the reason of regular development. In all others in which the smalles sequeles existed, intensive physical treatement with periodical intermission was performed till the ending of grow, including alternatively electro stimulation of paretic muscles, hydrokinesi procedures, thermo and kinesitherapy.

CONCLUSION

In treatement of such deformity in newborn infants all the authors give the priority to physical therapy with additional orthopedic treatement such as abduction splints.
Our opinion is that the treatement of such defect should start as soon as possible, i.e., soon after birth. This kind of treatement should be long lasting with a lot of patience and persistence. The aim of the treatement is to prevent the muscular atrophy, to stimulate neuromuscular apparatus and to prevent the muscular connective aontractures which cause heavy disability of the young patients.
Practically children inadequately treated remain invalids all their lives because such an arm will have complete function. Furthermore, from the aesthetic point of view, such an arm makes a negative impression on one's circles and society.
Therefore, we appeal and insist on early, adequate treatement since only such a treatement gives a quaranty for good results.

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The Study of Distribution and Types of the Muscle Spindles of the Mouse EDL Muscles

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Purpose

The muscle spindle is one of the important mechanoreceptors. After the invention of the electlon microscope, there have been many researches of muscle spindles in the view point of ultrastructure. However, there has been a few studies of it at the light microscopic level. This study tried to find out the distribution and type of the muscles spindle in the mouse extensor digitorum longus (EDL) muscles.

Materials and Methods

Twenty pieces of EDL from 10 ICR mice (30～４０g weight, 5 female and 5 male) were used in this study. Each EDL muscle was put on a silicon-coated laboratory dish, and dissected into four parts along each tendon with two pincettes under a stereomicroscope.

Results

There was no EDL which had the same numbers of muscle spindles in it. From seven to thirteen muscle spindles were found in each EDL. Four types of dispersion of muscle spindles were classified into four types.

The first type was the typical one which had a spindle-like shape covered with an oval capsule. The second type had similar length to the first one, but much more slender like a thin belt. The third was much shorter type than the first one. The forth had two equatorial resions in one spindle. In addition, several spindles were arranged to be overlapped each other.

Futher investigations must be necessary in the view points of differentiation and and development of the muscle spindle and the peripheral nerve.

P-302

Electroencephalographic characteristics of imipenem/cilastatin induced seizures

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INTRODUCTION

The purpose of present experiments was to characterize imipenem/cilastatin (Imi/Cil) evoked electroencephalographic (EEG) changes by continuous spectrum power analysis, and to correlate the EEG changes to specific convulsive behavior.

METHODS

Under intraperitoneal sodium thiopental anesthesia (40 mg/kg, i.p.) adult male Wistar albino rats were chronically implanted with electrodes over frontal, parietal and occipital cortices and cannulas were inserted into lateral ventricle. Groups of eight rats were injected intracerebroventricularly (i.c.v.) with Imi/Cil in doses of 10/10, 25/25, 50/50 and 100/100 µg. The electrocortical activity was recorded by means of an 8 channel EEG machine. Analog data were digitized at a sampling rate of 128/s and after analog to digital conversion the analog EEG data were stored on hard disk and power spectral analysis were provided by FFT (Fast Fourier Transformation). Behavioral seizures were scored according to the descriptive scale: 0 - normal behavior, 1 - twitching, 2 - forelimb clonus and head nodding, 3 - kangaroo posture and falling back, and 4 - jumping, clonic and tonic convulsions.

RESULTS

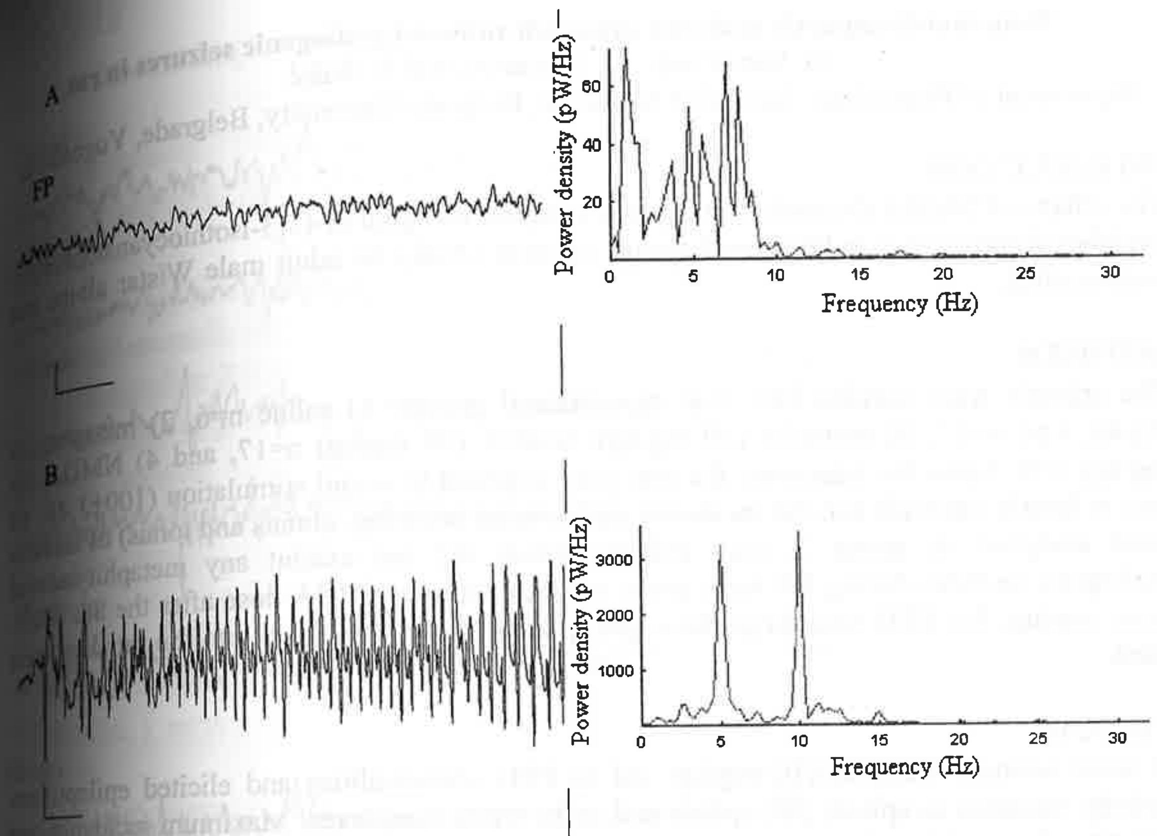
Imi/Cil induced seizures in a dose-dependent manner (Table 1). After the highest dose employed all animals displayed severe clonic-tonic convulsions and died 13±2 min after the injection.

Table 1. The incidence and severity of Imi/Cil-induced seizures in rats

Imi/Cil (µg)	n	Convulsive response 0	1	2	3	4	Grade	Lethality
10/10	8	5	1	2	0	0	0.6±0.9	0
25/25	8	1	0	1	3	3	2.8±1.3	2
50/50	8	2	0	0	0	6	3.0±1.8	6
100/100	8	0	0	0	0	8	4.0±0.0	8

Imi/Cil was administered i.c.v. in stated doses. n - number of animals in group.

The EEG signals before Imi/Cil administration in all animals were characterized by low spectral powers. Imi/Cil injection provoked paroxysmal discharges and increase in power spectra. Epileptiform activity induced by Imi/Cil characteristically corresponded to clinical manifestations. Twitching was associated with isolated spikes, while during head nodding short-lasting bursts of spikes were recorded in the EEG. Kangaroo posture was accompanied by high-voltage rhythmic spikes which lasted for 10-15 s. Clonic-tonic seizures were characterized by uninterrupted bursts with high amplitude and high frequency (5-7 Hz) spikes.



EEG records and corresponding power spectra. A - baseline, B - clonic-tonic seizures 4 min after Imi/Cil injection (100/100 µg). FP - fronto-parietal cortex. Time calibration 1 s, voltage 100 µV.

DISCUSSION

Imi/Cil administered both centrally and systemically produced convulsions in experimental animals. Despite the existing data, there have been few electrophysiological studies on the EEG correlates of the behavioral effects. The present results extend previously published reports of an convulsant action of imipenem/cilastatin and correlates respective EEG changes to seizure behavior.

CONCLUSION

Our data provide evidence that intracerebroventricular administration of Imi/Cil induced seizures in a dose-dependent fashion, and that each behavioral seizure response had a characteristic EEG correlate.

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P-303

N-methyl-D-aspartic acid and metaphit-induced audiogenic seizures in rat

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INTRODUCTION

The effects of NMDA (N-methyl-D-aspartic acid) on metaphit (1-(1(3-isothiocyanatophenyl)-cyclohexyl)piperidine)-induced audiogenic seizures (AGS) on adult male Wistar albino rats were studied.

METHODS

The animals were divided into four experimental groups: 1) saline n=6, 2) metaphit (10 mg/kg, i.p.) n=12, 3) metaphit (10 mg/kg)+NMDA (70 mg/kg) n=17, and 4) NMDA (70 mg/kg) n=6. Upon the treatment, the rats were exposed to sound stimulation (100±3 dB, 60 sec) at hourly intervals and the incidence and severity (running, clonus and tonus) of seizures were analyzed. In group 3, only animals which did not exhibit any metaphit-induced audiogenic seizures during 8 h were given a subconvlusive NMDA dose after the 8th audiogenic testing. For EEG recordings three gold-plated screws implanted into the rat skull were used.

RESULTS

In most animals metaphit (10 mg/kg) led to EEG abnormalities and elicited epileptiform activity recorded as spikes, polyspikes and spike-wave complexes. Maximum incidence and severity of metaphit-induced convulsions occured 8 h upon injection (9/12) to abate gradually after that and disappear 30 h later. NMDA (70 mg/kg) alone did not lead to a spontaneous and AGS-induced seizures during the observed postinjection period. As seen from continuous bipolar EEG recordings from the cortical leads before (0 min) and after (10-120 min) NMDA injection and sequential power spectra of the corresponding EEG activity (Fig. 1), NMDA led to a certain EEG abnormalities in most animals. NMDA potentiated metaphit-induced audiogenic seizures in 8 out of 17 rats which never displayed seizures in 8 previous testings.

DISCUSSION

Subconvulsive dose of NMDA increased general brain excitability as evidenced by epileptiform activity in the EEG. It is possible that in metaphit-treated animals which did not exhibit audiogenic seizures NMDA administration was additional stimulus for reaching the "threshold" for audiogenic seizures.

CONCLUSION

Subconvulsive dose of NMDA induced audiogenic seizures in metaphit-treated rats which never exhibited seizures in previous testings.

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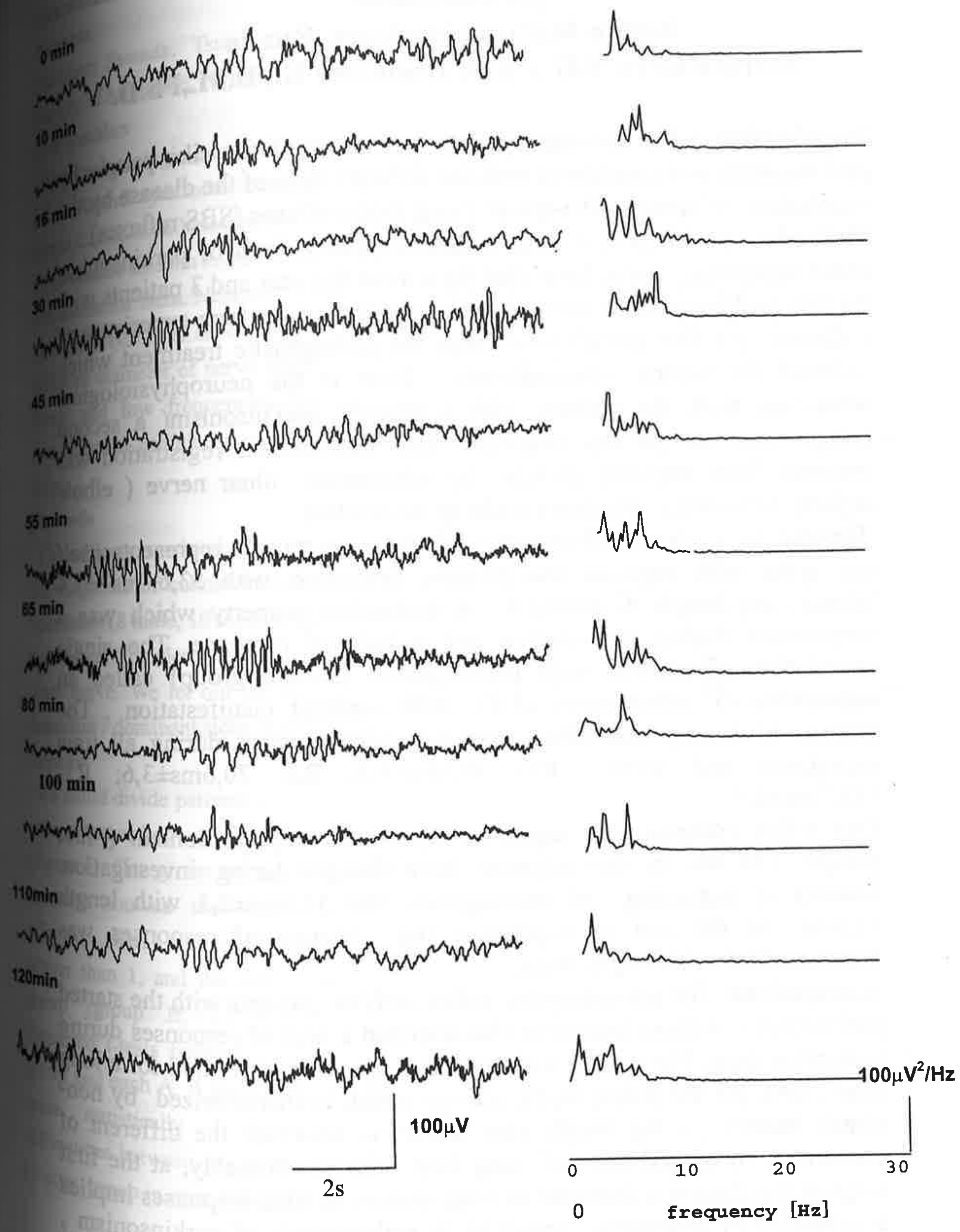

P-304

Neurophysiological estimate of sensomotor system of parkinsonism.

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Introduction : The moving systems pathology of the sikc people by parkinsonism was considered with the different time of the disease by the registration of spino-bulbo-spinal (long loop) reflexes (SBS reflexes).

Methods: 8 sick people with akinetico-rigidity form of parkinsonism under supervising , who have illed for a more the year and 3 patients with the first parkinsonism discovering. The patients with a long experience of a disease (a first group) were taken the pathogenetic treatment which included the central adrenomimetic. Prior to the neurophysiological researches start, the patients with a primary parkinsonism(a second group) were not got any treatment. The SBS-reflexes registration was response from trapesius muscle by stimulation ulnar nerve (elbow region). 60 healthy volunteers made up the control.

Results: In a norm SBS-response of trapesius muscle represents itself one spike with negative and positive deviations with 53,6 ms ±7,4 latency, the length 47,4ms±5,4 : a distinctive property which was a suppression during examination and a lack of response. The single stimulation of patients with parkinsonism (second group) called an appearance of spikes series (3-4) with constant manifestation . The indexes of latency this SBS-responses kept constant during all time experience and were R1- 30,6ms±4.3; R2- 70,6ms±3,6; R3- 183,5ms±4.4.

One reflex complex was registered by patients parkinsonism (first group) . The latency this response have changed during investigation. Latency in beginning of investigation was 51,0ms±2,1 with length 52,9ms. At the end of experience the latency of responses was 105,9ms±25,6 with length 40ms.

Conclusions: The polysynapthic reflex activity patients with the started parkinsonism without treatment characterized a host of responses during researches time. The people with parkinsonism who have illed for a long time , have got the polysynaptic activity which is characterized by non-steady latency , a big length what allows to conclude the different of conformity to natural laws of long loop reflexes. Probably, at the first stage of the disease a character of a big amount of SBS-responses implies a superactivity structures , involved in pathogenesis of parkinsonism , eventuality , additional irritation of sensomotor system of multi-level sunergies building.

P-305

Quantitative Sensory Evaluation by Neurometer® in Early Cubital Tunnel Syndrome Patients

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Introduction

Electrophysiologic examinations are useful for the entrapment neuropathy patients such as cubital tunnel syndrome, but it is often difficult to find out those patients in early stage by Nerve Conduction Velocity (NCV) and Electromyography (EMG). It is very important to find those disease as soon as possible, but there are few objective evaluation for them. Neurometer® Current Perception Threshold (CPT) is an electric machine which can stimulate different diameter of nerve fibers ; high frequencies for large fibers and low frequencies for small one (table 1). We demonstrated usefulness of this device for patients in cubital tunnel syndrome in its early stages.

Table 1 Sensory nerve fibers corrresponding to CPT's frequencies

2000Hz	Aβ
250Hz	Aδ
5Hz	C

Methods

The subjects consisted of 16 patients (14 male, 2 female, mean age 27.3 years; SD 27.3) with the diagnosis of cubital tunnel syndrome at the first medical examination, and 18 healthy volunteers (8 male, 10 female, mean age 22.7; SD 1.4) as a control group (Healthy group) was also tested. The electrodes were put on both side of DIP joint of little finger, and we examined ulnar nerve. We let out the ratio of affected sides / normal sides in patients, and of non-dominant / dominant sides in volunteers.

Results

We could divide patients into two groups according to the results (figure 1). One group (group A, 4 persons) showed the value on affected sides / normal sides higher than 1, and the other was group (group B, 12 people). Unpaired t-tests between Healthy group and each A, B group. There were statistically significant differences between group A and Healthy group in each 2000Hz and

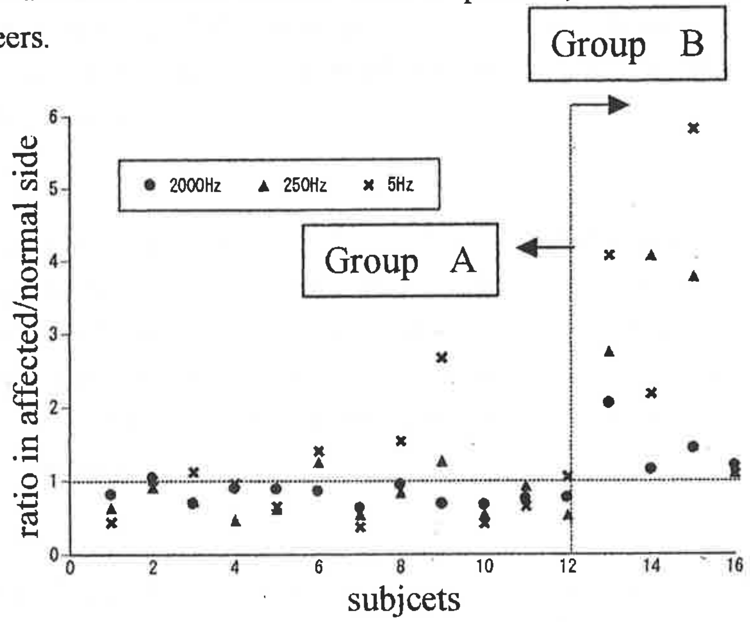

figure 1 Two groups dividing patients from ratio

250Hz ($p<0.01$). There were no statistically significant differences in 5Hz. There were not also statistically significant differences between B group and Healthy group in all stimulation.

Discussion

The fact that we could distinguish high threshold group A from low threshold group B suggested the clinical findings that it occurred hyperesthesia before hypesesthesia in entrapment neuropathy. The results that there were statistically significant differences in 2000Hz, 250Hz, and not 5Hz corresponded to previous study which nerve was gradually injured from big to small diameter. Owing to low patient numbers in group B, statistical analysis was not performed on this group. Most reports of CPT was about diabetes, and there are few reports about CPT in orthopedical surgery disease. CPT is objective evaluation, easy to examine , and it takes little time. Consequently CPT is useful evaluation for entrapment neuropathy in its early stages to screening of sensory.

Conclusion

Neurometer was useful screening evaluation for cubital tunnel syndrome in its early stages.

P-306

An experimental study of the double crush syndrome using sciatic nerves in rabbits

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INTRODUCTION

In 1973, Upton and McComas presented a hypothesis that a proximal source of nerve compression would render the distal nerve more susceptible to compression at another site. They called this hypothesis “double crush syndrome”. We made an experimental model of “double crush syndrome” using a sciatic nerve of the rabbit. The nerve conduction studies were carried out using this experimental model.

METHODS

Single Silastic tube (1cm in length and internal diameter of 2mm or 3mm), that was proposed by Mackinnon, applied to a sciatic nerve of the rabbit for the preliminary experiments. Furthermore, double tubes applied at the two different sites on the same nerve in this study. Bipolar electrodes for the electrical stimulation were placed on the nerve proximally and distally to the tubing site, and motor conduction velocity (MCV) was recorded every week after the operation.

RESULTS

In the experiments of compression with 2mm tube, diminution of the MCV was noted. In the compression with 3mm tube, MCV had no changes even after 20 weeks. However in the double banded cases (2mm tube at the proximal site and 3mm tube at the distal site, and 3mm/2mm tubes respectively), diminution in the MCV was noted in the every tubing sites. Even in the cases in which the electrical stimulation was applied at proximally to the 3mm tubing site, MCV diminution was also apparent.

DISCUSSION

Considering the mechanism of the double crush hypothesis, Upton has regarded changes in axoplasmic flow. In 1986, Loundborg proposed a “reversed double crush hypothesis” that a distal source of nerve compression would make the proximal nerve more susceptible to compression. He thought it would be caused by the disturbance of the retrograde axoplastic flow. Our results were considered to be the evidence of the hypothesis of the “double crush syndrome” and “reversed double crush hypothesis”

CONCLUSION

We made an experimental model for double crush syndrome using a sciatic nerve of the rabbit. We have confirmed that proximal source of chronic nerve compression make the distal nerve more susceptible to compression. We also confirmed that distal source of chronic nerve compression make the proximal nerve more susceptible to compression.

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P-307

Current perception thresholds in cerebrovascular disease

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INTRODUCTION

It has been reported that current perception threshold (CPT) is useful for detecting perceptional disturbance of neurological diseases such as diabetic neuropathy and carpal tunnel syndrome[1-8]. This time, we studied CPT in patients with cerebrovascular diseases (CVD) with sensory impairment.

METHODS

15 CVD patients with unilateral sensory impairment were studied. CPT testing was performed using Neurometer manufactured by Neutron Inc. The device emits graded sinusoidal alternative current stimulus at 5Hz, 250Hz, and 2000Hz. CPT test was done at hand (index finger) and foot (near external malleolus) on the impaired side and opposite side. The results of impaired side were compared to those of the opposite side.

RESULTS

The thresholds at 2000Hz and 250Hz frequencies at hand and foot were significantly increased in the impaired side, compared to the opposite side.

DISCUSSION

It has been reported that value of CPT at 2000Hz, 250Hz and 5Hz are associated with large myelinated fibers, small myelinated fibers and unmyelinated fibers, respectively. CPT may be increased by a lesion in the sensory pathway including the peripheral nervous system and the central nervous system. In the present study, the patients with polyneuropathy were excluded. Therefore, the increased CPT in the present study is considered to be due to a lesion in the sensory pathway in the central nervous system.

CONCLUSION

CPT test is useful for evaluating sensory impairment in patients with cerebravascular disease.

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P-308

The Relation Between Muscle Fiber Conduction Velocity and Muscle Strength in Patients with Lower Limb Disorders .

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Introduction

It has been known that muscle fiber conduction velocity(MFCV) reflects the condition of muscle fiber metabolism, and it has been used as a non-invasive tool for evaluating muscle activity. It may be a useful measure to assess the muscle activity in the field of physical therapy where we often encounter the muscle weakness due to various origin. Many reports of MFCV are seen from the study on neuromuscular diseases as peripheral nerve injuries or multiple myositis, etc. However, few reports are seen on the secondary muscle weakness like disuse from bed rest or lowered joint function due to skeletal abnormalities.

The purpose of this study is to study the relation of weakness secondary to the skeletal disorders and MFCV .

Methods

In this study, MFCV and knee extensor strength of 19 patients and 19 normal persons were measured. Patient group was composed of 6 males and 13 females(mean age:66.1± 16.0 years), and they had osteoarthritis of the knee in 4 cases, osteoarthritis of the hip in 4 cases, rheumatoid arthritis in 4 cases, and meniscus injury of the knee, fracture-dislocation of the hip and fracture of the leg in 1 case respectively. Normal control group was of 8 males and 11 females (mean age:33.9 ± 11.0 years).

Measurements of MFCV were done in sitting position where the hip and knee were in 90° flexion. Surface electrode array in which eight copper electrodes (10mm in diameter, 1 mm in thickness) were arranged on a plastic plate in a line with 5mm distances, was placed in direction of muscle fibers. EMG from vastus medialis muscle at 5cm above patella was recorded by Viking IV(Nicolet Inc.). Total seven EMGs were derived bipolarly from two electrodes adjacent each other. Distal portion of the vastus medialis muscle, at just above the patella was electrically stimulated with 0.5 msec square wave at 1 Hz. Evoked potential nearest to the stimulation was called as the 1st wave, then 2 to 7th in order. Stimulation in strength and place was chosen to have the negative peaks appear consecutively 1st to 7th , in certain delays each. Potentials were averaged 10 to 20 times. MFCV was calculated from the next: electrode distance (30mm)/conduction time from 1st to 7th .

Measurements of strength of the knee extensors were done in patients with lower limb disorders, at angular velocity of 60° /sec, using isokinetic exercise machine (Biodex, Biodex Inc.).

Results

MFCV of the patient group and the control were 2.88 ± 0.39 m/sec and 3.61 ± 0.23

m/sec respectively(Fig 1), indicating significant decrease in the former group (p<0.01).

Muscle strength of the patient group was 43.0 ± 37.5 Nm, ranging from extremely lowered to nearly normal. In patient group, it was demonstrated that the muscle strength was positively correlated to MFCV (r=0.62, p<0.01, Fig 2) and the decreased MFCV in patients with lower limb disorders thought to be attributed to decreased muscle strength due to disuse atrophy.

From this study, we can say that MFCV is useful to evaluate how the muscle is impaired by disuse, in the skeletal disorders.

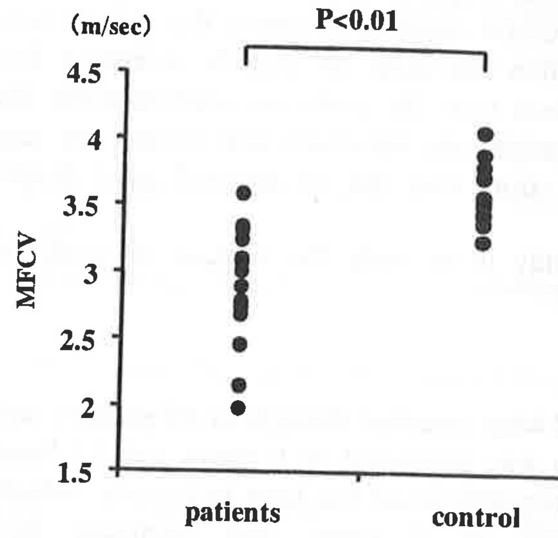

Fig 1 Comparisons of MFCV

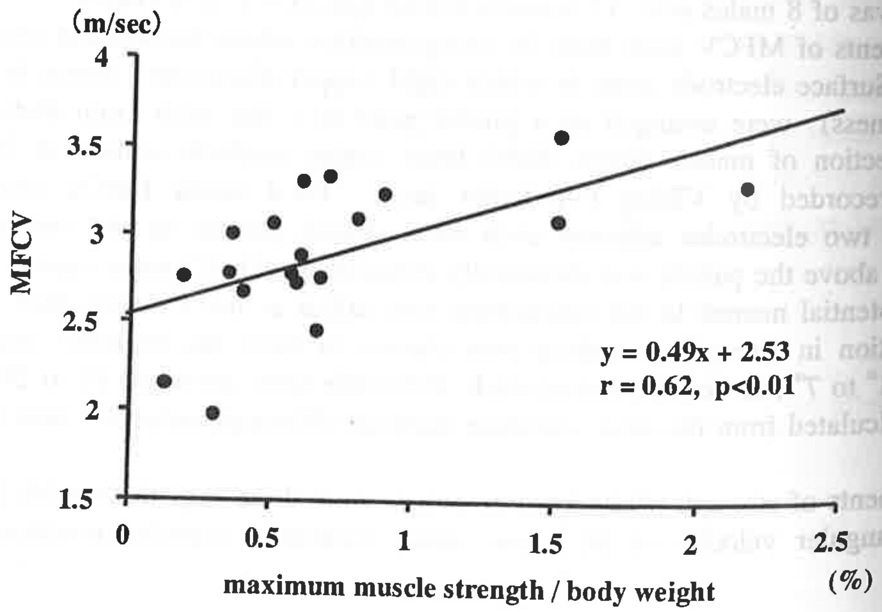

Fig 2 The relation between MFCV and maximum muscle strength / body weight in patients group.

P-309

Automatic evaluation of EEG coherence after traumatic brain injury

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INTRODUCTION

Electroencephalography (EEG) coherence provides a measure of functional correlation between two EEG signals. It is used to study connectivity between cortical regions. For correct EEG coherence estimation it is necessary to solve the problem of nonstationarities in EEG. In this work we present a solution based on neural networks used for data reduction, global segmentation and artefact recognition. Such approach enables fully automated evaluation of EEG coherence.

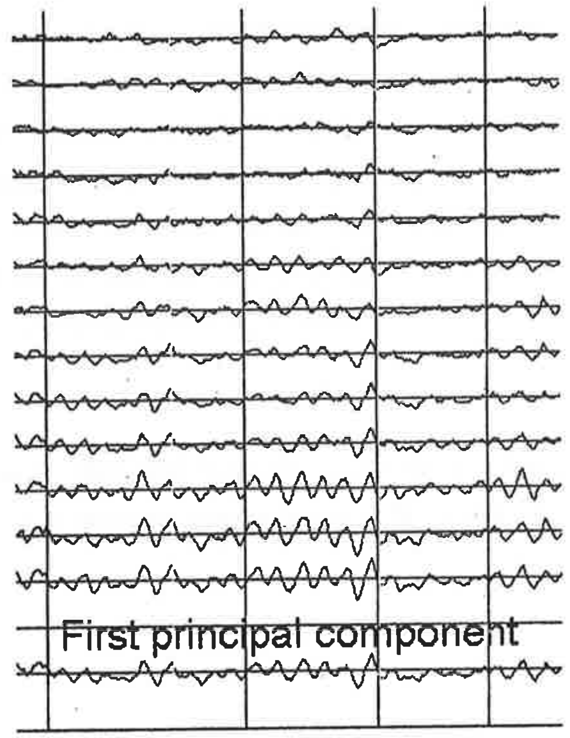
Widespread damage to axons in the white matter of the brain is a well-recognised consequence of non-missile head injury. This diffuse axonal injury is characterised by a gradual swelling of the axon associated with an accumulation of cellular organelles and proteins. Diffuse axonal injury is an important cause of morbidity and mortality after traumatic brain injury (TBI), and its severity is therefore a major determinant of outcome. There have been suggestions that the extent of DAI may be reflected in quantitative measures of cerebral function, including the electroencephalogram coherence, because reduced integrity of protein/lipid neural membranes after DAI may decrease the efficiency and effectiveness of short- and long-distance neural synchronisation following traumatic brain injury.

METHODS

EEG coherence was obtained from two independent groups of TBI patients. There were 9 patients with MRI proved DAI in the first group and 9 patients with mild degree of TBI without MRI changes characteristic for DAI in the second group. We compared first EEG recording obtained in the first 3 weeks after trauma with the second recorded up to the 3rd month after trauma. Coherence was estimated for all combinations of electrode pairs with electrodes selected according to the international 10-20 system for frequency 0-20 Hz. Measurement was fully automated and went through several steps:

1. Reduction dimensionality of 19-channel EEG with self-organised principal component analysis neural network
2. Adaptive segmentation based on 1st principal component
3. Pattern recognition with 2-layer perceptron and identification of artefacts
4. Coherence evaluation on segments recognised as not included artefacts
5. Averaging coherence for all 0.5 Hz frequency bands in the range 0-20 Hz and for all combinations of electrode pairs

Fig.1: 1st principal component segmentation



VARIMAX rotation and factor analysis was used to reduce data. The first four factors explained 91% variability of the data. Coherence of the first and second measurement was compared for first four factors for all electrode pairs with T-test.

RESULTS

The first factor covers conventional alpha and beta bands (8-20 Hz), only 12,5 and 13 Hz compose fourth factor. The second factor (0,5-5,0 Hz) approximates delta band and the rest of the theta band (5,5-7,5 Hz) constitutes third factor. In the whole group of TBI patients (18) rise in coherence was highly significant only for the first factor for electrode pairs P3-Pz and P4-Pz ($P < 0.01$). However, evaluation of the coherence for DAI patients indicate significant decrease for most of electrode pairs ($P<0.05$) for the first and the third factor and increase coherence for the second factor while in the second group the results are inverse.

DISCUSSION

Decrease coherence in the DAI group for the conventional band alpha, beta and upper part of theta band in the third month after trauma may reflect degeneration of the cortical pathways due to secondary or delayed axotomy. The opposite tendency in the group without MRI changes may be an evidence of recovery from cortical disconnection. Increase coherence for slow waves in DAI group may reflect ongoing deafferentation of the cerebral cortex. Fully automatic evaluation of coherence removes subjective factor in the segment selection and artefact recognition and gives fully reproducible results.

CONCLUSION

The finding that the coherence decreases in the DAI group and increases in the TBI group without MRI changes characteristic for DAI indicated different evolution of cortical connectivity after traumatic disconnection depending on the heaviness of trauma and probably also different prognosis. Automatic evaluation EEG coherence gives highly reproducible results making possible statistical study without subjective errors.

P-310

Sympathetic Responses to Letter Matching as a New Communication Channel for Persons with Severe Motor Disability

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INTRODUCTION

Individuals with severe motor disability can access various communication aids with the help of adaptive switching systems. Many of such switching systems, however, require some voluntary motor control of users. That is of disadvantage for persons with motor disability. Physiological signs related to emotional or cognitive process before movement execution, rather than motor output, may be more suitable for individuals with very limited motor function if such signs are detectable. In this study, we explored sympathetic responses to letter matching as possible cues of emotional responses to create a new switching method.

METHODS

Subjects were three healthy volunteers who gave informed consent for the study. The subject sat in an armchair facing a video display and placed his/her right hand on a mouse. Skin potential activity was obtained from left palm and sole with surface electrodes, and filtered with time constant of 0.3 s and high-cut of 1000 Hz. One of eyes of the subject was recorded on videotape to measure pupil size. The sympathetic responses were examined during three tasks that were presented in a screen of a personal computer. The tasks were as follows: a letter matching, a letter choosing with a row-column scanning, and a word completion. Each task consisted of 10 trials with different target letters. In the letter matching task, a target letter (a hiragana letter) was instructed at the beginning of each trial. The subject was asked to watch letters presented one by one in random order, and to press the mouse button when a letter matched the target letter. In the second task, the subject chose the instructed letter on row-column scanning (the scanning task). In the word completion task, a Japanese noun with a blanked letter was presented. The correct word was pronounced at the beginning of each trial. The subject was asked to press the mouse button when an appropriate letter was presented in a blank. The interval of letter presentation and the scanning time was 3 s. Additionally, the latency of sympathetic responses to sound stimuli was measured.

RESULTS

Figure 1A shows an example of skin potential activity recorded from the palm during the letter matching task. In figure 1B, traces of skin potential activity were aligned at the onset of letter presentation. The latency of skin potential wave from presentation of the target letter was equal to that of skin sympathetic response (SSR) evoked by sound stimuli. For presentation of non-target letters, waves occurred with variable latency, or did not occur. In 40-70% of trials in the one-letter task examined for 3 subjects, presentation of a target letter elicited a response in skin potential activity with latency comparable to the sound evoked SSR. On the other hand, 0-6.5% of non-target letters were followed by skin potential waves with latency equal to that of sound evoked SSR. In column selection of the scanning task and the word completion task, presentation of the target letter elicited SSR more frequently than non-target one. Occurrence and amplitude of SSR tended to decrease with time through the task.

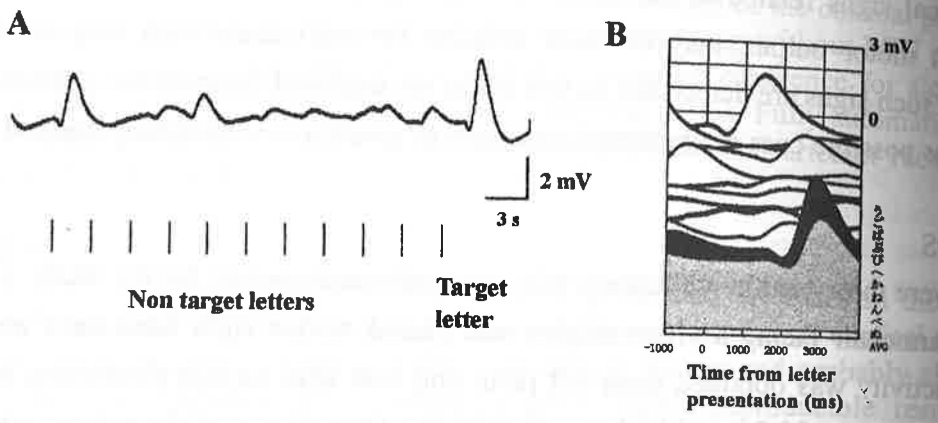

Figure 1. An example of SSR during a letter matching task. Vertical bars in A indicate presentation of letters. A target letter was presented at the last bar. In B, symoathetic skin potential in A was aligned at the onset of presentation of each letter. White: SSR after non target letter. Black: SSR after the target. Gray: averaged SSR evoked by sound stimuli.

DISCUSSION

The target letters elicited a response of skin potential activity with constant latency equal to that of sound evoked SSR. It is probable that the response is SSR evoked by presentation of the target letter. The response may reflect changes in the arousal level relating to cognition or movement execution process.

The advantage of SSR as an alternative switching aid is minimum requirement of recording technique, easiness of discrimination, and no need of training of users. There are some limitations to use SSR as a switch. In addition to cognitive ability, the sympathetic nervous system controlling mental sweating must be intact. The long latency (negative peak: 2.1 s, positive peak: 3.0 s) limits the speed of switching system. Habituation and somewhat low occurrence (40-70%) may bring problems in practical use.

P-311

Grading stretch reflex responses according to target positions during quick adjustment movements of human wrist

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[Introduction] Gains in stretch reflex response may be modified by anticipating a stimulus and by motor preparation for a given direction and type of movement. This is especially true for the change in the long latency (M2) component, believed to be a transcortical reflex, which are larger than for the short latency (M1) component, that is a spinal reflex. Furthermore, some studies have reported that the changes in the long latency component were more remarkable for subjects with short reaction times [1, 2, 3]. The results in these papers indicate that subjects who can react to a stimulus quickly are able to make a good motor preparation, suggesting, as a result, that it may be useful in initiating quick movements to change the long latency activity of the muscles involved in a movement through such preparation. Therefore, the stretch reflex activities of the muscles involved in the movements must be modified too in order to perform quick adjustment movements precisely, which are mainly based on open loop control. However, there is not experimental data concerning the question of whether it is possible to grad changes in the M2 component by motor preparation appropriate for a given target position during adjustment movements.

In this study, we investigated that influence of three target positions for the wrist joint during adjustment movements on stretch reflex modulations in the wrist flexor. In the adjustment movement task, human subjects were required to make quick adjustment movements to align the wrist position with a target position following a muscle stretch to the wrist flexor.

[Methods] Normal healthy subjects (16 males), ranging in age from 22 to 29 years (mean 23.2 years) participated in the study. A DC torque motor was used to apply (give) a stretch stimulus to the wrist flexor. A oscilloscope display, in front of the subjects, showed the handle position and a target position simultaneously. The motor tasks in this experiments were a non-action and three target-alignment movements to an identical stretch stimulus. The target positions were a neutral wrist position (neutral-target task), a position 30° to the extension side (extension-target task) and a position 30° to the flexion side (flexion-target task) of the neutral position. When the subjects felt a rapid angle displacement in the direction of wrist extension they were required to make an adjustment to align a handlebar with a target position as quickly and as accurately as possible in the three target-alignment tasks. In the non-action task, the subjects were required to refrain from making any voluntary movements to the stretch stimulus applied to the flexor. The measure of performance was an adjustment time, the time taken to align the handle with the target position from stretch onset in all the target-alignment tasks. The short and long latency responses (M1 and M2 components) were measured by averaging the rectified electromyogram(EMG)s recorded with surface electrodes over the wrist flexor. In order to compare the degree of change in reflex activity between subjects, the integrated EMG for reflex activities in each target-alignment task was expressed as a percentage of that in the non-action task.

[Result] The integrated EMGs, that is, the areas of the M1 and M2 components in the extension-target tasks showed the decrease of 7% - 40% and 20% - 60% compared to the same areas in the non-action task, respectively (see Fig 1). The areas of the M1 and M2 components showed a decrease of 2% - 30% and 3% - 40% in the neutral-target tasks, respectively. The area of the M2 component in the flexion-target tasks showed an increase of 10%-80%, but the change for the M1 components was not notable. For subjects who had short adjustment times, there was a clear tendency for the changes in the M2 components to be large in all the target-alignment tasks. However, a tendency for small changes was observed for subjects with long adjustment times.

[Discussion] The results of this study suggested that normal healthy subjects were able to grade the long latency response (M2 components) according to different target positions during adjustment movements. Moreover, there was individual differences in the degree of modulation for the M2 component, and a relationship was found between the degree of the (rational) modulation and adjustment times in all the target-alignment task. Based on these findings, we believe that good performances in adjustment movements may be due to the ability to grad (regulate or control) stretch reflex response with appropriate motor preparation.

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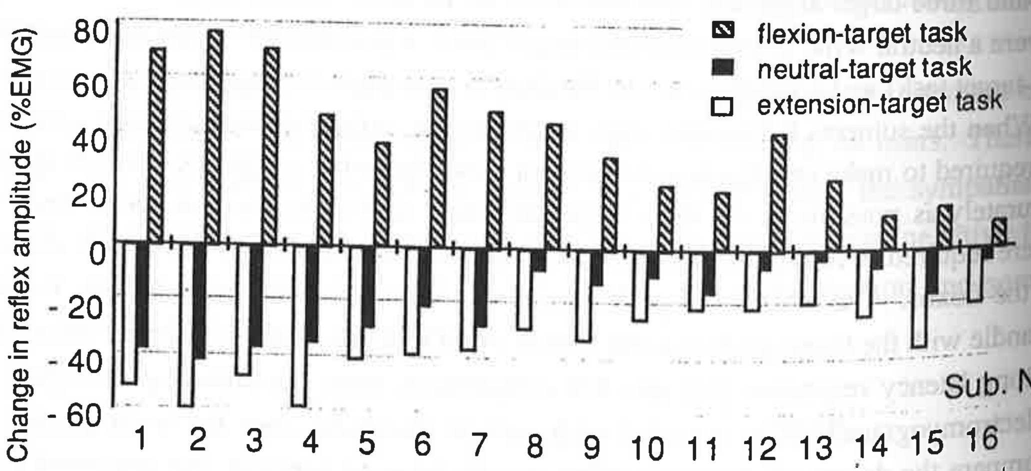

Fig. 1. Amplitude of the modulated M2 component for all subjects

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Fractal dimension of alpha-rhythm fluctuations and paroxysmal activity formation in case of epilepsy.

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RATIONALE

The electrical paroxysmal activity of a brain cortex as suddenly arising highamplitude potentials is closely related with epilepsy and the features of epileptic attacks. In some cases, for example in an initial stage of epilepsy, such expressed changes of an electroencephalogram (EEG) are revealed only during long monitoring. Yet the neurophysiological processes preceding paroxysms appearance have not been insufficiently investigated. Large interest and considerable importance represents the new criteria searching of EEG estimation [1,3], in particular for indication of the preparoxysmal stage, especially by the point of view forecast of the epileptic disease.

METHODS

The EEG recording was performed using the 19-channel digital encephalograph "Encephalan-131-01" (Taganrog, Russia) based on an IBM-compatible personal computer. A frequency of signals discretisation was 160 Hz. Electrodes were placed according to the international 10-20 system. The derivations F3, F4, C3, C4, P3, P4, O1, O2 were selected for analysis. Fractal dimension of alpha-rhythm power spectra fluctuations served as a quantitative characteristic of the results. Fractal dimension was measured for background EEG without a paroxysmal activity on the analysis epoch of 3 min.

RESULTS

Fractal dimension of alpha-rhythm fluctuations in the group of the neurology healthy subjects (n=20) was the lowest (fig.1). Fractal dimension was obtained to increase for the group of an initial stage of epilepsy without revealed paroxysmal activity (n=20) and for the group of the chronic epileptics having clear paroxysms (n=20) more else. It has been shown that normal distribution of fractal dimension on the cortex is characterized by the significant growth from O1, O2 toward F3, F4. A disturbance of this detected regularity, smoothing of the differences between occipital and frontal lobes are revealed on the preparoxysmal EEG stage and related with a high risk of paroxysms appearance in the case of epilepsy.

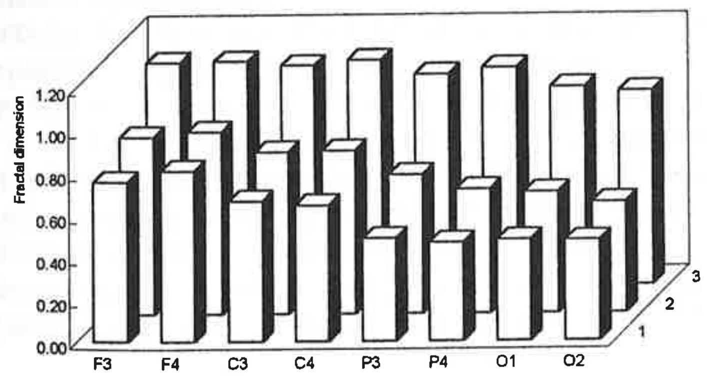

Fig.1. Fractal dimension of alpha-rhythm fluctuations.
1 – the healthy subjects, 2 – the epileptics without revealed paroxysms (initial stage of epilepsy), 3 – the epileptics with paroxysms.

DISCUSSION
The founded particularities of fractal dimension distribution on the brain cortex in the health subjects have coincided with the dates of the other authors [2]. The changes of the EEG chaotic component during paroxysmal activity formation were supposed to indicate on increasing disassociation of the central mechanisms of alpha-rhythm controlling. Probably, the obtained results reflect the changing work of alpha-rhythm pacemaker structures.
CONCLUSIONS
Thus, the preparoxysmal stage was found to consist in the growth of the EEG fractal chaos and smoothing of its interregional cortex differences. The estimation of an EEG structure by means of the fractal analysis allows to prognosticate the epileptic disease development to choose an adequate medicinal therapy as soon as possible.
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The characteristics of the women's EEG alpha rhythm in their state of pregnancy.

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RATIONALE
Pregnancy may be regarded as a specific state of illness to which the woman's organism must to adapt. Such adaptation success first of all depends on the health of pregnant woman and, also, on activity of the central nerves system (CNS), which assures the normal course of pregnancy. The abnormal deviations of the brain activity may reflect the problems in adaptation processes for pregnancy, and by this way be revealed at EEG activity. So in longitudinal EEG experience we can estimate such deviations and relate them to probability of premature pregnancy interruption.
METHODS
The investigation was carried out the 17 pregnant women aged from 21 to 36 years. They were investigated in each trimester, so, in general, three times during pregnancy. The active electrodes were located due to the system 10-20 on the left at F3, C3, P3, O1, T3 and on the right at F4, C4, P4, O2 and T4. EEG was registered by the computer encephalograph monopole with ears referents for the each hemisphere separately. The alpha rhythm spectra power was estimated
RESULTS
All subjects due their gynecological anamnesis were divided into four groups. The first, the normal, was the group, where nobody and never has threat of the premature pregnancy interruption (6 women). Their EEG characterized by high stability during all period of pregnancy, low spectral power of alpha rhythm without hyper synchronization, its parietal-occipital dominance on the right hemisphere and with marked frontal-occipital gradient.
The second group consists of the pregnant women with permanent threat of the premature pregnancy interruption (5). One part of this group characterized by the paroxysmal generalized alpha rhythm and the second - by the only rarely appeared flashes of alpha activity. Its frontal-occipital gradient was poor represented and it has dominance in the parietal-occipital regions on the left hemisphere.
In the third group were the women (4) that had threat of the premature pregnancy interruption only in the first trimester. In this period their EEG characterized with practically alpha rhythm absence. Its necessary to note that during the period of pregnancy alpha activity was markedly represents in the anterior regions of the brain.
And, at last, the forth group consists the pregnant women (2) which had threat of the premature pregnancy interruption only at third trimester. In these women alpha rhythm dominated in the anterior regions of the right hemisphere especially in the last trimester.
DISCUSSION
At least three factors influence on the EEG at the time of pregnancy. The first - everything connected with metabolic changes especially hypoxia and homeostasis disability. The second - toxic influence of the kidneys, liver and immune system dysfunction if it's present. And the third-everything what guides to uterus hypersthenia. In complex they consists whole pattern of EEG, characterized for the

pregnant women. The special dysfunction any organisms system, which can to guide to abortion also reflects in brain activity and relatively in EEG pattern (paroxysmal activity, alpha rhythm dominance in anterior regions and so on). In general it give the possibility to forecast the pregnancy dysfunction with high probability.

CONCLUSIONS

It was showed up that EEG in women with normal pregnancy is like to EEG in normal subjects without pregnancy. In the case of pregnancy dysfunction EEG is variable and its patterns depends on the disease character itself.

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PATHOLOGICAL TEMPORAL ALPHA-ACTIVITY OF HUMAN BRAIN

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INTRODUCTION

To study neurophysiological mechanisms of providing integral behavioral human activity and its disturbances we analysed patients with limbic structures involvement in the pathological process. These structures are responsible for the formation of behavioural reactions, memory mechanisms and emotions.

METHODS

We studies peculiarities of the EEG spatial-temporal organization alterations in 50 patients with tumors of mediobasal part of the temporal lobe, involving the hippocampus and adjacent structures. Topography of the local lesions was verified on the basis of CT data and surgery. We conducted spectral analysis with further topographic mapping of EEG power characteristics by the programme «Neurokartograf» (MBN, Russia). Spectral analysis date were considered together with the published data about the spatial and temporal organization of the EEG in healthy people and in patients with focal lesions of various brain structures reviewed in our monograph [1]. Brain electrical activity was analyzed at rest and under the influence of the afferent stimuli (visual and acoustic stimulation, opening of the eyes, flexion of the fingers). The EEGs were analyzed together with the results of complex clinical examination.

RESULTS

Performed clinico-EEG comparisons showed that formation of the pathological centre of stationary stimulation in limbic structures in the examinated patients was accompanied by the form of alpha-rhythm spacial organization disturbances in the cortex - its increase in the tumor projection zone (temporal region). Unlike in early above-described peculiarities of the alpha-rhythm spatial organization disturbances in diencephalic structures lesions, when the effect of generalization or transfering the alpha-activity focus into anterior portions was of a bilateral character [2,3], the hippocampus formation involving in the pathological process resulted in the unilateral type of alpha-rhythm topography changes. Most distinctly the effect of alpha-rhythm intensification in the affected hemisphere was revealed in afferent stimulation, under the activation conditions, thus reflecting unadequate character of the brain reaction to external stimuli.

DISCUSION

The marked functional features of the alpha-activity, increased in the affected hemisphere, and its localization characteristics, revealed in the topographic mapping, makes it possible to consider it as a reflection of hippocampus activation reaction. This reaction unlike in activation of the brain formation reticulation is revealed not in relaxation but in biopotentials synchronization increase [4]. Conventionally this form of activity reflecting formation not typical for healthy brain of the hippocampus-cortex relations, can be marked as «Hippocampal alpha-rhythm» of a human brain.

Spreading of this alpha-activity in the affected hemisphere and the character of its relations with the cortical alpha-rhythm in our observations were determined by the degree of tumor effect on hippocampus and reflected peculiar features of interrelations between thalamo-cortical mechanisms of alpha-rhythm generation and the work of nonspecific activating brain systems.

CONCLUSION

At clinico-EEG comparisons at patients with focal limbic lesions marked that the degree of spatial reorganization alpha-activity correlated with degree of psychoneurological disorders. Thus, specific features of the EEG spatial-temporal organization alterations can reflect the neurophysiological mechanisms of integral cerebral functions disturbances.

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Interhemispheric coherence asymmetry of EEG as a reflecton of specific functional states of the human consciousness

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INTRODUCTION

We have shown earlier [4] that brain electrical activity of senders /S/ displays certain spatio-temporal organization, which is manifested in the visually observed pattern of potential oscillations with a number of EEG phenomena, as well as in the structure of intercentral relations of EEG coherence characteristics with specific reorganization of t the latter during different kinds of autogenous activity (intentional change of brain functional change of brain functional state). We believe that studying the brain electrical processes of receivers /R/ is one of the other approaches to investigation of extrasensory activity.

METHODS

Bearing in mind the possibility to assess cerebral activity in terms of interhemispheric EEG coherence asymmetry (EEG Coh As) [1], in this work we studied hemispheric relations of cortical potentials in 12 R in different functional states, namely, in the background, during sender's actions («brain activation»), and during its aftereffect. Intra- and interhemispheric coherence of EEG recorded from the occipital, parietal, central and frontal areas of the left and right hemispheres were analysed (the mean level were calculated for entire frequency band as a whole and for separate diapasons of physiological rhythms). For correctness of experiments the double blind control was used. The data on EEG Coh of 25 S obtained by us earlier under similar experimental conditions were used for a comparison. These persons subjectively assessed themselves as extrasensors [4], whose autogenous activity was directed to R examined in the present work.

RESULTS

In the background state of relative rest the level of EEG Coh As in R was in the limits of normal values [1] with increased coherence in the dominant (left) hemisphere. The same relations were observed in the group of S as a whole, however, they were less expressed than in R; there were cases when EEG Coh As was reduced to zero, and sometimes its inversion was demonstrated with the dominance of coherent relations in subdominant (right) hemisphere. During sender's action («brain activation») in 78% of cases a distinct increase of EEG Coh mean level was observed in R in all the cortical areas (intrahemispheric connections), however, there was certain hemispheric specificity, i.e., this index was higher in the right hemisphere (by about 11% on the average) and lower in the left one (by up to 4%). Sometimes EEG Coh As was smoothed over to increase of Coh of potentials in the right hemisphere. The most expressed modifications of EEG Coh were revealed in R in the aftereffect of the action of S with appearance of EEG Coh As due to a sharp increase of Coh of electrical processes to the right (on the average by 25%) and recovery of EEG Coh indices in the left hemisphere almost up to the background values. On the contrary, in the S during autogenous activity under study decrease of EEG Coh level was shown in both hemispheres (somewhat more the right), left-side asymmetry of EEG Coh being mainly retained. In R as well as in the group of S the maximal modifications of EEG Coh As were manifested in the parietal and central cortical areas. Concerning frequency characteristics of EEG Coh As, in the group of S a sharp increase of EEG Coh was observed in the theta-band (with a peak value 7Hz), with the prevalence in the right hemisphere, and that in the beta-band with the prevalence in the left hemisphere. All these changes occured at the background of general decrease of EEG Coh level. In the group of R as a whole most expressed EEG Coh modifications were observed predominantly in the theta-frequency with the prevalence of the right-side lateralization of EEG Coh with less pronounced peaks of maximal manifestations, than in the group of S.

DISCUSSION

Thus, the maximal changes of EEG Coh during autogenous activity under study («brain activation») were observed both in the groups of R and S in parieto-central cortical areas (area of the cortical projection of diencephalic structures), with the prevalence of the right-side asymmetry in the theta-band. Basing on the clinical EEG-studies [1,2 et al.] with have demonstrated functional connections between diencephalic structures with the right hemisphere, the obtained results may testify to participation of diencephalic structures in this process [4]. However, the character of EEG Coh As was different in the groups of subjects. One can suppose that increase of EEG Coh in R during the action of S with the purpose of «activization of cerebral processes» and, in particular, during the aftereffect of this action, reflects increase of the cortex tone [5] under these conditions and testifies to a possibility of intentional change of receiver's brain functional state under extrasensory influences. At the same time, decrease of the mean level of EEG Coh in S during autogenous activity with its selective increase in the theta-band in the right hemisphere and in the beta-band in the left one, leads to a supposition that extrasensory activity may be performed with sharp irritation («self-stimulation») of the diencephalic structures [4] at the background of general cortical inhibition. One can judge about the latter from the decrease of the mean level of EEG Coh (with is a reflection of lowering cortex tone [5]) as well as from increased EEG Coh in the left hemisphere in the theta-band as one of the signs of a decrease of the level of wakefulness [1].

CONCLUSION

In this paper our earlier conclusions [4] have been developed, the possibility being realized not only to demonstrate objectively existence of extrasensory activity, but also to apply an adeguate methodological approach for revealing neurophysiological mechanisms of this special form of human cerebral activity which is prospective for further studies of this still misterious natural phenomenon.

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SIGNIFICANCE OF THE FRONTAL LOBES IN THE PROCESS OF MENTAL RECOVERY AFTER LONG-TERM POSTTRAUMATIC COMA

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INTRODUCTION

According the information about morpho-functional brain organization, accumulated to our days, brainstem structures and frontal lobes may be consider as the parts of the united activating system, which takes part in the ensuring of consciousness. Normal functioning of the brainstem structures creates its "foundation", that is to say necessary level of wakefulness (1); the frontal activation (mainly of the left hemishpere) accompanies proceeding of the conscious processes (2).

Analysis of the neurodynamic reconstructions in patiants with severe traumatic brain lesions (with drowing of the brainstem) during consciousness recovery after long-term coma makes it possible to refine the role of the frontal lobes and character of the brainstem-frontal interaction on the different stages of the adaptive-compensatory process.

METHODS

Spontaneous EEG analysis was carried out in 55 patients with severe traumatic brain injury and prolonged (10 days and more) coma for the period from several days up to 5-10 years after trauma. EEG was registrated from the symmetrical cortical areas with further processing by the spectral-coherence analysis programme. Findings of visual and coherent EEG analysis were compared with clinical data by rank statistical methods and analysis of tables of contingency. Patient's state was evaluated by stages of recovery and outcomes suggested by T.A.Dobrokhotova et al. (3).

RESULTS

The coherent EEG analysis revealed, that in the cases with positive mental dynamics (in contrast to the patients with persistent vegetative state) transition to both inter- and intrahemispheric frontal cortical relations predominance (F-F and C-F connections) was marked a step by step. This change is called "recovery of frontal control". According to our opinion, it is the necessary condition of the further consciousness restoration. On the definite recovery stages we revealed mainly one-sided intensification of the frontal functional activity. Thus, on the early unconcsiousness stages the rise in coherence of the left frontal-central-temporal area (mainly in delta, teta, rarely alfa1-bands) accompanies the formation of eyes-movement reactions and involuntery attention while outcome from the apallic syndrom. Appearance of the emotional reactions and broadening of motor activity in posttraumatic mutizm attended wiht the relative coherent rise in the frontal-temporal region of the right hemisphere (with the connections in alfa- and beta-bands too).

At the same time it was shown the important role of the front hemispheric regions in the vital outcomes of brain injury: among the deceased patients the observations with primary lesions of the frontal lobes and pathological EEG- signs in this regions are prevailing.

DISCUSSION

Represented data find the significant correspondence with the results of our preceding EEG-investigations in patients with acute focal brainstem lesion (after extraction of brainstem tumor) (4), as far as with the experimental investigations attached to associated brainstem and orbitofrontal electrolytic coagulation in rats (5). In the aggregate they show that frontal lobe activation has the adaptive value in the processes of visceral regulation under the brainstem lesion. Bringing up principles are corroborated by our data about positive changes of bioelectrical, psychical and motor activity in patients with posttraumatic vegetative state under the influence of therapeutical transcranial frontal lobes electrostimulation (6).

CONCLUSION

So, the frontal lobes take part not only in the formation of the realizing process, but also in the ensuring of the definite foundational, unrealizing functions. The front hemispheric regions may to appear as brainstem's "partner" or "functional counter-part" in conditions of stem's lesion.

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The Effects of Gravity on H-reflex in the Human Soleus Muscle During Parabolic Flight

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INTRODUCTION

The influence of position in normogravity on motor function mechanics, including H-reflex configuration, has been investigated extensively. Recent work has shown that the H-reflex excitability of the human soleus motoneurones is modulated in reduced gravity and accompanied by a corresponding change in electromyographic (EMG) activity during space flight mission or different gravitational load (Ruegg 1985). This paper reports the quantitative evaluation of the H-reflex exhibited by parabolic flight with exposure to micro and high-gravity. With respect to previous findings in parabolic flights and short-term space missions, the analysis focused on reflex activity of sensorimotor adaptation to weightlessness.

METHODS

The experiments were performed in four healthy male volunteers. Their ages ranged from 22 to 37 years (mean age 30.1, S.D. 6.4). All the subjects gave fully informed consent to the all procedures of this experiment, which were approved by the ethics committee in National Space development Agency of Japan (NASDA) and Japan Space Forum (JSF). The subjects were performed lying on the bed in aircraft. The EMG from the soleus muscle and the tibialis anterior muscles were displayed digital oscilloscope (HP5602B, Hewlett Packard). Test reflexes were evoked on land and each parabola environments. Surface electrode were used for stimulation and recording EMG signals. The soleus test reflex was evoked by electrical stimulation of the tibial nerve through a monopolar-stimulating electrode placed in the popliteal fossa. The anode was placed proximal to the patella. A ground electrode was placed between stimulating and recording electrode. Monitoring ensured that the same result was obtained when the peak-to-peak amplitude of the H reflex was measured and stored using a personal computer for later analysis. At the beginning of the each experiment, the size of the maximum motor response (Mmax) was measured and the size of the test reflex was expressed as a percentage of this. In most cases the electrical stimulation were given every 4 s in randomized alternating sequence of pules duration time 1 msec. A small M response was observed with H reflex recorded from the soleus muscle.

RESULTS

About Forty parabolas were acquired with four subjects in this study (see Fig.1.). The typical data of Gz during the hypergravity to microgravity transition period flight is presented in figure 2B. Figure2A shows the time course of the excitation of the normalized soleus H reflex at a parabolic flight. In a microgravity period, all subjects showed increasing of the soleus H reflex.

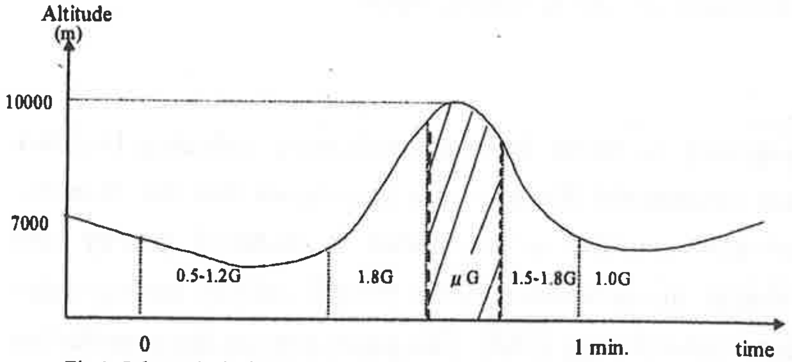

Fig.1. Schematic depicting different phases of parabolic flight profile, mild hypergravity(1.8Gz) = 20-25sec, microgravity(0Gz) = 20-25sec.

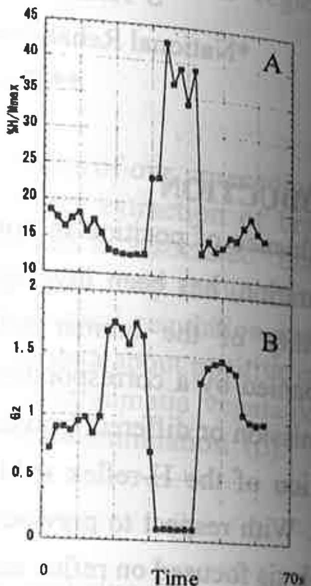

Fig.2. Tracing of typical pattern during a parabola. A: Normalized H reflex amplitude of Mmax value. B:Trajectory of aircraft Gz data.

DISCUSSION

Aircraft microgravity represents a unique environment, which allows the isolation of variables assumed to be involved in the mechanism of neural modulation in space. The amount of H reflex amplitude is increased during micrograviry. However, H-reflex was not considered precisely scaled to the gravitational effects under normal, micro-gravity and high-gravity conditions, because a few H-reflex responses changed in parallel with the background activity during the parabolic flight between hyper- and microgravity.

CONCLUSION

We stúdied effects of test H-reflex size on hyper- and microgravity in forearm muscles. In all subjects, the amount of spinal cord excitability increased as the test H-reflex size during micro-gravity. It is possible that soleus H-reflex in micro-gravity reported might be overestimated due to gravitational effects used in the parabolic flight than in the controls environment.

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Treatment of complex regional pain syndrome(CRPS) type I(a case report); combination therapy of ketamine continuous infusion and transcutaneous electrical nerve stimulation(TENS)

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INTRODUCTION

CRPS (complex regional pain syndrome) is characterized by overproportionately chronic intolerant pain following injuries or diseases, autonomic dysfunction and dystrophy. CRPS type I is that used to be called reflex sympathetic dystrophy (RDS), type II is causalgia and type III is that unclassified.

CRPS is treated with medications (non steroidal anti-inflammatory drugs, antidepressants, antiepileptics, $alpha_1$-blockers, $alpha_2$-agonists, muscle relaxants, adrenal cortical steroids, membrane stabilizers, capsaicin, etc.), regional anesthetic(local anesthetic, sympathetic block, epidural block), neurostimulation (peripheral or epidural), physical therapy (warm bath, contrast bath, etc.), or exercise therapy[1)]. There are some reports of analgesic effect of transcutaneous electrical nerve stimulation (TENS).

We had a case of CRPS type I of which we could alleviate the pain by combination therapy of ketamine continuous infusion and TENS. We also tried TENS therapy at home and appraised effectiveness and usefulness of it.

CASE PRESENTATION

The patient was a 23 years old man, whose chief complaint was a pain in the right foot. On July 25. 1996, he was contused in the lateral, dorsal part of his right foot. 4 days later, he had swelling and flare of his right leg below the lower femur and had a pain like burn injury. Instead of some therapies; drip infusion of antibiotics, intramuscular injection of elcatonin, intraarticular injection of lidocaine and agitated-water bath, he didn't have the pain alleviated enough. On July 1. 1998, he admitted to our hospital in order to control the pain and embrace exercise therapy.

When we examined him on admission, he had an irritable pain in the right foot from the ankle joint to the dorsum pedis. He had hyperalgesia around the ankle joint, dysesthesia on the sole without position sense disturbance of the ankle and toes joints. He walked with the right leg external rotated and could nether run nor walk for more than 30 minutes.

We found no abnormal finding by ankle joint radiography, nerve conduction study and bone scintigraphy. By thermography, we found chillness of his right foot. We diagnosed him as CRPS type I. We found that ketamine infusion alleviated the pain by drug challenge test; ketamine, lidocaine and phentolamine,

METHODS

We asked him to assess the pain by himself with visual analog scale (VAS). We applied ketamine continuous infusion (70mg/day) for 3 weeks and physical therapy (warm bath, contrast bath, ankle joint stretching and a bicycle ergometer). We also applied TENS (fig. 1) on the painful part; the frequency was 40Hz, the amplitude and the duration of sessions were controlled by the patient on his own.


fig.1. TENS; ENS 931, Enraf- Nonius

RESULT

Ketamine continuous infusion reduced the pain and he could embrace physical therapy more than before. TENS alleviated the pain approximately in one hour (20 to 50 % of before TENS) and its effect persisted for two or three hours after the sessions of stimulation(fig. 2). With these treatments for one month, we sufficiently controlled the pain and the patient improved in walking ability. He could discharge home with continuing ambulatory rehabilitation training and TENS therapy at home. We medicated diclofenac and amitriptyline. We asked the patient to continue to assess the effect of TENS at home and the result was similar to that of in hospital(fig. 3).

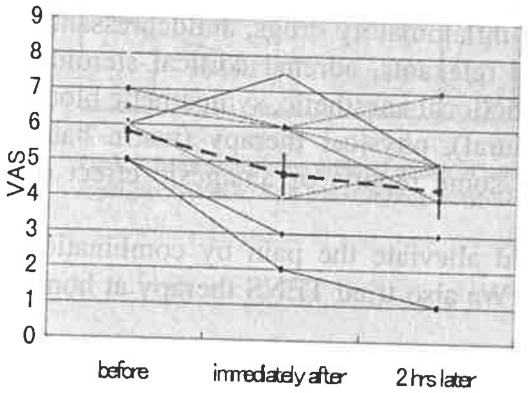

fig. 2. The effect of TENS in hospital. Each lines show the degree of the pain by VAS before, after and 2 hours later from each sessions of TENS. The broken line shows the average and standard error.

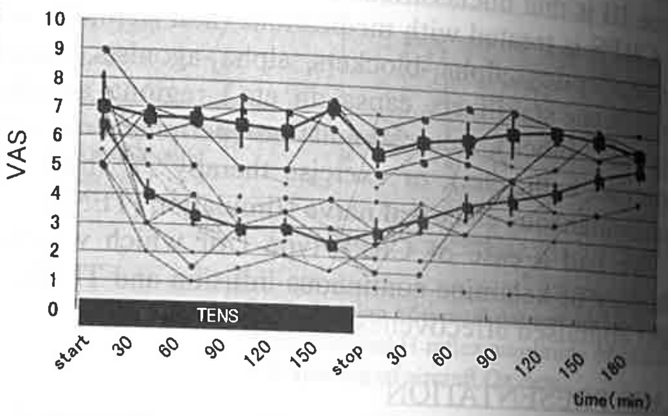

fig. 3. The effect of TENS at home. Each sessions of TENS were 2 hours from the same times of days. Light lines show course of the pain with TENS, dark lines without TENS. Thick lines show the average and standard error.

DISCUSSION

Ketamine is an antagonist of NMDA on A δ fiber and C fiber receptor in posterior horn of spinal cord and inhibits conduction of noxious stimulus. "Gate control theory", published by Melzack and Wall in 1965, explains the mechanism of the analgesic effect of TENS, but it doesn't cover the mechanism of the remaining effect after turning off the stimulation. The effect of TENS to central nervous system has been reported, but there is still much to be known.

We suppose, in this case, ketamine continuous infusion blocked plastic changes in the nervous system induced by chronic pain and TENS continued this relaxant state. Long-term use of TENS for chronic pain is reported to contribute to increase of activity, return to work, management of pain and decrease of medication[2]. We think TENS therapy at home is also effective for CRPS type I in the point that it reduces pain persistently and prevents dystrophy.

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P-319

Quantification of the Spasticity by Reflex Torque and Reciprocal Inhibition

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INTRODUCTION

Spasticity is one of the commonest sequels of central nervous system disease. It is characterized by a velocity-dependent increase in muscle tone due to abnormal stretch reflex. An ideal quantification tool is still not available so far. We use an on-line spasticity measurement system to quantify the stretch reflex torque by stretching the paretic elbow at a ram-and-hod mode of varied constant velocities vertically. Reciprocal inhibition on the same limb is also tested. The measured reflex torque and the changes in the reciprocal inhibition are used to quantify the spasticity in this study.

METHODS

Clinical assessment of spastic hypertonia was made by flexing and extending the upper limb before the objective studies. Spastic hypertonia was graded on an ordinal scale from 0 to 5 based on modified Ashworth scale (MAS).

The spasticity measurement system consists of three subsystems: mechanical structure, measurement, and control subsystem. Subjects were tested at supine position with face up while the elbow was positioned at approximately 110° elbow flexion and 90° shoulder abduction. Then, the upper limb was stretched toward the ground, i.e. in a vertical-stretching mode. The motor would extend the elbow for 75° at a constant angular velocity. According to the experience, 80 deg/sec was chosen as the stretch velocity. Nine tests with the stretch velocity in 80 deg/sec and four tests in 5 deg/sec, which were measured and averaged as the baseline torque, in a randomly chosen sequence were performed for each subject. The averaged difference between the measured torque at the speed of 80 deg/sec and the baseline torque in the dynamic range is called as averaged speed-dependent reflex torque (ASRT).

In the reciprocal inhibition study, disc electrodes are used to record the surface electromyogram (EMG) from the bellies of the flexor carpi radialis (FCR) and the extensor digitorum communis (EDC). The "test stimuli" were delivered to the median nerve at the antecubital fossa and their intensity was adjusted to be approximated 70 % of the maximal H-reflex from the FCR. The "condition stimuli" were delivered to the radial nerve at the spiral groove and their intensity was set to be 90 % of motor thresholds. Time intervals between test and conditioning stimulus were -1, -0.5, 0, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 70, 100, 200, 300, and 500 ms. The averaged peak-to-peak amplitude of conditioned H-reflex was expressed as a percentage of the averaged peak-to-peak amplitude of test H-reflex for each delay.

RESULTS

In normal subjects, the torque measured in the high velocity (80 deg/sec) is closed to, but not overlapped with, the baseline, which is measured in the velocity of 5 deg/sec. In patient groups, the curves of measured torque are different in patients with distinct severity of spasticity. The changes of torque are more significant in patients with higher score graded on modified Ashworth scale (MAS). The Spearman's rank correlation coefficient was used to analyze the correlation between the clinical assessment and the measured ASRT. It showed significant linear relationship between the ranks of the two variables. ($r=0.815$, $p<0.005$) The result of reciprocal inhibition test discloses significant change between patients with spasticity and normal controls in the third inhibitory phase. The inhibition of the third inhibitory phase is diminished in patients with spasticity, as compared with the control groups. The changes in the first and the second inhibitory phases are not significant.

DISCUSSION

In our study, the value of ASRT is greater in patients having more marked spasticity. The Spearman's rank correlation coefficient also shows significant linear correlation between the ASRT and the clinical scale. On the other hand, the value of ASRT measured in control groups is small and the curve closes to but not equals to the baseline, suggesting that the muscle tone caused by the stretch reflex is indeed presented in normal subjects. The only difference between normal subjects and spastic patients is the abnormal increase of stretch reflex in patients with spastic hypertonia. The increased amount is proportional to the severity of the spasticity. The physiology of the third inhibitory phase of reciprocal inhibition is not well known, it is believed to be mediated by the polysynaptic long latency stretch reflex pathway. The changes of the third inhibitory phase in patients with spasticity is significant in this study. That may prove the relationship between the third inhibitory phase and the stretch reflex. However, the amount of the change is unpredictable and not related to the severity of the spasticity.

CONCLUSION

We may conclude that the normalized relative torque deviation, ASRT, is a useful tool to quantify the spasticity. On the other hand, the results show that the third inhibitory phase of the reciprocal inhibition is affected by the spasticity, thought it is not suitable for quantifying the spasticity.

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P-320

Influence of Bimanual Coordination on Activation in the Sensorimotor Cortex and Supplementary Motor Area: Analysis Using Functional Magnetic Resonance Imaging

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INTRODUCTION

Functional magnetic resonance imaging (fMRI) provides information on functional activation of the brain during motor and cognitive tasks. The physiological roles of the sensorimotor cortex (SMC) and supplementary motor area (SMA) during various unimanual motions have been investigated in a number of studies.

However, the activations of the SMA and SMC during bimanual motions have not been fully investigated by PET or fMRI studies. Some studies have suggested that one of the functions of the SMA is related to bimanual coordination. In the present study we investigated the activations of the SMA and SMC during bimanual antagonistic, alternating motions using fMRI. The data were compared with those of bimanual, agonistic, and unimanual motions.

METHODS

We studied 21 healthy right-handed volunteers. Fifteen of them, aged 22 to 39 (mean 26) years, participated in experiment 1, and the other six, aged 24 to 35 (mean 28) years, participated in experiment 2.

In experiment 1 the subjects performed 3 (1 unimanual and 2 bimanual) motor tasks requiring the repetitive closing and opening of one or both fists: unimanual movement of the non-preferred (left) hand (task A); simultaneous agonistic movement of both hands (task B); simultaneous antagonistic movement of both hands (task C). In task B, the subjects simultaneously made fists with both hands and then simultaneously opened them, whereas in task C they made a fist with one hand while simultaneously opening the contralateral fist, and then the reverse. The only difference between task B and task C was the timing of the closing and opening of the contralateral fists. In experiment 2 the subjects performed only bimanual motions (tasks A and B).

Each task consisted of alternating periods of 20 seconds of rest (resting period) and 20 seconds of motor execution (activation period). A task included eight (experiment 1) or six (experiment 2) repetitions of a rest-activation cycle.

The functional image data (three axial slices in experiment 1 and bilateral sagital slices in experiment 2) were obtained by gradient-echo and echo-planar sequences. Cross-correlation with time domain was used to detect activated pixels. We counted the total number of activated pixels (correlation coefficients of 0.6 or greater) located in the SMC and SMA. Experiment 2 was conducted to clarify the part of the SMA (pre-SMA or SMA proper) in which the activated pixels were located.

RESULTS

Experiment 1

The SMC activation during task C was significantly larger than that during task B, whereas hemispheric differences in the activation were not found. The SMA activation during task C was more pronounced than that during the other two tasks.

Experiment 2

The activated pixels during tasks B and C were found in the SMA proper. These activations did not extend to the pre-SMA area.

DISCUSSION

The results suggested that, at least during the simple motion used in the present study, the activation of the SMA was little influenced by whether the motion was unimanual or bimanual, but how the bimanual motion was composed of the motion element of a single hand. Some studies using functional imaging confirmed the functionally different roles of the pre-SMA and SMA proper during a hand motion[1,2]. In the present study there was no activation in the pre-SMA area even during task C. This suggested a more important role of the SMA proper in the alternating bimanual movement.

Shibasaki et al.[3] investigated the dependency of the SMC activation on the movement complexity. They pointed out that the activities in both the SMC and SMA may depend on the task complexity of a unilateral hand movement, and that the SMC may have a role in the execution of complex sequential movements. For the same reason, the greater SMC activation in task C was believed to be related to its role in the control of bimanually antagonistic coordination. Therefore, our result suggested that Shibasaki et al.'s opinion on unimanual motions might also be applicable to the complexity of bimanual movement.

CONCLUSION

The SMC and SMA activation during hand motion were modified by the complexity of the bimanual task.

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P-321

Muscle weakness in Parkinson's disease: A follow-up study

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INTRODUCTION

We previously have reported that patients with Parkinson's disease who demonstrated marked asymmetry of motor symptom severity also showed less isokinetic muscle strength on the more affected side than on the less affected side, especially for movements at relatively rapid velocity 1). The findings suggested that muscle weakness in these patients might depend on movement velocity 1,2) and led us to suspect that velocity-dependent weakness is an inherent feature of the disease reflecting dysfunction of central mechanisms that normally ensure adequate muscle strength at rapid movement velocities 1,3). In the present study, we considered how changes in isokinetic muscle strength were influenced by antiparkinsonian drugs,disease progression, aging, and other factors.

METHODS

From 23 patients with Parkinson's disease with marked laterality in symptom severity whom we have described in a previous report 1), we chose 10 who could repeat the same isokinetic strength testing later. The 10 patients were assigned to one of two groups according to clinical condition at the time of first measurement and subsequently. The 5 patients placed in group A were untreated or in poor condition at the time of the first measurement, and had improved due to the effect of treatment at the time of the second measurement. The 5 patients assigned to group B were in good clinical condition due to the effect of treatment at the time of the first measurement, but had worsened by the time of the second assessment. The equipment employed in this study was a CYBEX II+ isokinetic dynamometer. The subjects were asked to extend and then flex their knees five times as quickly and powerfully as possible between 90 and 0 degrees. The velocity of the movement was set at two different target speeds, 5 and 15 revolutions per minute (rpm). The subjects performed the same trial on each side at each target speed. Maximum peak torque values for both extension and flexion were measured as the largest value of the torque peaks within five trials 1,3). Values obtained were compared between the earlier and present sessions.

RESULTS

Group A showed no significant differences in maximum peak torque at 5 rpm between initial and subsequent measurements either for the more or less affected side. At 15 rpm, while the maximum peak torque for the less affected side showed no significant differences between the initial and subsequent measurements for either extension or flexion, the more affected side produced significantly greater torque in the follow-up measurement than the initial one for both extension and flexion ($p < 0.01$ for extension, $p < 0.05$ for flexion). In group B, at 5 rpm, while the maximum peak torque for the less affected side showed no significant differences between the earlier and later measurements for either extension or flexion, the more affected side produced significantly less torque in the later measurement than in the first for both extension and flexion ($p < 0.05$ for extension, $p < 0.001$ for flexion). At 15 rpm, while the maximum peak torque for the less affected side showed no significant differences between the first and second measurements of flexion, torque was significantly less in the second measurement than the first for extension on the less affected side and both extension and flexion on the more affected side ($p < 0.05$ for extension on the less affected side, $p < 0.05$ for extension and $p < 0.01$ for flexion on the more affected side).

DISCUSSION AND CONCLUSION

The results in the clinically improved group A were dependent on velocity, showing significant increases in torque on the more affected side between measurement sessions only at the faster of two rates (15 rpm). Greater torque on the second occasion was consistent with a response to medical treatment such as drug therapy. These results support our hypothesis that muscle weakness in Parkinson's disease is likely to depend on movement velocity[1-3]. In the clinically worsened group B, decreased isokinetic muscle strength at both 5 and 15 rpm on the more affected side seems to be related not only to diminishing drug effect but also to the additional factors such as aging, disease progression, disuse, and patient volition. In our previous reports [1,3] we concluded that our data could not be a simple consequence of bradykinesia or of peripheral factors such as disuse syndrome. However, the influence of rigidity or akinesia on muscle strength it is difficult to completely exclude. Hallett et al. [4] demonstrated that bradykinesia resulted from inability to energize the appropriate muscles to generate force at a sufficient rate. Accordingly, although isokinetic muscle strength is likely to depend on movement velocity in the early stages of Parkinson's disease, it could be influenced by various motor symptoms such as muscle strength, rigidity, and akinesia, as the disease progresses, not merely simple muscle strength.

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Development of an Exercise-Therapy Evaluation System for the Elderly

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INTRODUCTION

The elderly population is increasing in Japan. Physical ability declines if an elderly person does not take a certain amount of exercise. Therefore, maintenance of health (as well as care and rehabilitation) is a significant problem. The effect of exercise is not only to improve physical ability, such as muscle power, agility and endurance, but also is used as restoration training of lost function during exercise therapy. Exercise at less than the anaerobic threshold (AT)[1)] is recommended for exercise therapy in the elderly. The AT can be evaluated by exercise testing using a bicycle ergometer. To keep a constant workload, the bicycle ergometer is controlled so that torque rises when the rotational frequency of the pedal decreases. However, it is difficult for elderly people with declined physical ability to maintain the workload. To develop a safe, efficient and long-term system for evaluating exercise therapy for the elderly, we have developed a new exercise test using surface electromyogram (EMG).

METHODS

Eight young subjects (27±5 years) and five elderly subjects (73±10 years) participated in the experiment. Written informed consent was obtained after a description of the protocol, which was approved by Chubu National Hospital Ethics Committee. Experimental data were obtained during exercise on the bicycle ergometer (Examiner 400, Lode). All subjects performed three minutes of warm-up activities at 0 W before the experiment. In the experiment, subjects pedaled the bicycle ergometer at 60 rpm. The slope of ramp exercise was 20 $W \cdot min^{-1}$, and the workload increments were continued until the subject could no longer maintain a pedaling frequency of 60 rpm. Energy consumption was measured by breath-by-breath method using a cardiopulmonary exercise system (Vmax29, Sensor Medics). Heart rate (HR) was simultaneously recorded by electrocardiograph. Surface electrodes were used to measure the EMG from the rectus femoris muscle on the right side of the body. The EMG signal was amplified and recorded in a PCMCIA card recorder (DR-C2, TEAC). A trigger signal from a magnetic sensor fixed on one pedal of the ergometer indicated the onset of leg extension and that of rectus femoris muscle contraction. Root-mean-square of EMG (rmsEMG) computation started at the beginning of the rectus femoris muscle contraction and covered all the muscle contraction. The AT was estimated from gas exchange parameters (oxygen uptake and carbon dioxide output) and from EMG parameters (rmsEMG versus workload) using the V-slope method[2)].

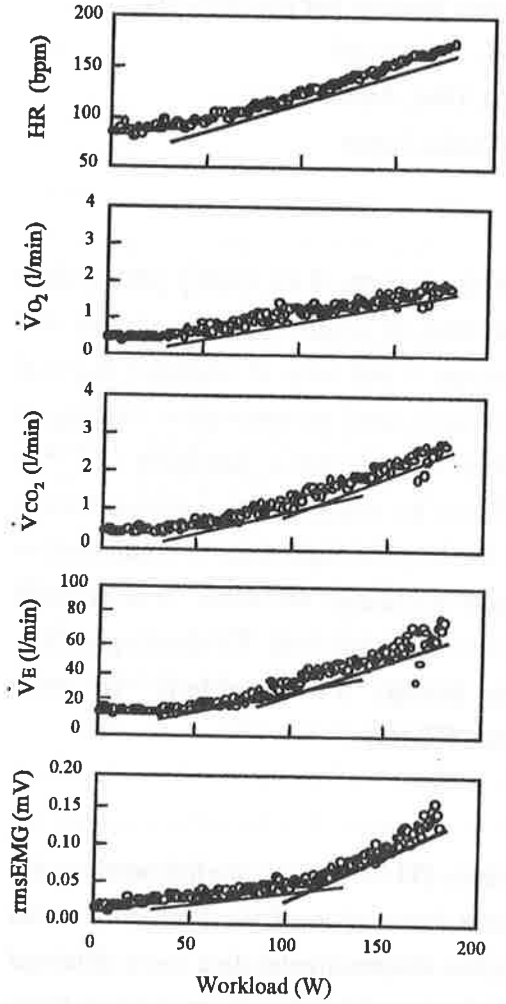

Figure 1. Typical example for the changes in gas exchange parameter and rmsEMG as a function of workload.

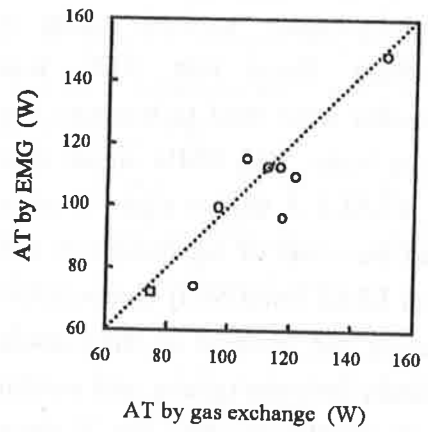

Figure 2. AT estimated from gas exchange and from EMG parameters. (○: young, □: elderly)

RESULTS AND DISCUSSION

Figure 1 shows a typical example for the changes in gas exchange parameters and rmsEMG as a function of workload. All parameters were unchanged until about 30 W, then two different types of slope were observed. One is approximately linear, in HR and $\dot{V}O_2$, the other contains two linear segments, in $\dot{V}CO_2$, $\dot{V}E$ and rmsEMG (Figure 1). These results confirm a previous study[1]. Figure 2 shows the ATs estimated from gas exchange and from EMG parameters. Only one elderly subject is shown, because four of the five subjects could not reach the AT level of work. There was a high correlation between the two estimates of AT. In 75% of all subjects, the AT estimated from EMG parameters was lower than that from gas exchange parameters. The AT level could be estimated more quickly using the EMG method.

CONCLUSION

The present study clearly demonstrates that AT estimates by gas exchange and by EMG have a high correlation and age-independency. In conclusion, the AT could be estimated by EMG measurement, and an appropriate exercise level can be easily obtained in this method earlier than by using gas exchange to indicate muscle fatigue.

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REFLEX AND NON-REFLEX COMPONENTS OF MUSCLE TONUS IN HEMIPLEGIC PATIENTS

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INTRODUCTION

As a quantitative evaluation of muscle tonus, the resistive joint torque in passive motion has been measured by using various measurement systems. It is considered that the increase of the resistive torque is mainly caused by the muscle spasticity defined as velocity dependent hyperactive tonic stretch reflex. In addition, many reports suggested that some non-reflex factors can increase the resistive torque. The purpose of this study is to establish a clinical method, which separately measure these reflex and non-reflex components of the resistive torque in order to analyze the characteristics of the muscle tonus in hemiplegic patients.

MATERIALS AND METHODS

Seven male hemiplegic patients (age range of 33-73) with the increased resistance to passive ankle dorsi-flexion (Modified Ashworth Scale 1+ and over) but no significant ROM limitation, and ten male normal volunteers (age range of 20-29) were subjected to this study. Cybex 6000 with the foot attachment was used to generate quick passive dorsi-flexion of 180°/sec., and to hold the ankle at dorsi-flexion of 0°. In these dynamic and static situations, the resistive force on the metatarsal heads was measured at dorsi-flexion of 0° by a loadcell mounted in the foot attachment, and converted to the resistive torque against the passive dorsi-flexion. During the measurements, the subjects took the supine position with knee flexion of 30°, and requested to relax the leg muscles. The foot was strapped to the foot attachment. At the same time, muscle activity of the medial head of gastrocnemius (GC) was measured by the surface electromyogram (EMG). In addition, in order to investigate the inter-trial reliability, the measurement was repeated twice in the normal subjects in different days, and the intra-class correlation coefficients (ICC's) were computed.

Because the static resistive torque can be considered as the non-reflex component, and which has also been included in the dynamic resistive torque, the balance after subtracting the static resistive torque from the dynamic resistive torque was supposed to be the reflex component.(Fig.-1) Regarding the reflex and non-reflex components, the paired t-test was used to compare the affected and unaffected sides of the hemiplegic patients.

RESULTS

Both the measurements showed good intertrial reliabilities with the ICC's of 0.77 in the static resistive torque and 0.84 in the dynamic resistive torque. On average, both reflex and non-reflex components were higher in the affected side than those of the unaffected side. (p<0.05) In addition, hemiplegic patients with sustained ankle clonus showed higher reflex component than that of others with unsustained ankle clonus.(Table-1)

DISCUSSION

The dynamic resistive torque consists of the reflex and non-reflex components, that have been tried to separately measure in many reports. We applied a simple method to subtract the static resistive torque as the non-reflex component. The residual from the dynamic resistive torque can be considered as the reflex component. The validity of this subtraction method was confirmed by the relationship between the clonus and the reflex component, the stretch reflex activities in GC.(Table-1, Fig.-2) The increase of the non-reflex component was probably caused by pathological changes in the spastic muscles.

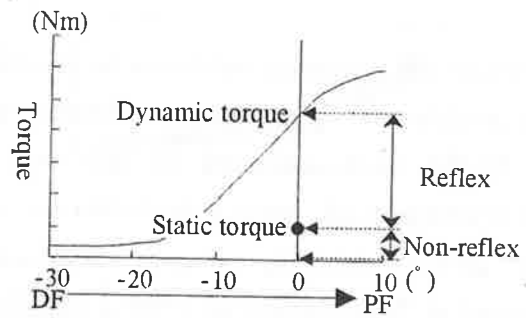

Fig.-1. The dynamic torque is supposed to consist of the reflex and non-reflex components.
(DF: dorsi-flexion, PF: plantar-flexion)

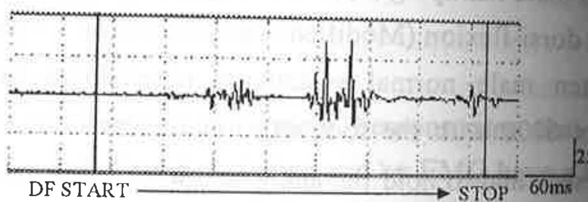

Fig.-2. The stretch reflex activity of gastrocnemius during the dynamic resistive torque measurement.

Table-1. State of clonus and results of the measurements.

Patient No.	Clonus	GC EMG Reflex activity	Reflex comp. (Nm) Affected	Reflex comp. (Nm) Unaffected	Non-reflex comp. (Nm) Affected	Non-reflex comp. (Nm) Unaffected
1	Sustained	+	17.0	1.7	6.2	3.7
2	Sustained	+	16.4	1.7	4.5	1.7
3	Sustained	+	8.2	1.1	2.6	2.0
4	Unsustained	+	7.0	2.4	5.1	1.3
5	Unsustained	+	1.8	1.3	4.0	3.1
6	Unsustained	+	1.6	1.2	4.4	2.9
7	Unsustained	−	1.6	1.4	3.3	2.6
Mean			7.6±6.7*	1.5±0.4	4.3±1.2*	2.5±0.8

*Significantly different from the unaffected side.(p<0.05)

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Influence of Body Weight Unloading(BWU) and Treadmill Gait Training on Hemiplegic Gait

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INTRODUCTION

Hemiplegic gait disorder is due to poor muscular activation, poor weight-bearing capacities, poor balance and hyperactive stretch reflex(1). One of new gait training method is body weight unloading in dynamic condition(2).

To investigate the biomechanic influence of treadmill training with body weight unloading compare with conventional physiotherapy in hemiplegia gait and to provide database for optimal strategies of gait training through treadmill with BWU in patients with gait disturbance

METHODS

We evaluated Functional Ambulatory Category(FAC), Standing Balance Test(SBT), Modified Ashworth Scale(MAS), and temporal parameters of gait and walking velocity for 10 hemiplegic patients with regular physiotherapy based on Bobath concepts and treadmill training with 30% partial body weight unloading. Body weight unloading was done by LiteGait®(Mobility Research, USA) in which force transducer was added to evaluate the amount of body weight unloading.

A-B single case study design was used for the analysis of the effect of gait training, A(regular physiotherapy based on the Bobath concept) and B(treadmill training with partial body weight unloading). Each training was lasting for 3 weeks, 15 sessions

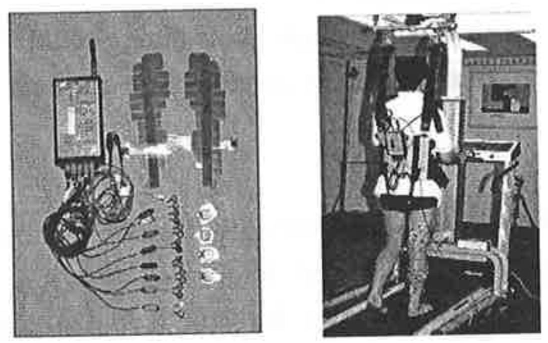

Figure 1. Gait training with partial body weight unloading and gait analysis

RESULTS

1) FAC and SBT was increased significantly after treadmill training with unloading compare to physiotherapy only, but MAS was no change.
2) Walking velocity and gait symmetry was increased significantly after treadmill training with unloading compare to physiotherapy only.
3) Temporal parameters of affected side was increased significantly after treadmill training with unloading compare to physiotherapy only.

Table 1. Functional Performance and Spasticity

	FAC	SBT	MAS
Initial	2.41.4	2.21.2	1.30.7
A training	2.61.2	2.31.1	1.30.7
B training	4.00.9*	3.80.6*	1.00.7

Functional Ambulatory Category(FAC), Standing Balance Test(SBT), Modified Ashworth Scale(MAS)

Table 2. Temporal Parameters of Affected Side

	Stance(%)	Swing(%)	SLS(%)	DLS(%)
Initial	56.84.6	43.24.6	23.43.9	38.74.9
A training	59.04.2	41.04.2	25.42.7	35.51.7
B training	65.72.6*	34.32.6*	29.64.3*	30.92.3*

SLS: Single limb support, DLS: Double limb support

DISCUSSION AND CONCLUSION

Treadmill training with body weight unloading could be advantageous as a therapeutic approach to retrain gait in hemiplegic patients.

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A Study on the Quantitative Biomechanical Measurement for the Spasticity with Newly Developed Protocol for Pendulum Test

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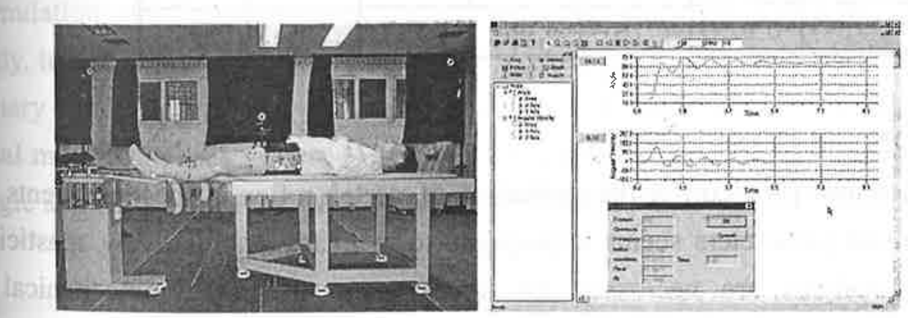
INTRODUCTION

Spasticity comprised a variety of clinical manifestations that accompany upper motoneuron (UMN) disease. Specifically, spasticity is the increased resistance to passive movement that results from the appearance of hyperactive spinal and brain stem relaxes following UMN lesions.[1].

In this study, newly developed test equipment and program were used to evaluate the stretch reflex of thigh muscle with muscle length model, joint angle and dynamic electromyography during pendulum motion of leg in the patients with spasticity.

METHODS

The stretch reflex of thigh muscle during pendulum motion of leg in 32 spastic patients were evaluated by muscle length model[3], hip, knee and ankle joint angle and dynamic electromyography in seven muscles. To avoid the interpersonal differences, every test made at the same time of the day, and preliminary tests were made before the test to reduce the tone[2].



(a) (b)

Fig. 1 (a)Pendulum test apparatus, (b) Anaysis program, Spar I

RESULTS

All of the parameters were decreased according to severity of spasticity. Among them, Angular Velocity Threshold(AVT) and Lengthening Relaxation Index(LRI), Muscle Length Threshold(MLT) were highly related with the clinical scale.

Table 1. Parameters of pendulum test according to clinical scale of spasticity

MAS	ARI	AT	AV	AVT	LRI	MLT
1	1.32±0.11	38.85±3.39	353.89±40.0	268.18±22.8	1.22±0.17	1.16±.015
2	1.16±0.16	27.47±1.21	279.92±45.0	247.64±27.6	1.11±0.14	1.15±0.03
3	0.95±0.14	20.55±1.99	241.30±22.3	209.11±13.7	0.98±0.11	1.14±0.02
Total	1.21±0.18	32.01±2.89	310.47±59.8	251.49±29.4	1.147±0.17	1.16±0.02

Angular relaxation index (ARI), Angular Threshold (AT), Angular Velocity (AV), Angular Velocity Threshold (AVT), Length Relaxation Index (LRI), Muscle Length Threshold (MLT), Modified Ashworth Scale (MAS)

Table 2. Correlation Coefficient with modified Ashworth scale (MAS) and Pendulum test parameters

	ARI	AT	AV	AVT	LRI	MLT	MAS
ARI	1						
AT	0.63*	1					
AV	0.63**	0.20*	1				
AVT	0.50*	0.92**	0.75**	1			
LRI	0.87**	0.67**	0.41*	0.54*	1		
MLT	0.74**	0.89**	0.49*	0.83**	0.83**	1	
MAS	-0.73**	-0.92**	-0.76**	-0.95**	-0.71**	-0.95**	1

DISCUSSION and CONCLUSION

Results from new protocol for the evaluation of stretch reflex in spastic patients shows that newly employed parameters seems appropriate to evaluate quantitatively spasticity. Further studies and analysis are necessary for development of new biomechanical spasticity evaluation parameters .

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P-326

A Study on Nonlinear Analysis of Plastic Ankle Foot Orthosis (AFO) based on 3-Dimensional Gate Analysis

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INTRODUCTION

The plastic ankle foot orthosis is a device to support the ankle and foot. Its function is to support stability during stance phase, to prevent foot drop during swing phase, and to assist push off at the end of stance phase right before swing phase of patients with stroke, cerebral palsy, and spinal cord injury.

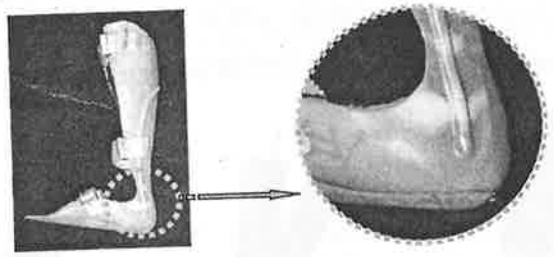


Fig. 1 Plastic Ankle Foot Orthosis (AFO) & deformed plastics around ankle joint

There are several studies on the effects of AFO for the abnormal gait pattern of many kinds of patients. AFOs play very important role in supplementing weak dorsiflexion in the swing and early stance phase. Thomas et al.[1] measured mechanical properties with cyclic loading simulation, and Chu[2] measured strain with strain gages for 5 different type of AFOs. In this study, to develop new design of solid type AFO, serial analysis for AFO were made as a preliminary study. Especially nonlinear analysis has made for the solid type. Three dimensional motion analysis system (VICON 140) and force plate were implemented to get flexion angle and reaction forces. ANSYS code was used to analysis to get stress distribution of AFO.

METHODS

Tensile test and 3 points bending test were made for 9 specimens of AFO to get mechanical properties. The specimens that are commonly used for AFOs were domestic made and imported material. Universal test machine was employed for the tensile tests. The test results showed very close value to the reference values in the polymer handbook. These material properties were used as an input data for the FE model. Especially nonlinear material characteristics were considered. To get flexion angle of AFO, 6 markers, 4 markers on AFO and 2 markers on femur, were attached onto subject body. The flexion angles of AFO were measured by the motion analysis system, and used as a finite element model input parameter.

The maximum flexion angle was 10.3 degree (coefficient variant < 0.04) at 12 trials.

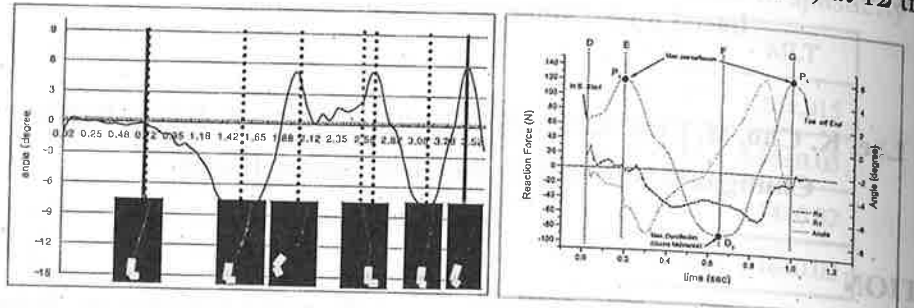
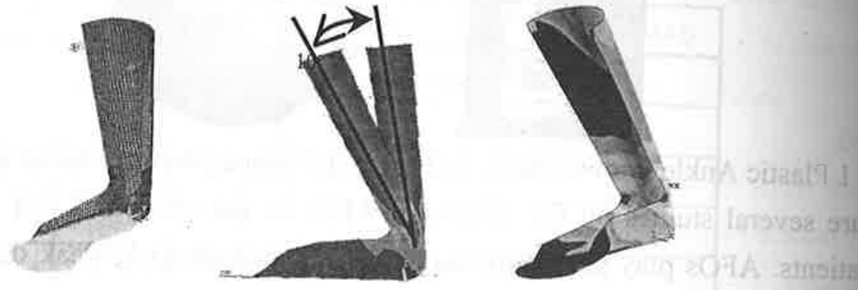


Fig. 2 Ankle flexion angle of right leg during stance phase.

RESULTS AND DISCUSSION

FE analysis results showed very similar stress contour to the real objects. Peak stress appeared in the medial and lateral side arc of ankle joint.



(a) (b) (c)

Fig. 3 Finite element analysis (a) boundary condition (b) flexion angle (c) stress contour

Absolute value of the peak stress in the side arc was 23.2 MPa. It is somewhat higher level comparing to the previous studies[2], but it could be happened considering different AFO shape and material properties.

CONCLUSION

A FE model analysis for AFO was made to get reference stress distribution during a stance. The final aim of this study is to develop new functional AFOs. This result and analysis protocol will be used as reference data in the future parametric study concerned with the shape and thickness changes of AFO.

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P-327

Importance of Physical Therapy in the Treatement Children with Arthrogryposis Multiplex Congenita

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INTRODUCTION

Arthrogryposis is a serious congenital defect of locomotor system, that most frequently affects all extremites where muscular tissue is replaced by connective tissue. This congenital defect is relatively frequent on birth.

Etiology of disease is unknown. This disease is frequent in families, but no data recorded on heredity. Some authors are of the opinion that conduct of such children imitates some stages of a fetus/picturel Disease usually affects extremities symmetrically. Sometimes even spinal column may be affected. Neither joint luxation, particularly dislocation of the hip, is rare.

METHODS

Up-to-date comprehensions are based on the knowledge that changes on a joint are secondary nature. Limitation of joint movements are conditioned fully extraarticulatory, but joints due to their immobillity are not regularly developed. Absence of movements brings to flexibile contractures. Muscles are differently affected depending on a case to case.

A medical rehabilitation in children with arthrogryposis represents a success of general rehabilitation. Plan of rehabilitation should be made for each individual case, even for each extremity, respecticely a joint. It is necessary to accept the attitude that this state is not hopeless and such a child is to be trined for self-helping. Such an aim is to be explanied to parents as maximal.

The basic rule of treatement is to be applied immediately after birth. It consist of a passive starining of shortened structures and of early usage of corrective plastercast. It particulary relates to feet and kness which later on are very difficult to be corrected. One should bear in mind the fact that recidives are frequent.

RESULTS

Plan of medical rehabilitation of lower extremities includes:
a) stability achievement
b) standing and walking capability

Plan of rehabilitation of upper extremities includes:
a) catching
b) fists and fingers using

To reach success the most important moment is that rehabilitation begins as earliest as possible. The most efficient measuresare:

a) straining of soft tissues
b) passive mobilization of joints with relaxation
c) application of splints and orthopedic helping devices

Any joint should not be neglected in treatement. This therapy is of the greatest significance and it is carried out to the effect of providing joint stability and enabling maximal mobility (change of position and place in the place of a residence).

DISCUSSION

The treatement of this disease is rather complicated, but nowdays it is more successful than earlier. These children are mostly intelligent. The most important moment in the treatement of this disease is to reject a feeling of hopelessness when a task is set that such a child has to be prepared for independent helping.
A surgical operations may help much in the general plan of treatement.

CONCLUSION

So the final goal of the treatement of arthrogryposis is to provide for joint stability controlled by functional musculature.
Of particular significance is that parents are correctly involved in the plan of rehabilitation. Only in such way a complete medical, social and economic rehabilitation of a sick child can be achieved.

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P-328

EEG Estimation of the Rehabilitation Effects in Head Injury Patients

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INTRODUCTION
The choice of informative approach in estimating of rehabilitation effect of patients with head injury is a great importance. The purpose of the present study was to provide a detailed comparison of complex of EEG parameters and patient's clinical status during rehabilitation.

METHODS
22 patients (right-handers) after severe brain injury were examined before, during and after rehabilitation course (from one to some months). Rehabilitation course included massage, motor and cognitive training, pharmacological treatment and others procedures. All examinations included EEG, psychoneurological and neuropsychological investigations. EEG study included calculation of power mapping, analysis of source localization of pathological EEG activity, calculation of intra-, intrahemispheric coherence and integral asymmetry coherence coefficients – Ca. A group of healthy persons (20 right-handers) served as a control one.

RESULTS
Analysis of EEG and clinical data observed correlation between some parameters and showed that EEG coherence was the most informative for estimation of the brain functional state dynamics of patients during rehabilitation. It was shown that the most successful clinical recovery was observed in patients who demonstrated during first stage of rehabilitation a phase of right hemispheric EEG coherence activation with signs of diencephalic activation as well (with negative values of Ca). This EEG phase accompanied to improving of emotional, vegetative functions and motor activity. For provocation of this effect were used special rehabilitation procedures and pharmacological drugs (L-glutamate, Bio-Normalizer of OSATO Bio-Industry Corporation, Japan). Following improving of clinical status especially in cognitive sphere was accompanied by the most increase of EEG coherence in the left hemisphere and tendency to normalization of Ca (to positive values). The results of rehabilitation course depend on some factors and correlated to values of Ca after rehabilitation.

DISCUSSION
EEG coherence analysis is a measure of the functional connections between cortical regions and it was used for evaluation of the brain functional state of healthy persons and patients with the brain damage (1, 2). We propose that observed in the present study phases of EEG parameters and clinical status reflected the successive order of activation of different subcortical and cortical structures of the brain during rehabilitation course. This process can be corrected by using of special rehabilitation procedures and pharmacological drugs (3,4).

CONCLUSION

The presented approach by using of EEG coherence and clinical data was the most informative for estimating of the rehabilitation effect and allowed to evaluate specificity of recovery process in patients with brain injury.

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P-329

Clinical Effect of Therapeutic Exercise on Dialysis Patients with Complicating Arteriosclerosis Obliterans (ASO)

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[INTRODUCTION]

Recently, the medical treatment of ASO should be approached in three ways. The first should be to minimize the risk factors of " atherosclerosis", the second should be the treatment of leg ischemia, and the third should be the management of other ischemic organs.

In order to relieve symptoms such as ischemic sensations, drug therapy such as vasodilatory drugs are useful in treatment of some patients with ASO. And, daily physical exercise are also effective in extending the waling distance in patients with intermittent claudication.

In this study, we gave therapeutic exercise to dialysis patients with complicating ASO and evaluated it by transcutaneous blood oxygen ($TCPO_2$) monitoring for comparison between groups given exercise (exercise group) or no exercise (non-exercise group).

[SUBJECTS]

The subjects were 9 dialysis patients diagnosed as having Fontaine I -Ⅲ(average age 59.8 years, average history of dialysis 7.3 years). The subjects were randomly divided into two groups. Five patients did not train and served as the control, 4 patients trained with walking exercise in our laboratory room.

[METHODS]

$TCPO_2$ was measured in both groups at the first visit to the Outpatient Clinic and 2 months later. The recovery time from a value during exercise loading to that before exercise loading and the difference ($\Delta PCPO_2$) between a pre-loading value and a minimum value were recorded. Throughout the test period, the exercise group was subjected to therapeutic exercise three times weekly.

[RESULTS]

The recovery time from an intra-loading to a pre-loading value shortened by 3.7±1.8 min in the exercise group, but remained unchanged in the non-exercise group. Δ $PCPO_2$ decreased significantly in the exercise group ($p<0.05$), but tended to increase in the non-exercise group.

[DISCUSSION]

On the basis of the findings of shortening of the recovery time on exercise loading and Δ $PCPO_2$ decrease in the exercise group, we considered that peripheral circulatory disturbance in the exercise group improved, compared with that in the non-exercise group.

[CONCLUSION]

These results suggested that the continuity of therapeutic exercise is more effective for dialysis patients with complicating ASO when it is combined with drug therapy.

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P-330

Preservation of motor neuron excitability during the cutaneous silent period in amyotrophic lateral sclerosis

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INTRODUCTION

Electrical stimulation of a cutaneous nerve can transiently suppress electromyographic (EMG) activity in a voluntarily contracting muscle. This period of electrical silence, known as the cutaneous silent period (CSP), is mediated by a poly- or oligosynaptic reflex at the spinal level, modulated by supraspinal centers, resulting in motor neuron inhibition after an intense cutaneous stimulus. F-waves result from the antidromic activation of motor neurons and can reliably detect a decrease in spinal motor neuron excitability. In order to evaluate whether the inhibitory component of the CSP directly inhibits the excitability of the spinal motor neuron pool in patients with ALS, we examined F-waves in the abductor pollicis brevis (APB) muscle generated in response to antidromic stimuli during the CSP.

METHODS

Eight patients with ALS (7 males and 1 females; 42 – 68 years old) and 13 healthy subjects (6 males and 7 females; 34 – 70 years old) were studied. Paired surface-stimulating ring electrodes were placed on the fifth finger and stainless-steel disc recording electrodes were taped over the ipsilateral APB muscle. Using an Excel EMG machine (Cadwell, WA, USA) with an amplifier filter bandwidth of 20 to 2,000 Hz, the CSP was recorded during 50% maximal voluntary abduction of the thumb in response to an electrical stimulus (0.2 ms duration) that was near the pain threshold. The CSP onset was defined as the complete cessation of EMG activity and the endpoint was defined as the return of any EMG activity. To test motor neuron excitability during the CSP, F-waves were examined in the patients with ALS. To elicit F-waves, the median nerve was stimulated at the wrist with (test condition during the CSP) and without (control condition) stimulation of the fifth finger. The presence or absence of the F-wave was determined and the latencies of the F-waves obtained in the control and test conditions were compared.

RESULTS

The latencies of the onset and endpoint of the CSP in the normal subjects were 84.3 ± 10.9 and 122.4 ± 9.7 ms (mean ± SD), respectively. In the patients with ALS, the onset was 100.0 ± 13.4 ms and the endpoint was 132.8 ± 17.8 ms, showing that the CSP was delayed (p=0.01). Of the 8 patients, F-waves were seen in seven in the control condition. No F-waves were seen in one patient with marked APB muscle atrophy. Six out of the 7 patients generated F-waves in the test condition. The latencies of the F-waves in the test and control conditions were similar.

DISCUSSION

The onset of the CSP is determined by the temporal summation of the afferent and efferent conduction times to and from the spinal cord, plus any central processing time. In spite of normal peripheral nerve conduction studies, our study showed that the onset of the CSP was prolonged in the patients with ALS compared with normal subjects. Therefore, we reasoned that there must be a delay in the central processing time in the patients with ALS. We also found that F-waves were not suppressed during the CSP in the patients with ALS. Although persistence of the F-waves during the CSP is not synonymous with the absence of postsynaptic inhibition, the preservation of F-waves suggests that a mechanism other than postsynaptic inhibition of spinal motor neurons is responsible for the inhibition of voluntary EMG activity. It is also possible that F-waves may be preserved during the CSP because the motor neurons in the pool that generate the F-waves are different from the motor neurons that relay corticospinal tract inhibition.

CONCLUSION

The preservation of F-waves during the CSP indicates that the inhibitory activity of cutaneous afferents does not have a direct effect on the alpha motor neurons in ALS patients. The physiology underlying the CSP is unclear, the delayed onset of the CSP in ALS patients may reflect that the site of inhibitory action lies above the alpha motor neuron.

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P-331

High frequency oscillations evoked by posterior tibial nerve stimulation in multiple system atrophy.

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OBJECTIVE:

High-frequency oscillations (HFOs) evoked by posterior tibial nerve (PTN) stimulation were recorded by using electroencephology (EEG) in normal subjects and patients with multiple system atrophy.

METHODS:

Somatosensory evoked potentials (SSEP) were recorded with a filter set at 5 – 1500 Hz to PTN. The HFOs were obtained by digitally filtering the wide-band SSEPs with a band-pass of 300 – 900 Hz. To eliminate the far-field potentials we analyzed from the latency of 35 msec.

RESULTS:

HFOs were recorded in most subjects. Amplitudes and area of HFOs were significantly smaller and interpeak latencies were longer in patients group. While P37 or N37 amplitude and area was not differ between two groups.

DISCUSSION:

In multiple system atrohpy, the thalmo-cortical input might be involved as seen in glial cytoplasmic inclusion bodies. On the other hand cortical abnormalities have not been reported. We speculate the thalmo-cortical input abnormalities have the effect on HFOs.

CONCLUSIONS:

This study supports the theory that HFOs are related to the thalmo-cortical input with a high-frequency (600 – 900 Hz) burst of short duration spikes shown in animal experiences.

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P-332

RESPIRATORY DYSFUNCTION IN PATIENTS WITH PARKINSON'S DISEASE.

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INTRODUCTION

Respiratory abnormalities have been noted in patients with Parkinson's disease(PD) since its initial description in 1817 and these problems commonly contribute to morbidity and mortality of PD. We investigated the characteristics and clinical significance of respiratory function in patients with PD.

METHODS

We studied 38 patients (male 19, female 19, mean age 65.5 years, mean duration of disease 6.7 years) who had no history of respiratory disease and/or smoking. PD patients were divided in to subgroups based on age of patients and the severity by Hoehn and Yahr(H-Y). The number of PD patients were 15 in H-Y 2, 18 in H-Y 3, and 5 in H-Y 4, respectively. The respiratory functions such as %vital capacity (%VC), forced expiratory volume in 1 second (FEV1.0%) and flow volume curve were measured by spirometry and were compared among groups.

RESULTS and DISCUSSION

The results disclosed that elderly patients and advanced stage patients with PD tended to show the decreased %VC and FEV1.0%. The group means±SD of %VC and FEV1.0%, respectively, were 90.6±17.6 and 75.5±9.9; 105.9±20.6 and 82.5±8.8; 103.8±18.2 and 81.9±9.5; 97.1±18.8 and 78.8±

6.2; 79.1±21.2 and 68.1±16.8 for elderly PD; younger PD patients; H-Y 2; 3; 4 PD patients in this order. The values of elderly PD patients and H-Y 4 PD patients were significantly lower than those of younger PD patients (P<0.05:two tailed t-test), and those of both H-Y 2 and 3 PD patients (P<0.05), respectively. Nine of them had obstructive dysfunction and six of them had restrictive dysfunction as judged by abnormal values according to the criterion of respiratory function; obstructive and restrictive patterns were diagnosed with FEV1.0%<70% and %VC<80%, respectively. Conversely, twenty five patients(66%) presented the lower flow volume under maximal expiratory condition and the juts out curves into downward. This revealed the presence of peripheral airway obstruction as judged by pattern analysis in flow volume curve. There was no relationship between these results and both age and severity of PD patients. These results suggested that respiratory dysfunction had relation to the clinical disability, however peripheral airway obstruction was independent of disability seen prevalently in PD patients. We would like to suggest that these results may be caused by autonomic dysfunction of airway in patients with PD.

CONCLUSION

The patients with PD had both the obstructive and restrictive respiratory dysfunction. In addition to them, they also showed the pattern of peripheral airway obstruction in flow volume curve.

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P-333

FUNCTIONAL RESTORATION IN PATIENTS WITH PERIPHERAL NERVES INJURIES FOLLOWED-UP BY EMNG CONTROLS

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In the period from July 1991 to December 1995 in our Laboratory 6703 EMNG analyses were performed.
The war activities in the region and the aggression on Croatia began in May 1991 and in July the first patient with a peripheral injury caused by a war missile came for EMNG analysis to our Laboratory; such patients were continuously arriving for analyses from the City during the whole period of siege of Osijek, up to 1995.
Altogether 1803 EMNG analyses (26,89%) from the above number were performed in the injured persons, civilians or the defenders of the City, caused by the war missiles or explosive devices.
The peripheral nerves injuries were followed-up by EMNG controls during all the this period and afterwards, in order to evaluate the functional and structural aspects of the respected nerve structures for possible indication for surgical management, resp. for the follow-up of its sucdess.
Quantitative analysis has shown that from the whole material pertaining to the peripheral nerves injuries was in 34,88% related to lesions of upper extremities, in 40,32% of lower extremities, while the rest of 24,79% was performed in injuries of face or trunk.
Our analyses have shown that these EMNG controls did not have only diagnostic imortance, but in some cases were essential for the dynamic funkcional evaluation, having sometimes relevance in the consideration for further management program and functional rehabilitation.

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Effect of spasticity in cerebral palsy and spinal cord injury

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**Hokkaido Rehabilitation Counseling Center for The Handicapped

Introduction

Little information has been amassed spasticity of cerebral palsy and spinal cord injury, although increasing numbers of these patients represent an important problem socially as well as medically. It may be more suitable for quantitative evaluation for spasticity, however, such data have been reported in the literature only rarely. Our study should help to clarify problems of spasticity.

Subjects and Methods

All patients with cerebral palsy and spinal cord injury who arrived at the Hokkaido Rehabilitation Counseling Center for the Handicapped from January 1995 to December 1997 were consecutively enrolled in the study. There were 256 individuals (140 males and 116 females; age, 31.6 years; SD 14.8) of cerebral palsy, and 94 individuals (71 males and 23 females; age, 50.2 years; SD 17.7) of spinal cord injury.

Patients were evaluated according to types of motor deficit, muscle power, muscle tone, deformity, sensory disturbance, and pain. We classified the topography of motor deficits into four categories (quadriplegia, diplegia, hemiplegia, and monoplegia). Other characteristics (muscle power, muscle tone, deformity, sensory disturbance, pain) were evaluated in their most disabled part of body. Muscle strength was classified by manual testing into six grades. We classified muscle tone into five grades by the Ashworth scale. Deformity, sensory disturbance, and pain each were rated by severity as normal, mild, moderate, or severe.

Activities of daily living were evaluated by the Barthel index. Correlations between the Barthel index and other measures were analyzed statistically.

Results

Proportion of spasticity in patients with cerebral palsy and spinal cord injury was extracted from this analysis. Table 1 summarizes the results and the 95% confidential intervals for manual muscle testing and the muscle tone scale.

Correlations between other factors and activities of daily living were analyzed. Main clinical factors affecting activities of daily living were the topography of motor deficits, muscle power, and muscle tone. The Barthel index decreased by about 20 points when severe hypertonus or severe deformity was present, and by 30 points when severe muscle weakness was present.

Discussion

Statistical investigation of spasticity in patients with cerebral palsy and spinal cord injury has been reported only rarely. Topography of motor deficits, the manual muscle test score, the muscle tone scale, and deformity affected the Barthel index. Since deformity was

Table 2 : Proportion of Ashworth scale and 95% confidence interval

Cerebral palsy Ashworth scale	No. of patients	(ratio)	95%CI
Grade 1	31	(0.122)	0.082-0.162
2	21	(0.082)	0.048-0.116
3	52	(0.204)	0.155-0.253
4	84	(0.322)	0.265-0.379
5	62	(0.243)	0.19 -0.296
Unknown	5	(0.02)	(-)
Total	255	(1.0)	(-)

Spinal cord injury Ashworth scale	No. of patients	(ratio)	95%CI
Grade 1	12	(0.128)	0.06 -0.196
2	25	(0.266)	0.177-0.355
3	20	(0.213)	0.13 -0.296
4	17	(0.181)	0.103-0.259
5	18	(0.191)	0.112-0.27
Unknown	2	(0.021)	(-)
Total	94	(1.0)	(-)

influenced by muscle tone, major factors having a impact on activities of daily living in adults with cerebral palsy were topography of motor deficits, muscle power, and muscle tone. Muscle weakness did not correlate with muscle tone in our study. Therefore, muscle strength and muscle tone must be separated to assess characteristics of cerebral palsy and spinal cord injury. We must manage these two problems independently.

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The Comparison with Exercise Load and Thermal load at Respiratory-Circulatory Responses

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INTRODUCTION

Responses of respiratory-circulatory systems by exercise load and thermal load with water pressure are known generally. However, it is insufficient for the responses by the whole body thermal load without water pressure. We studied influence of exercise load and the whole body thermal load without static water pressure at respiratory-circulatory responses.

METHOD

Subjects were six healthy volunteers(age 22~33 years old , male) . In atmosphere at 25°C(temperature)・50%(humidity) , they were got exercise load by ergometer . In the different days , they got the whole body thermal load in atmosphere at 48°C (temperature)・100%(humidity). by mist sauna for 15 minuets. Vmax29c (SENSER MEDICS Corp.) and Finapress (Ohmeda Corp.) were used for measurement.

RESULTS

Heart rate increased along the time, and decreased from the end of the load at both the exercise and thermal. The mean blood pressure showed the similar progress of heart rate at the exercise. Compared to the increase of heart rate , the mean blood pressure and VO2 did not increase after the thermal stress .

CONCLUSION

The thermal stimulation of sauna dilates the peripheral vessels and the blood pressure dose not increase by the significant(HR > 140) tachycardia . It is considered that the monitoring heart rate is not good indicator for under water exercise.

On oxygen consumption and VO2 of cardiac muscle, the exercise load were larger than the thermal load without water pressure. These differences reflect the existence of muscle movement. It is suggested that rate of increase on heart rate and oxygen consumption of cardiac muscle were almost equal at the thermal load without water pressure.

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NEEDLE EMG FINDINGS IN POST-POLIO SYNDROME (PPS)

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SUMMARY

This time, we investigated 16 PPS patients and the correlations between symptoms, needle EMG findings and muscle CT findings. We performed needle EMG in 165 muscles. Denervation potentials were shown in 36 muscles. Denervation potentials were shown relatively more frequent in MMT 2 grade, and in moderate fatty change in CT findings.

INTRODUCTION

Decades after recovery of acute paralytic poliomyelitis, PPS patients may develop a new and slowly progressive muscle weakness, atrophy, excessive fatigue, muscle and joint pain, and diminished functional capacity. Needle EMG studies have provided important information about the size of the motor units, the degree of reinnyervation, and denervation potentials in muscles of patients with PPS. Information about the ongoing subclinical denervation is very important for therapy. In Japan, studies about needle EMG for PPS are few.

In this study, we investigated the relationship of symptoms, muscle strength, CT findings, and needle EMG findings.

PATIENTS

We studied 16 patients (men 6, women 10; mean age 49; range 38-72 years) with PPS who consulted the department of rehabilitation, Hokkaido University Hospital.

METHODS

PPS was diagnosed by the criteria reported by Dalakas in 1995.

Muscle strength was assessed by manual muscle testing (MMT). Nerve conduction studies (NCS) were performed for almost four extremities of all patients. Muscle computer tomography (CT) was performed to every patient and the degree of fatty change was assessed for normal, mild, moderate and severe

change. After that, conventional needle EMG was performed. Tested muscles were selected by signs and CT findings.

Needle EMG findings were classified as denervation potentials (positive sharp wave, fibrillation potential and fasciculation potential), neurogenic pattern (high amplitude, long duration potential, long duration poly phasic potential) and decreased interference pattern. Each finding was assessed to 5 grades (0-4).

RESULTS

Summary of patients was shown in Table 1. We investigated 16 patients with PPS (male 6, female 10; mean age 49; range 38-72). Needle EMG was performed for 165 muscles totally.

Muscle weakness and fatigability were most frequent symptoms, shown in 15 patients (94%) out of 16. There were 67 symptomatic muscles (muscle weakness, muscle pain and fatigability) in 165 muscles. Symptoms were shown equally in all MMT grades (Table 2).

Neurogenic patterns were shown in every patient and in 110 muscles shown in all MMT grades (51-88% in each MMT grades). The amplitudes of neurogenic potentials were ranged 4-30 mV. About the correlation of fatty change and neurogenic patterns, neurogenic patterns were shown more frequent in mild and moderate fatty change (about 90%).

Denervation potentials were shown in 15 patients out of 16, and 36 muscles (22%) out of 165. Denervation potentials were shown relatively more frequent in MMT 2 grade (50%)(Table 3), and in moderate fatty change in CT findings (42%)(Table 4). Symptoms (muscle weakness, muscle pain and fatigability) were shown in 20 muscles (56%) out of 36 muscles shown denervation potentials. And Denervation potentials were shown in 20 muscles (30%) out of all 66 symptomatic muscles.

CONCLUSIONS

In muscles shown denervation potentials, symptoms were shown in 56%. Needle EMG is useful to catch subclinical neuromuscular dysfunction. To catch subclinical dysfunction, we need to perform needle EMG to broad area including asymptomatic muscles.

And in symptomatic muscles, denervation potentials were shown in 30%. The factors that are difficult to catch by needle EMG may be influenced to PPS symptoms.

In this study, denervation potentials as the sign of ongoing dysfunction were relatively shown in muscles with mild and moderate CT changes and MMT 2 grade. So we think it is very important for us to treat the patients in this grades very carefully.

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Table 1 Summary of patients

Table 2 Correlation of muscle strength and symptoms

Symptoms (muscle weakness, muscle pain and fatigability) were shown equally in all MMT grades.

Table 3 Correlation of muscle strength and denervation potentials

Denervation potentials were shown relatively more frequent in MMT 2 grade

Table 4 Correlation of fatty change and denervation potentials

Denervation potentials were shown relatively more frequent in moderate degree of fatty change.

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Delayed radiation-induced brachial plexopathy : A case report

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SUMMARY

INTRODUCTION

Late effect of radiotherapy usually occurs from some weeks to several months of irradiation. Some patients occasionally suffered radiation neuropathy several years after radiation. We experienced a patient with delayed radiation-induced brachial plexopathy (RBP) which occurred at 24 years after radiotherapy for breast cancer operation and demonstrated typical electrophysiological findings.

CASE REPORT

A 55-year-old woman was admitted the Hokkaido University Hospital suffering from severe swelling and sensory-motor disturbance of left arm. She had be diagnosed to breast cancer and treated with mastectomy and postoperative radiotherapy (RT) in 1975. Irradiation area involved the brachial plexus. Lymphedema appeared to her left hand within half year after RT. In 1996, her lymphedema went from bad to worse, and her left arm's sensor-motor disturbance gradually progressed. Lymphovenous anastomosis was done for recovering lymphedema on September 16, 1999. Although her lymphedema was moderately improved, motor function of the arm did not recover. She was admitted to our hospital on November 14, 1999. On admission, the results of manual muscle testing were as follows; upper trapezius 3-4, supraspinatus 4 rhomboideus 3-4, serratus anterior 3, Latissimus dorsi 4, deltoideus 4, biceps 2, triceps 2, extensor carpi radialis 4, extensor carpi ulnaris 4, abductor pollicis brevis 4, abductor digiti minimi 3, interosseus palmalis 0, and flexor disitorum profundus 0. Electrophysiological studies were done as follows. Distal latency (d-l), F wave latency (F-w-l) were normal in left median and ulnar nerve. Left median SCV did not evoke. Left median M wave amplitude was low. Short-latency sensory evoked potential (SSEP) of the left median and ulnar nerve did not be evoked, because lymphedema might increase the skin resistance. Motor evoked potential (MEP), evoked by transcranial magnetic stimulation to the right cerebral cortex, demonstrated delayed latency (23.0ms) and low amplitude (0.6mV). But stimulation of the left C8 cervical root did not evoke MEP of APB nor ADM. CT images demonstrated atrophic change of the left arm muscles; slight atrophy of deltoid, infraspinatus, and rhomboideus muscles, severe atrophy of serratus anterior. Levator scapulae and trapezius muscle did not show atrophic change. MRI images showed elongation and thinning of the left brachial plexus. The left brachial plexus was not enhanced by Gd-DTPA, which did not suggest active inflammation nor tumor reoccurrence.

DISCUSSION

The biological mechanisms of RBP were suspected that, (1) irradiation-induced fibrosis surrounding the brachial plexus might lead to progressive entrapment of the nerve fiver, (2) poor circulation of the neurotrophic vein, and (3) irradiation might damage Schwann cells. We supposed that the delayed RBP of the presented patient might occur due to these mechanisms, and axons developed dying-degeneration toward distal.

Electrophysiological examinations against RBP were useful not only to diagnose and find injury site, but also distinguish RBP from neoplastic brachial plexopathy. Electrophysiological findings of this patient were summarized that low amplitude of NCV in the forearm, non-evoked SSEP, non-evoked MEP by the stimulation of Erb's point, and weak MEP by the stimulation of the right cortex. We suggested that the distal part of the brachial plexus's' roots was damaged, and the electrophysiological findings might support.

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Spinal Cord Injury associated with Brachial Plexus Injury in Neck Trauma

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INTRODUCTION

Abilities of daily living (ADL) of patients with traumatic spinal cord injury is related with the function of upper extremities and shoulder girdles. Spinal cord or brachial plexus injuries are sometimes caused by traffic accidents. However the combination of these two neurologic pictures is quite rare. We report a patient with spinal cord injury and brachial plexus injury.

CASE REPORT

A 19-year-old male was injured in a car accident in Hokkaido. On admission to an acute care hospital both lower extremities were completely paralyzed. On his left upper extremity deltoid had grade-3, biceps grade-4, triceps grade-2, extensor carpi radialis grade-4 on Manual Muscle Test (MMT), whereas, his right upper extremity was almost completely paralyzed. He could not move his fingers voluntarily. Anesthesia was found in the right side of the body below the level of C6 and in the left side of the body below the level of C7. Cervical radiography displayed a burst fracture of C6. Cervical tomography displayed a right facet inter-locking of C5/6. He had a posterior fusion of C5-C7 on the same day of the injury. Nine days after injury he was transfered to another hospital in Tokyo. Eleven days after injury he had an anterior fusion to stabilize his neck for early rehabilitation. On that time his right deltoid recovered grade-1, biceps grade-1 on MMT, but his both lower extremities were completely paralyzed. Forty-six days after injury the patient was transfered to our hospital for an examination for right brachial plexus injury and rehabilitation.

On admission to our hospital his right upper extremity was flaccid. Only external rotation of his right brachium and extension of his right wrist were found without anti-gravity. Myelography did not show clearly because of implants. Needle EMG was performed on muscles of his right shoulder and brachium. Serratus anterior, levator scapulae and rhomboid did not show abnormal findings. Infraspinatus, deltoid, biceps brachii, brachioradialis showed positive sharp wave at rest and polyphasic action potencials at mild voluntary contraction. Triceps brachii showed positive sharp wave at rest and showed electrical silence at weak contraction. He was diagnosed right brachial plexus injury, but it was out of indication of surgery. Six months after injury he noted improvement in motor function of his right upper extremity with 3/5 strength of his deltoid , biceps brachii, extensor calpi radialis.

DISCUSSION

The combination of spinal cord injury and brachial plexus injury is quite rare. Rajiv Midha reported the epidemiology of brachial plexus injuries in a multitrauma population in 1997. In the report only 2% of patients who were injured brachial plexus injuries associated spinal cord injury.

He was injured C6 complete tetraplegia and right brachial plexus injury. Usually, young C6 tetraplegias are almost independent in ADL. At first, his impairment of right upper extremity seemed to inhibit the improvement of ADL. If there had been some evidence of root avulsion, it would be some indication of surgery. But in this case, EMG findings suggested that the function of right upper extremity would be conservatively recovered. The assessment of his function of upper extremity was useful in predicting his ADL and making his treatment plan.

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ELECTROMYOGRAPHY

R/L	MUSCLE	at rest	at mild voluntary contraction	
		p wave	polyphasic active potentials	interference pattern
R	serratus anterior	normal	normal	1+
R	levator scaplae	normal	normal	2+
R	rhomboid	normal	normal	2+
R	infraspinatus	3+	1+	2+
R	deltoid	2+	3+	2+
R	biceps brachii	3+	3+	2+
R	brachioradialis	3+	3+	1+
R	triceps brachii	3+	electrical silence	0

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Cardiovascular responses to isometric exercise during head-out water immersion

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INTRODUCTION

Extraordinary increase in blood pressure (BP) is one of the characteristics of isometric exercise. It has been reported that changes in stroke volume (SV), BP and heart rate (HR) are dependent on water temperature and that SV increases due to an increase in venous return during head-out water immersion (HWI) (1). Considering the increase in preload to the left ventricle during HWI, cardiopulmonary responses to isometric exercise during HWI are thought to be different from those in air. Although many studies on cardiovascular responses to dynamic exercise during HWI have been reported (2-4), little is known about the effects of isometric exercise during HWI. The purpose of this study is to examine the continuous changes in BP, HR and left ventricular function during isometric exercise in HWI at a thermoneutral water temperature, and to compare these changes with those in air.

METHODS

Seven healthy male subjects, whose mean age, height and body mass were 24 ± 3 (Mean ± SD) years, 1.69 ± 0.05 m and 63.9 ± 17.3 kg, respectively, participated in this study. Informed consent was obtained from all the subjects. We first performed the experiments in air and then after a week interval, the HWI experiments were done.

After taking a rest in a chair for 1h, the subjects sat on an experimental chair in the pool. Isometric right knee extension was performed with 90° knee flexion. A cuff was fixed around the right ankle joint and a wire was connected to a load cell. At first, both BP and HR were measured for control values, and then a 10-s maximal right knee extension was performed to establish the force transducer output level to 100% maximum voluntary contraction (MVC). After both BP and HR returned to control values, submaximal (60%) right knee extension was performed until the subject was exhausted. In HWI experiment, water temperature was kept at thermoneutral value of 35.0 ± 0.5 °C (5,6). Both BP and HR were measured continuously by an Ohmeda 2300 Finapres. Left ventricular imaging was monitored continuously in the long axis view using an Aloka SSD-870 ultrasound imaging system. Both left ventricular images and electrocardiograms were recorded on a videotape cassette before, during and after the isometric exercise. Afterward, left ventricular end-diastolic (dd) and end-systolic diameters (ds) were calculated from M-mode pictures.

RESULTS

In air, systolic (BPs), diastolic (BPd) and mean (BPm) BP increased progressively during contraction ($P<0.05$ or 0.01). During HWI, BPs, BPd and BPm at rest were not different from those in air and they increased progressively during contraction ($P<0.05$ or 0.01). Changes in BP during HWI tended to be less than those in air (NS).

The difference of the HR between in air and in water at rest was insignificant. They increased progressively and significantly during contraction. During HWI, changes in HR tended to be smaller than those in air (NS).

Before, during and after contraction, dd in HWI was significantly greater than that in air. DD during HWI did not change during and after contraction compared with that at rest. DD in air decreased significantly at the end of contraction ($P<0.01$). Ds decreased immediately after the end of contraction both in HWI ($P<0.01$) and in air ($P<0.05$). Before, during and after contraction, the differences in ds between the two conditions were insignificant.

DISCUSSION

Changes in BP and HR during contraction were similar in HWI and in air. In addition, dd was larger in water and ds was not different between the two conditions. These facts suggest that SV during HWI is greater than that in air and that vascular resistance during HWI at this water temperature might be smaller than in air.

Sympathetic nervous activity decreases at rest during thermoneutral HWI (7). This activity is controlled by baroreflexes associated with the central shift of blood volume, resulting in a decreased vascular resistance. Thus both BP and HR at rest during thermoneutral HWI were maintained at the same values as in air despite of the increased SV.

It is reported that plasma renin activity decreases at rest during thermoneutral HWI (8,9), and the activity is much lower after swimming than after running (10). As a result, reduced plasma volume lowers the vascular resistance in HWI.

In HWI, dd was thought to be unchanged due to the increased venous return caused by hydrostatic pressure. The decrease in ds may be attributed to the effect of a reduction in afterload and enhanced contractility.

CONCLUSION

Isometric exercise during thermoneutral HWI was characterized by a greater dd and exercise in water might be useful for the patients with orthostatic hypotension.

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Serial Central Motor Conduction Studies in the Miller Fisher Syndrome

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Objective:
The Miller Fisher Syndrome, defined by the triad of ataxia, areflexia and ophthalmoplegia, is an uncommon form of acquired inflammatory demyelinating polyneuropathy. Its exact site of abnormality remains poorly defined in terms of clinical, radiological and neurophysiological evidence. For the first time central motor conduction times were studied serially in patients with aims to demonstrate dynamic corticospinal tract dysfunction in correlation with clinical features.

Methods:
All 3 consecutive patients showed the classical triad and had nerve conduction studies upon diagnosis. Magnetic stimulation was performed with a Dantec Mag 2 stimulator with recordings on a Dantec Counterpoint EMG machine. Facilitated motor evoked potentials from the first dorsal interosseous and abductor hallucis muscles were recorded. Central motor conduction times (CMCT) were calculated with the F waves method. Studies were repeated at each clinical review with simultaneous clinical assessment for resolution of signs. We also studied CMCTs of 15 normal controls.

Results:
2 patient showed prolonged CMCTs to the upper limbs which diminished significantly with complete resolution of eye movements and ataxia. The third patient had prolonged CMCT to the lower limbs which diminished with complete resolution of eye signs and ataxia. All patients had normal MRI of the brain and positive antiGQ1g antibodies.

Conclusions:
Electrophysiological evidence of corticospinal dysfunction is present in the Miller Fisher Syndrome. The degree of coticospinal abnormality in terms of CMCT appear to parallel the resolution of clinical signs. The findings support an underlying central, reversible and demyelinating pathological process.

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The Effects of Electrical Nerve Stimulation of the Lower Extremity on H-Reflex and F-Wave Parameters.

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Abstract:

The main purpose of this study was to investigate the effects of electrical nerve stimulation on alpha motoneurons excitability. The electrophysiological parameters of H-reflex and F-wave were assessed for this object.

These experiments was performed on ten non-athletic healthy men without neurologic disorders with mean age 25.6 æ 4.4 years and three spastic hemiplegic patients with mean age 65.33 æ 6.32 years. In the experimental protocol, electrical simulation (TENS) applied on common peroneal nerve with frequency 99 Hz and pulse width (duration) 250 μs for 30 minutes. H-reflex and F-wave of the soleus muscle were recorded in three stages sequenced immediately, 5 minutes and 10 minutes later on. The parameters such as amplitudes and latencies of H-reflex and F-wave were compared with the data of first record befor stimulation. Finally, after 30 minutes application of TENS the following results were obtained :

1- The mean peak to peak amplitude of H-reflexes and F-waves were significantly decreased after application of TENS in normal subjects. ($P<0.05$)

2- H/M ratios and F/M ratios were significantly decreased after application of TENS in normal subjects. ($P<0.05$)

3- The mean latency of H-reflexes and F-waves were significantly increased after application of TENS in normal subjects. ($P<0.05$)

4- In spastic patients, the mean peak to peak amplitude of H-reflexes and F-waves, H/M and F/M ratios were significantly decreased and the mean latencies of H-reflexes and F-waves were significantly increased after application of TENS.

The reduction of amplitude of H-reflexes and F-waves, H/M and F/M ratios demonstrated reduction of spasticity in the patients group. The above-mentioned parameters are parts of electrophysiological indicators about assessment of spasticity.

Key words: H-reflex, F-wave, Electrical stimulation, TENS, Spasticity

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Endurance Test of New Material FES Electrode

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INTRODUCTION

In order to develop reliable total implantable FES systems, it is important to investigate the properties of new materials for FES electrodes. While fine stainless steel SUS316L has been used as percutaneously indwelling intramuscular electrodes since 1985, NAS106N, high nitrogen high manganese stainless steel, has been developed as FES electrode recently. In our previous study[1], the rotating-bending fatigue test was performed in air and 0.9%NaCl solution and it was showed NAS106N had higher fatigue life and less elution of nickel than SUS316L. The purpose of this study is to evaluate the character of these two kinds of electrodes in disconnection and migration.

METHOD

The electrode was made as a helical coil wound from a Teflon-coated 19 strand wires. The electrodes were implanted in hinder legs of 4 adult dogs, SUS316L in left legs and NAS106N in right. In each leg, 10 electrodes were implanted in quadriceps muscles and placed subcutaneously. After surgical operation, the dogs were physically exercised for 10 minutes per day. Functional state of each electrode was confirmed by muscle response to electrical stimulation at 1 month after operation. Impedance of the electrodes was measured at the same time.

RESULT

All electrodes were functional with low impedance and strong muscle contraction.

CONCLUSION

In this condition, these two kinds of electrodes showed no difference in character of disconnection and migration.

ACKNOWLEDGEMENT

This study supported by Miyagi Organization for Industry Promotion.

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P-342

The Use of Therapeutic Electrical Stimulation for Gait disturbance Due to Severe Flexor Reflex: A Case Report

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INTRODUCTION

Although all post-stroke patients want to be re-acquired walking ability, some pathological conditions limit it's achievement. Recent meta analysis supports the continued use of therapeutic electrical stimulation (TES) in post-stroke patients for promoting recovery of muscle strength.[1,2] We applied TES not only for that purpose but also for correcting gait disturbance due to lower extremity flexor reflex in walking.

CASE REPORT

A 51-year-old man was admitted to a local hospital suffering from sudden dizziness and loss of consciousness due to intracerebral hemorrhage on January 26th, 1998. Although he underwent surgical evacuation, left hemiparesis was remained postoperatively. He was complicated hemorrhagic enteritis, and the beginning of rehabilitation was delayed. After the first 6months of rehabilitation, the patient was able to walk with KFAO and Quad cane. For more intensive rehabilitation, the patient was admitted to Hokkaido University Hospital on October 21st ,1998.

REHABILITATION PROBLEM

1 Poor recovery of lower extremity extensor muscles strength including hip extensor and knee extensor.

2 The presence of pes varus.

3 Severe synergistic flexor reflex appeared in left leg during heel contact, resulting in gait disturbance.

Because of these problems, the goal in locomotor activities of daily living seemed to be wheel chair bound by conventional rehabilitation technique.

METHODS

We applied TES to this patient to suppress the synergistic flexor reflex and improve the gait. He underwent percutaneous intramuscular electrodes inlaying operation, putting electrodes on superior gluteal, inferior gluteal, femoral, tibial and peroneal nerves. That made it possible to stimulate individual muscle more precisely by using portable stimulator programmed extension pattern. Postoperatively the patient exercised gait training with the help of real time stimulation that was synchronized with walking cycle by physical therapist (PT). This hybrid exercise has been conducted for 6 months.

OUTCOME

A marked and prolonged decrease of flexor reflex was observed. The patient was able to walk only with T-cane and ankle-foot-orthosis (AFO) even when stimulation was off. Gait analysis revealed the improvement of walking speed and stability with weight bearing.

CONCLUSION

Gait disturbance due to severe synergistic flexor reflex was corrected by TES. TES could be a good application to improve gait disturbance due to synergistic flexor reflex.

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Task-dependent excitabilities of motor evoked potential (MEP) were not modified by different muscle contraction modes.

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INTRODUCTION: We have re-examined the contradictory evidence which task-dependent excitation of motor evoked potential (MEP) in first dorsal interosseous (FDI) muscle was stronger in precision grip than in power grip (Datta et al, 1989; Flament et al, 1993). Thus, the first purpose of this study was further insights into the task-dependent excitability of MEP using finger grip movement tasks. To examine above-mentioned task-related MEP responses in detail, we paid particular attention to investigate MEP amplitude dependent on background EMG activity of FDI muscle (Kasai and Yahagi, 1999). Because two basic neural mechanisms, rate cording and recruitment order, for performing tasks may play an important role and these interactions in different tasks reflect in MEP amplitude dependent on background EMG activity. In addition, the second purpose of this study was whether these task-related MEP differences obtained under the condition of tonic muscle contraction are modified by phasic muscle contraction modes, i.e., reaction time condition.

METHODS: In the first step of experiment, during the performing tasks an optimal stimulus intensity of the transcranial magnetic stimulation (TMS) was applied to the motor cortex. MEPs of FDI, extensor carpi radialis (ECR) and flexor carpi radialis (FCR) muscles were simultaneously recorded with increasing background EMG activities step by step in precision grip and power grip. We have compared functional differences of intrinsic and extrinsic hand muscles during isometric (tonic) muscle contraction of both tasks, respectively. In the second step of experiment, subjects were proposed for performing same precision grip and power grip under the reaction time paradigm, which need the phasic muscle contraction.

RESULTS and DISCUSSION: MEP amplitude of FDI muscle dependent on the background EMG activity was found to be different between precision grip and power grip, i.e., MEP amplitudes and regression coefficients in precision grip were larger than those in power grip. Thus, although our present results in MEP amplitude were similar to previous reported evidence, it was new evidence that contributions of synergistic muscle (in particular, ECR muscle) performing these tasks were definitely different. That is, in performing power grip the contribution of ECR muscle is indispensable but not in precision grip. Thus, corticomotoneuronal (CM) cells connected to FDI motoneurons seem generally to be more active during precision grip rather than power grip and there are different contributions of synergistic muscle for performing these tasks. In the second step of experiment, the result obtained from tonic muscle contraction as described above was similar to that of phasic muscle contraction, i.e., the contribution of synergistic muscle (ECR) to perform power grip was definitely different from precision grip, even under the reaction time condition.

CONCLUSION: The evidence obtained from the present study suggests that CM systems seem generally to be more active in precision grip than in power grip as previously suggested by Flament et al. (1993). Furthermore, motor programs related to precision grip and power grip encoded in the brain were not fundamentally modified by different muscle contraction modes.

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P-345

Affect of Visual Feedback on Motor Cortex Excitability during Voluntary Contraction

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INTRODUCTION

Transcranial magnetic stimulation (TMS) of the human motor cortex to elicit motor evoked potentials (MEPs) has been widely used in research on human motor control. TMS is a relatively new technique for the study of human motor pathway. In the exercise physiology field, motor cortex excitability using the technique of TMS is investigated with regard to fatigue, pre-post-exercise and motor image. Voluntary contraction of the target movement is regulated by the visual confirmation, sensibility, actual exerted performance and other feedback. Particularly, visual feedback affects exercise performance. However, no attempt was made to identify the mechanism of this phenomenon. In this study we aimed to investigate the effect of visual feedback of exerted force on the central nervous system using the techniques of TMS and electroencephalogram (EEG).

METHODS

Eight healthy volunteers (one female; aged 22-27 years old) participated. All the subjects provided informed consent for the study. The subjects performed two independent 10% maximal voluntary isometric contractions (MVC) of right elbow (15 seconds duration), with the elbow flexed at an angle of 90°.

Firstly, each right wrist of the subjects was placed in a cuff attached by a wire cable to a strain gauge force transducer apparatus (9E01-L5-100K 100KG SAN-EI). The transducer output was connected to a digital oscilloscope (SS-6122A SYNCHRO SCOPE IWATSU), allowing visual feedback of exerted force, located at eye level 1m from the subjects. Subjects obtained feedback of exerted force and sustained 10% MVC of elbow as accurately as possible. Secondly, as a control, each right wrist of the subjects was placed in a cuff attached to a given load of 10% MVC of elbow by a wire cable (no visual feedback).

In both experiments, Motor cortex was stimulated using a Magstim Model 200 (Magstim Company Ltd., UK) magnetic stimulator with a figure-of-eight coil of 70mm mean diameter windings (Maximum output 2T). MEPs were recorded from Biceps brachii muscle with surface electrodes (Neuropack Λ NIHON KOHDEN). To investigate the activity of cortical potentials, EEG signals were recorded with linked-ear reference from F_3, F_z, F_4, C_3, C_z, C_4, P_3, P_z, P_4, O_1 and O_2 of the 10-20 International System. The EEG signals were amplified and band-pass filtered between 0.5 and 70Hz by a EEG/DAE-2110 Neurofax NIHONKODEN and then sampled at

200Hz. The frequency range of 3-50Hz was analyzed. The power spectra were computed by a Fast Fourier Transform algorithm with a frequency resolution of 0.25Hz.

RESULTS

From Fig. 1 (A) typical responses of MEPs from a single subject are shown comparing visual feedback with control. The MEPs data from all the subjects are summarized in Fig. 2 (B). In all subjects the MEPs amplitude in Biceps brachii muscle during visual feedback was larger than control values. The differences were statistically significant (*P<0.01*). So as to clarify the same contraction level between visual feedback and control, we measured the integrated EMG. EMG of back ground activity between visual feedback and control was not significantly different. The alpha band oscillation over O_1 and O_2 decreased during visual feedback.

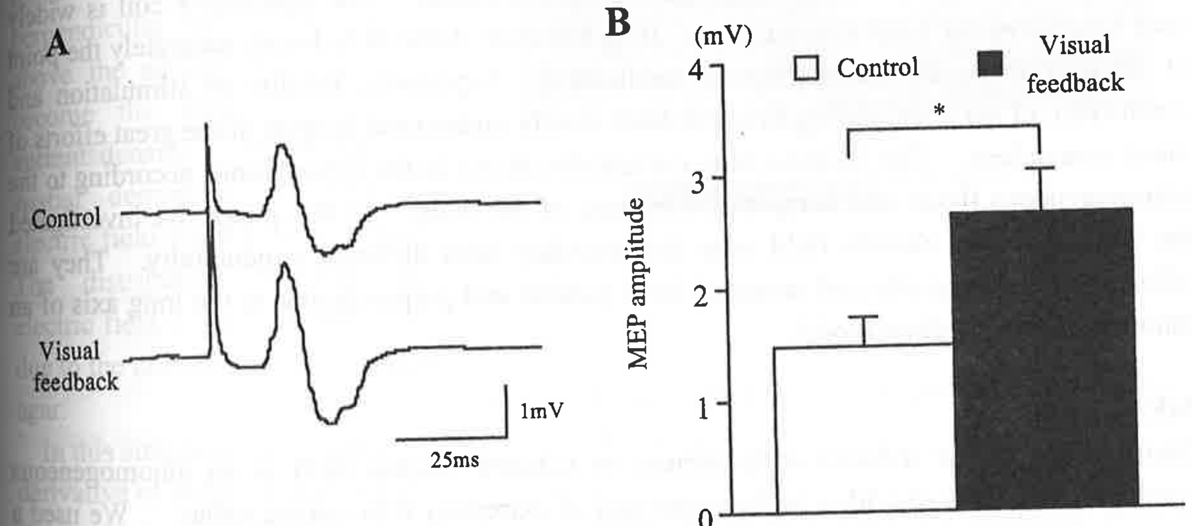

Fig. 1. (A) Typical MEPs responses of Biceps Branchii muscle during Visual feedback and Control. (B) Mean values (±S.E.) of MEPs for all subjects in the two experimental conditions. Significant difference between control and visual feedback **P<0.03*.

DISCUSSION

This study shows that MEPs facilitation occurs with visual feedback of exerted force, and this facilitation is likely to be primarily due to an increased cortical excitability. This mechanism explains the increased cortical excitability of motor cortex as being related to visual feedback. Furthermore, the alpha band oscillation decreased in the occipital lobe. It is likely that the increase in attention levels necessitated by visual information inhibits the alpha band oscillation in the occipital lobe. In addition, the processed visual information seems to affect motor cortex excitability. These experiments suggested that motor cortex excitability is closely concerned in visual feedback.

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Localization of Electric Field in an Inhomogeneous Medium exposed by Pulsed Magnetic Field

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INTRODUCTION

Many researchers have been interested in magnetic stimulation of the nervous system. It is non-invasive and free from pain in the treatment method, compared to the conventional therapy[1]. There are reports that the method can be applied to the clinical diagnosis, such as the examination of the brain nerve diseases. Recently, the magnetic stimulation has also been investigated in the other fields such as rehabilitation. The figure-of-8 coil is widely used to achieve the focal stimulation. It is, however, difficult to locate accurately the point of stimulation in an inhomogeneous medium[2]. Especially, focality of stimulation and mechanism of nerve excitation have not been clearly understood in spite of the great efforts of many researchers. The induced eddy current distributes in the living tissue, according to the inhomogeneous tissue and complexes structure of the body. In this paper, we investigated the localization of electric field near the boundary with different conductivity. They are affected by the magnetic coil arranged both parallel and perpendicular to the long axis of an inhomogeneous medium model.

METHODS

Distributions of the induced eddy current or induced electric field in an inhomogeneous conductor is measured with a probe composed of extremely thin coaxial cable. We used a magnetic stimulator, Magstim Model 200, which is widely used in clinical fields.

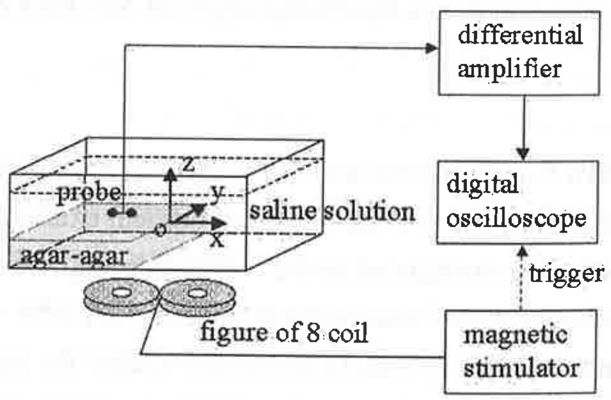

Fig.1 Experimental set-up of the inhomogeneous model.

A rectangular prism conductor with a base 7 cm x 27 cm and a height of 7 cm made of plastic are filled with saline solution in height 6 cm. Two types of agar-agars with different concentration (0.3% or 1.5%) are prepared and each of them is placed in the saline tank (inhomogeneous medium). We measured the distributions of induced electric field in the saline solution. From these results, we calculated the spatial derivative of induced electric field. Fig.1 shows the experimental set-up of the inhomogeneous model.

RESULTS

In the case of agar-agar whose sodium chloride concentration is 0.3% and placing the coil perpendicular to it, the parts above the surface of agar-agar become the point of highest current density. The results of spatial derivative of induced electric field are shown in Fig.2. The distribution of induced electric field is very complicated due to the arrangement of the agar-agar.

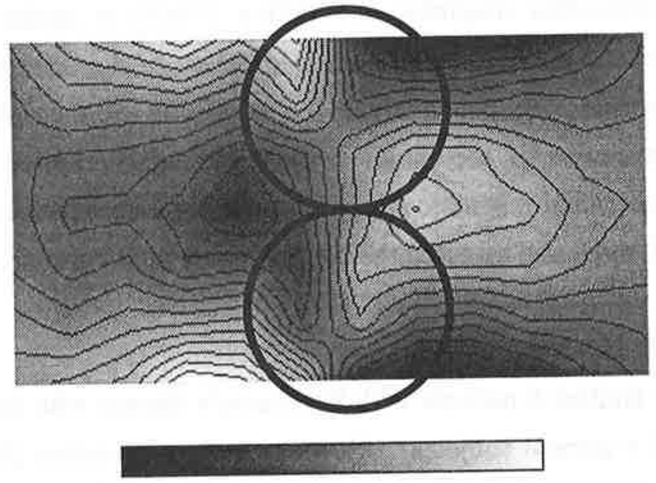

Fig.2 Contour map of spatial derivative of measured electric field.

In this situation, the negative derivative of induced electric field is very high not at the virtual cathode of magnetic stimulation but at the boundary between tank wall and saline solution. These results suggest that the flow of induced current by magnetic stimulation is influenced significantly on the conductivity or the structure of the human tissue.

CONCLUSIONS

This paper investigates the distributions and the spatial derivative of induced electric field by magnetic stimulation. The results of these experiments suggested that the spatial derivative of field depends on the structure of the volume conductor or the conductivity of medium.

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P－347

Central Motor Inhibitory Mechanism in Patients with Parkinson's Disease
A Study with Paired Transcranial Magnetic Stimulation

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INTRODUCTION

Transcranial magnetic stimulation (TMS) is useful to study the changes of the central excitatory-inhibitory system in diseases of the central nervous system including Parkinson's disease. We can analyze the condition of the inhibitory mechanism by measuring the amplitudes of the motor evoked potentials elicited by paired TMS. We applied paired transcranial magnetic stimuli at interstimulus intervals of 10 milliseconds ranging from 30 to 200 msec and assessed the central motor inhibitory mechanism in Parkinson's disease.

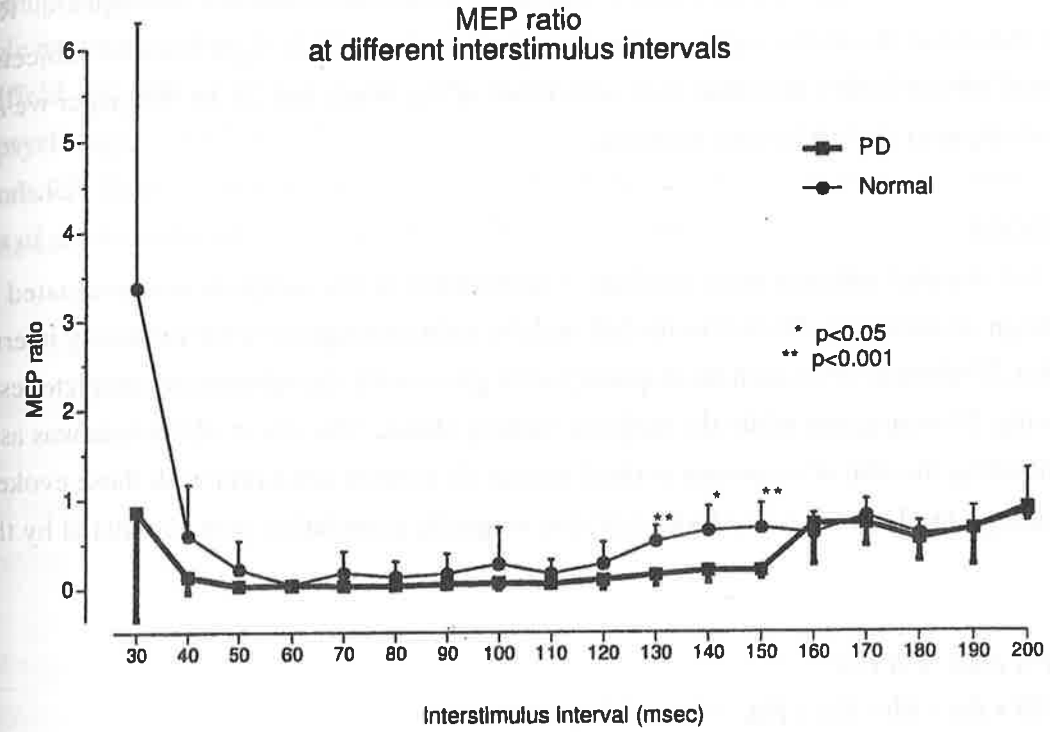
METHODS

We studied 6 patients with Parkinson's disease who had no tremor at the time of examination and 4 normal subjects. Two magnetic stimulators (Magstim model 200) and a circular coil (inner diameter, 50mm; outer diameter, 135mm) were connected to the device (BiStim Module) that controlled interstimulus intervals. Surface electrodes were placed over the first dorsal interosseous muscle and the position on the scalp contralateral to the side of EMG recording from which TMS produced a motor evoked potential (MEP) of the highest amplitude was determined, and thereafter, all magnetic stimuli were performed at this position. Threshold intensity was defined as the lowest stimulus intensity required to elicit five MEPs of at least 50 μV out of 10 stimuli given at rest, and was expressed as a percentage of the maximal output of the stimulator. Paired TMS pulses were given at the same intensity of 110% of the threshold intensity under conditions of rest. Interstimulus intervals were dropped every 10 milliseconds from 200 to 30 msec. The MEP ratio that was defined as the ratio of the 2nd MEP (evoked by the test stimulus) to the 1st MEP (evoked by the conditioning stimulus) in the amplitude was calculated at each trial. Ten trials were performed at each interstimulus interval and ten resultant MEP ratios were averaged.

RESULTS

There were no significant differences in the threshold intensities and the 1st MEP amplitudes between the normal subjects and the patients. MEP ratios were relatively low at interstimulus intervals ranging from 50 to 120 msec in both of the normal subjects and the patients, but MEP ratios were higher at intervals ranging from 130 to 150 msec in the normal

subjects than in the patients ($p<0.05$ at 130 and 150 msec, $p<0.001$ at 140 msec). There were similar MEP ratios at intervals ranging from 160 to 200 msec in both groups. MEP ratios tended to be higher at intervals of 30 and 40 msec in the normal subjects than in the patients, but there were no significant differences between groups due to large individual variations.



DISCUSSION and CONCLUSION

The MEP ratio represents the balance of the excitatory and inhibitory condition in the central motor system. The low MEP ratio means the inhibitory predominance. The conditioning stimulus activated the inhibitory mechanism in the central motor system and the MEP ratios were suppressed at interstimulus intervals ranging from 50 to 120 msec in both of the normal subjects and the patents. The MEP ratios recovered gradually in the normal subjects at intervals from 130 msec, but the MEP ratios were still low in patients at intervals ranging from 130 to 150 msec, which suggests that the inhibitory predominance lasts longer in the patients than in the normal subjects. The predominant inhibition in the central motor system that is shown in this study may be related to the slowness of the movement in patients with Parkinson's disease.

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Speech dominancy of left handeders evaluated by single magnetic stimulation

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INTRODUCTION

Tokimura et al.1) showed that speech could modulate the excitability of cortical arm areas. We proposed this new technique as a useful method to determine dominant hemisphere. Reading aloud enhanced the motor reponses in the right hand muscle in right handed subjects. The results of this technique correlate well with those of the Wada test.2) In this paper we applied this technique to the left handed subjects.

METHODS

Eight left handed subjects were studied. Handedness of the subjects was evaluated by the Edinburgh inventory3). Stimuli to the left and the right hemisphere were randomly intermixed. The first 20 stimuli (10 to each hemisphere) were given with the subjects at complete rest. The remaining 20 were given while the subjects reading aloud. The effect of the task was assessed by comparing the size of responses evoked during the control condition with those evoked during reading aloud. A laterality Index (*LI*) for magnetic stimulation was calculated by the formula;

$Rrt = Prt\ read / Prt\ rest$

$LI = 100 \cdot Rrt - Rlt / Rrt + Rlt, -100 \leqq LI \leqq +100$

RESULTS

EMG responses were enhanced only in the left hand in 4 subjects, in the both hands in 3, and only in the right hand in 1, which indicated that 4 were right hemisphere dominant, 3 were bilateral, and 1 was left. LI was from -86.2 to +38.8 (Mean = -17.0, S.E.M. = 12.8). 6 were minus and 2 were plus.

DISCUSSION

Our results were different from the previous work4) that 70% of left handers were left hemisphere dominant, 15% were bilateral, and only 15% were right hemisphere dominant in their series of amobarbital studies. This difference may originate from the charcteristics of our test which is indirect information through corticospinal excitability, or from the difference of the approaches; ours is an activation study and the amobarbital test is a suppression study.

CONCLUSION

Left handers may have mixed hemispheric dominancy than ever reported.

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P-349

Transcranial Magnetic Cerebellar Stimulation for the Treatment of Spinocerebellar Degeneration

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INTRODUCTION

To estimate the efficacy of transcranial magnetic stimulation (TMS) over the cerebellum for spinocerebellar degeneration (SCD). Symptoms of SCD limit patients' daily life. However, other than stale thyrotopin releasing hormone[1] which therapeutic effect is only limited, no innovational treatment has appeared yet in these days. Recently TMS is applied to neuro-psychological diseases as a therapeutic tool.[2-5]

PATIENTS AND METHODS

10 patients (27-76 years, five men, 1.5-17 years of disease duration) with SCD were enrolled (Table 1). They gave us written informed consent prior to the start. For consecutive 21 days 10 magnetic stimuli with strength of 2.5 times of motor threshold were delivered over Iz (international 10-20 system) and 4 cm lateral to the right and left from Iz, respectively.

RESULTS

No adverse events were observed. The time required and the number of steps during a 10 m walk significantly decreased from 11.18±4.31 (Mean±SD) sec to 8.06±2.79 sec ($p<0.005$) and from 20.60±6.72 to 17.33±5.68 ($p<0.005$), respectively. The number of feasible steps on tandem gait test significantly increased from 1.30±1.42 to 5.70±4.95 ($p<0.01$). The total length of tracing body balance for 30 seconds measured by a gravicometer was decreased from 75.52±43.55 cm to 67.43±41.00 cm, but it was not significant. Quantitative blood flow measured by SPECT using Patlak plot method[6] in the putamens, cerebellum and pons significantly increased from 50.11±11.43 ml/100g/min to 56.61±8.91 ml/100g/min ($p<0.05$), from 44.45±11.67 ml/100g/min to 51.14±9.35 ml/100g/min ($p<0.05$) and from 26.37±9.12 ml/100g/min to 34.71±8.45 ml/100g/min ($p<0.05$), respectively.

DISCUSSION AND CONCLUSION

We think TMS over the cerebellum is a potent candidate for an effective treatment to SCD. Although the actual mechanisms of the improvement are not clear, the increase of regional blood flow in the putamens, cerebellum and pons after three-week TMS may suggest the functional activation in the cerebellum and related regions.

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Patient number	Age / Gender	Diagnosis	Disease duration	MRI findings
1	57 / M	SCA 6	5 years	CR: moderate
2	27 / M	SCA 7	7 years	CR: moderate BS: mild
3	57 / F	OPCA	1.5 years	CR: moderate BS: moderate
4	32 / M	SCA 1	1.5 years	CR : mild
5	63 / M	OPCA	2 years	CR: moderate BS: moderate
6	76 / F	SCA 6	2 years	CR: moderate
7	54 / F	SCA 6	7 years	CR: moderate
8	61 / F	Holmes	11 years	CR: moderate
9	64 / M	OPCA	4 years	CR: moderate BS: moderate
10	61 / F	Holmes	17 years	CR: moderate

Table 1

Patients' profile enrolled in this trial.

CR: moderate; moderate atrophy in the cerebellum

BS: mild atrophy in the brainstem.

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Central Motor Conduction Time Study in a Patient with Lightning Strike Injury

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Clinical Picture
A patient sustained a lightning injury while using the telephone when he felt current passing through his whole body. He had a rapid onset of upper and lower limb weakness within half an hour of the strike. There were no sensory or bulbar complaints or sphincter disturbances. He had a history of diabetes mellitus for several years for which he was on medication. Neurological examination revealed proximal weakness in both lower limbs and milder involvement of the upper limbs. There were no sensory signs. Reflexes were present except for the knees.

Investigations
Investigations revealed a mild sensorimotor demyelinating polyneuropathy consistent with DM peripheral neuropathy. Cortical latencies were mildly delayed in the tibial somatosensory evoked responses. Transcranial magnetic stimulation(TMS) studies showed prolonged CMCTs to the upper limbs and lower limbs. MRI of the brain was normal but cervical spine showed degenerative changes with C3,4 disc prolapse not causing any serious cord compression.

Follow up
The patient showed clinical improvement one month post injury. A repeat TMS at 2 months revealed normalisation of the CMCTs to the upper and lower limbs. There was no residual neurological deficit detectable and he remains asymptomatic.

Conclusion
The TMS showed dynamic changes suggesting a transient non axonal insult to the motor tracts mainly. This suggests a probable demyelinating process caused by the high voltage electric current through the nervous system, in particular the central motor tracts.

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Changes in the electroencephalogram monitored during repetitive transcranial magnetic stimuli

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Introduction

Transcranial magnetic stimulation (TMS) and repetitive TMS (rTMS) have been widely used to evaluate the central nervous system since the first description of TMS in humans by Barker[1] in 1985. It has been suggested that rTMS has therapeutic potentials in various disorders[2]. For the clinical application of rTMS, it is necessary to evaluate the safety margin of the intensity and frequency of the stimulation. We experienced a case that showed changes in electroencephalogram (EEG) recorded during low-frequency rTMS without any clinical symptoms.

Case Report

A 56-year-old female was admitted to our hospital on October 6, 1999 for treatment of involuntary movement (IVM) of the trunk and lower limbs that had persisted for 8 years. In 1991, she suffered a spinal cord injury from the thoracical to lumbar levels and a shearing fracture at the L1/L2 level. IVM in her left thigh begun a few months after the injury. In 1997, the IVM became worse and spread from the trunk to both limbs.

Treatment for the IVM was performed by means of drugs, transcutaneous electrical nerve stimulation and lumbar extradural nerve block. However, none of these treatments had any effect on the IVM. Therefore, the indication of cordotomy was inquired for the patient. We have investigated the efficacy of rTMS for IVM. Before performing cordotomy, the patient was dully informed of rTMS and consented to the trial study of rTMS.

The trial study was done according to the following protocol: 50 stimuli of 0.25 Hz rTMS at the intensity of 110% of the motor threshold were delivered on each side of the frontal area, with one session lasting 5 days.

During rTMS, an EEG was recorded through F3, F4, C3 and C4 leads in addition to videotaping and monitoring an electromyogram (EMG) and motor evoked potentials (MEPs) on the bilateral obliquus externus abdominis. For the purpose of avoiding skin burn, slit-shaped electrodes were used while recording the EEG.

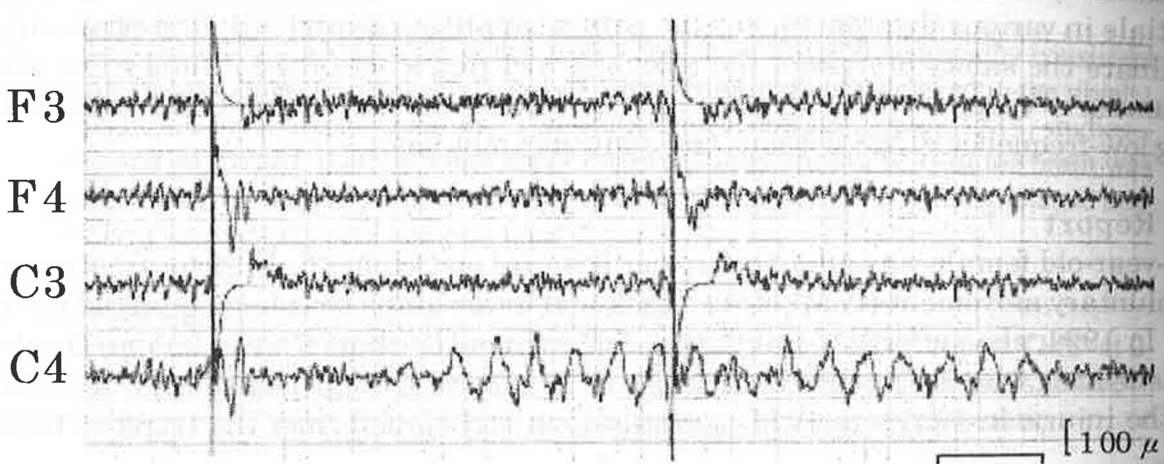
A slowing wave (3-4Hz) was recorded from the C4 lead just after rTMS was begun, and it disappered 3 seconds later. When we continued rTMS, the slowing wave of the EEG was lasted longer (Figure). The EEG did not show slowing before and after rTMS. The patient remained alert, and seizure did not occur. This change was reproducible by rTMS trial performed on another day, although the EMG did not show abnormal discharge in these short stimuli. We discontinued the trial of rTMS.

Discussion

We could not mention the efficacy of rTMS for IVM, because the trial study was discontinued in the middle of first session.

In the guidelines for rTMS[2], monitoring an EEG is only a recommendation. In some case studies[2,3], the relationship between seizure and EEG change was investigated. In most of them, the EEGs obtained immediately after the seizure showed slowing but normalized whithin 1 or 2 days. In our case, a slowing wave was observed without any symptoms. However, we do not know what would have happened if rTMS trial had been continued on this patient.

We believe that monitoring an EEG is necessary for the safe application, when rTMS is used for the therapeutic approach.



Figure

The EEG recorded during the magnetic stimuli showed slowing.

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P-352

MOTOR EVOKED POTENTIAL STUDY IN CAUSALGIA-DYSTONIA SYNDROME

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SUMMARY

To detect alterations in cortical excitability, we performed the study about paired magnetic stimuli and silent period for the patient with causalgia-dystonia syndrome and normal subject. This syndrome includes the strong pain and dystonia. The amount of inhibition at long interstimulus intervals in paired magnetic stimuli was stronger in the patient with causalgia-dystonia syndrome than normal subject. The amount of inhibition did not differ significant at short interstimulus intervals. No significant difference was detected between the affected side and the unaffected side in the patient with causalgia-dystonia syndrome in the response to paired magnetic stimuli. These results were similar to the results of the patients with Parkinson disease and dystonia papered in the past.

INTRODUCTION

Some attempts have been made to detect alterations in cortical excitability, including the measurement of silent period following evoked potentials and the technique using paired magnetic shocks. At short interstimulus interval in paired stimuli, Kujirai et al. found an inhibition of the test response at interval below 5 ms in relaxed as well as in active muscle, and provided evidence that this inhibition is the result of activity in intracortical inhibitory circuits. At long interstimulus intervals, Claus et al. found strong inhibition from 30 to 200 ms. They noticed complete suppression of the test response at 100 ms and strong inhibition at 200 ms. In patients with dystonia, Ikoma et al. studied in 1996, and Rona et al. studied in 1998 using paired stimuli.

This time, we performed the study about silent periods and paired stimuli to the patient with causalgia-dystonia syndrome to compare to normal subject and the patients with other diseases.

CASE REPORT

A 46-year-old female was admitted the Hokkaido Univ. Med. Hospital, suffering from severe pain and dystonia at the left hand. She underwent lumber laminectomy for lumber hernation at 43 years old. Immediately after operation, she developed pain and edema of left lower extremity. The pain was very strong like burning pain. She could move her left leg only a little and could not walk. She needed to use wheel chair for daily life. NSAIDs, morphine and other drug therapies were not effective. Only epidural block of lidocaine was effective for her pain and edema. At 45 years old, she underwent the operation of implantation of spinal cord stimulation. After the operation, pain and edema decreased remarkably and she became to be able to walk. But at 46 years old, she developed pain at left hand and dystonia with flexion contraction at left Ⅲ, Ⅳ, Ⅴ finger. The pain was moderately strong with hyperesthesia at rest and move. She was admitted to our hospital at 46 years old.

METHODS

We tested silent periods and paired motor evoked potentials for the patient bilaterally and normal subject (24-year-old female).

Stimulation technique: Patients were seated in a comfortable chair. Transcranial stimulation was performed with Magstim D200 magnetic stimulators and a large round coil with an outer diameter of 14 cm. Paired stimuli were delivered using two magnetic stimulators connected to the same stimulating coil through a Bistim module. In order to investigate the time course of the effects under study, we used a conditioning-test design with paired stimuli given at short (3, 5, 7, 10, 15, 20 ms) and long (100, 150, 200, 250 ms) intervals. Stimuli were delivered in four blocks of trials, consisting of eight trials each of 2 × 4 conditions for short intervals and 2 × 3 conditions for long intervals (that is, control + 3-5-7 ms, control + 10-15-20 ms, control + 100-150 ms, and control + 200-250 ms). Within each block, paired shocks at different intervals and control shocks were randomly intermixed and given every 6 s. To obtain an inhibitory effect, the intensity of the conditioning stimulus was set at 80% of motor threshold with short interstimulus intervals and at 150% of motor threshold with long interstimulus intervals; the test stimulus was always delivered at 125% of motor threshold. Threshold intensity was defined as the lowest stimulus intensity required to elicit five MEPs of at least 50 μV out of 10 stimuli given at rest. All stimuli were delivered though the Bistim module, which reduces the stimulator output by ~30%. Actual intensity values, therefore, are 30% lower than those shown on the stimulator display. Because of muscle contraction was very small amplitude, the threshold was determined and all paired stimulus experiments were performed during rest condition. We also measured the silent period obtained after a single magnetic pulse delivered at 150% of motor threshold during a submaximal muscle contraction.

RESULTS

Paired stimuli: *Short interstimulus intervals:* The waves of paired stimulation at short intervals were shown in Figure 1. The differences between patient and control subject at intervals from 3 to 20 ms were not significant (Figure 2). *Long interstimulus intervals:* The waves of paired stimulation of patient affected side at long intervals were shown in Figure 3. The test responses were significantly inhibited at 100, 150, 200 ms (100 ms, 0%; 150 ms, 0%; 200 ms, 26%)(Figure 4). Test responses were more inhibited in the patient compared with normal control.

Cortical silent period: The silent period after transcranial magnetic stimulation was significantly longer in the patient (affected side: 173 ms, unaffected side: 210 ms) compared with normal subject (129 ms).

Threshold: The threshold of patient was 63% at left ADM and 74% at right ADM, and that of normal subject was 50% at right ADM. The threshold was not significant different in the patient and normal subject.

Motor evoked potential amplitude: The mean amplitude of conditioning test in 150% of threshold showed 0.62mV in control, 4.33mV in the patient.

CONCLUSIONS

We performed the study about paired magnetic stimuli and silent period in the patient with causalgia-dystonia syndrome. Previous studies with subthreshold or threshold conditioning stimuli delivered at short interstimulus intervals have provided evidence for an inhibition of the test response at intervals up to 5 ms. With interstimulus intervals of 10-15 ms, slight fascilitation could be observed. The amount of inhibition at short interstimulus intervals did not differ significantly between patients and normal subject. No significant difference was detected between the affected side and the unaffected side in the patient with causalgia-dystonia syndrome in the response to paired magnetic stimuli. The amount of inhibition at long interstimulus intervals differed significant between patient and normal subject. The inhibition of test stimuli was stronger in the patient than normal subject. These results were almost the same as other patients with Parkinson disease and dystonia papered in the past.

The mechanisms responsible for the inhibition seen at long interstimulus intervals are studied. Several mechanisms might be responsible for this phenomenon including recurrent inhibition by the Renshaw cell system, after-hyperpolarization potential and cortico-spinal inhibitory inputs. And several neurotransmitters may be involved in the period of inhibition seen at short and long interstimulus intervals. Gamma-aminobutyric acid (GABA) has prolonged inhibitory effects that may last for 200 ms or more, and it is therefore likely that the release of GABA accompanies the inhibition of the test response.

Several authors have reported that the cortical silent period is shorter in patients with

Parkinson disease and dystonia, but this time, cortical silent period showed longer in the patient with causalgia-dystonia syndrome.

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Figure 1 Examples of the response to paired magnetic stimuli delivered at short interstimulus intervals in patient (left ADM).
Horizontal calibration 10ms, vertical calibration 2mV.

Figure 2 Motor potentials evoked by paired magnetic stimuli at short interstimulus intervals, expressed as percentage of an unconditioned control response.
Y-axis show % of unconditioned response, and X-axis show interstimulus intervals.

Figure 3 Example of response to paired magnetic stimuli delivered at long interstimulus intervals in patient (left ADM).
Horizontal calibration 50ms, vertical calibration 2mV.

Figure 4 Motor potentials evoked by paired magnetic stimuli at long interstimulus intervals, expressed as percentage of an unconditioned control response.
Y-axis show % of unconditioned response, and X-axis show interstimulus intervals.

P-353

The effects of repetitive transcranial magnetc stimultion in Parkinson syndrome

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Introduction

Barker firstly used transcranial magnetic stimulation (TMS) in human in 1985, and then TMS has been used to evaluate the central nerve system, for example the conduction time from motor cortex to the muscles, excitability and inhibition of functional motor system and the reorganization after brain damage, and so on. Recently, repetitive transcranial magnetic stimulation (rTMS) has been studied as a therapy in depression and akinesia in Parkinson disease. We studied the effects of rTMS in Parkinson syndrome and the safety of rTMS.

Methods

The subjects were 5 patients with Parkinson syndrome (5 females, average of age: 54.4 ±4.8years). They were 1 patient with progressive supranuclear palsy (PSP), 2 patients with multiple system atrophy (MSA), 1 patient with Parkinson disease (PD) and 1 patient with juvenile parkinsonism. In the method of rTMS, parameters of rTMS were ①slow frequency rTMS (0.3Hz), ②30times on each cerebral hemisphere per day, ③ 110~120% strength of motor threshold, ④5 days for a week and ⑤using of round coil. We were monitoring by EEG monitor, EMG monitor and video monitor during rTMS and after rTMS. We examined blood chemistry, SPECT, EEG and neurophisiological test. And we evaluated about Unified Parkinson Disease Rating Scale (UPDRS), Hasegawa Dementia scale (HDS-R), psychological test like MAS, SDS and CMI, 10m gait test and gait analysis.

Results

Table.1 shows the results. 4 patients with Parkinson syndrome were subjectively feeling the effects of rTMS. Their subjective symptoms were to be easy walking, to be clear in their head and to be fine. The test battery on their improvement after rTMS were UPDRS for 2 patients, SDS for 3 patients, MAS and HDS-R for 1patents and 10mgait test and grasping power for 1 patient. There were no side effects for 5 patients after rTMS.

Discussion

Patients with depression state had been received electric convulsion shock therapy, but it often induced them convulsion and memory loss. Recentry, rTMS on frontal lobe had been reported to be effective for patients with severe depression. And it was reported the effects of rTMS for Parkinson disease with gait disturbance. We examined 5 patients with Parkinson syndrome to have rTMS and the rTMS was effective to the 4 patients. In particular, the patients with PSP became good awareness and increased motivation in her daily living and physical exercise. rTMS induces no convusion by examined parameters like frequency, intensity, trains of rTMS and interval of trains. This indicates that rTMS is one of noninvasive therapies for patients with gait disturbance, low motivation and drowsy.

	age	sex	disease	improvement	change of the test battery
1	57	female	PSP	+	UPDRS,SDS,MAS,HDS-R
2	62	female	MSA	-	
3	50	female	JP	+	UPDRS,SDS
4	49	female	MSA	+	SDS,10m gait, grasping power
5	54	female	PD	+	subjective symptom (gait etc)

Table 1.

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Silent period in spinocerebellar degeneration and Parkinson disease

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Introduction

Transcranial magnetic stimulation (TMS) has been evaluated in the excitability and inhibition of motor cortex. The cortical silent period (SP) is one of the methods to evaluate motor function. We studied it in the difference between spinocerebellar degeneration (SCD) and Parkinson disease (PD).

Method

The subjects were 6 patients with SCD (4 males and 2 females,age of average:60.0±15 years) and 10 patiens with PD (6 males and 4 females,age of average: 62.0±6.8 years). They were ordered to effort their right abductor pollicis brevis muscle (APB) and were received TMS using round coil. The intensities of TMS were 80, 100, 120 ,140 160% of motor threshold (MT) of APB. SP was measured from the recording of the surface EMG of APB. We used ONE-facter ANOVA in data analysis.

Results

The average of SP in SCD was 0.0ms, 39.2ms, 107.5ms and 123.6ms by stimulation of each 80%, 100%, 120% and 140% MT. The average of SP in PD was 7.3ms, 17.1ms, 39.7ms and 47.3ms and 63.3ms by each stimulation of 80%, 100%, 120%,140% and 160% MT. There was a significant difference in SP between SCD and PD in 120% and 140% MT ($p<0.001$) (Fig.1).

Discussion

SP is the transient disappearance of muscle discharges during voluntary muscle contraction after TMS. It is used the evaluation of inhibition in functional motor system. The average of SP in normal subjects is generally more than 100ms, but it is changed by the intensity of TMS. Then, we studied to measure SP keeping the intensity of TMS with the basis of MT in their APBs. SP in patients of SCD became normal latency by TMS of 120% MT, and SP in patients of PD became normal latency by TMS of 200% MT. The results indicated that there was the different functional mechanism of inhibition in motor system between SCD and PD. We think that abnormal SP in PD

indicates the cortical dopamin loss and the excessive neuronal activity in medial pallidum. The dysfunction of inhibition system in cerebello-thalamo-cortical pathway was proved by paired-magnetic stimulation in SCD. It is said that late phase of SP shows the intracortical inhibition . Our hypothesis is that the intracortical inhibition in SCD is normal or rather excessive. The present study indicates that SP is non-invasive good method in evaluating of motor system function in each impairment.

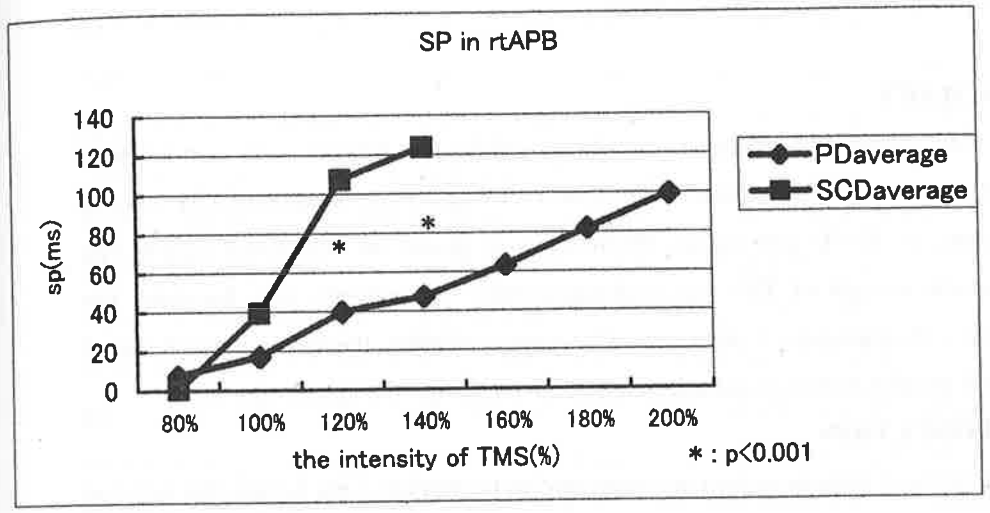

Fig.1 SP in SCD and PD

P-355

EFFECT OF TRANSCUTANEUS THERAPEUTIC ELECTRICAL STIMULATION ON SACRAL RESION.

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SUMMARY

We used therapeutic electrical stimulation (TES) for patients with non-inhibited neurogenic bladder. The patients underwent TES with a pulse duration of 150 μsec at frequency of 20 Hz and surface electrodes were placed on their sacral region. The maximum strength of TES was maintained below the patient's pain threshold. For patients with neurogenic bladder caused by spinal cord injury, the real time monitoring of internal bladder demonstrated a decrease of the pressure immediately after TES.

INTRODUCTION

Three types of nervous system are concerned to micturition. One is pudendal nerve as voluntary nerve which supplies motor fiber to external sphincter of urethra, one is pelvic nerve as parasympathetic nerve which supplies to bladder detrusor muscle with strong contruction and the last is hypogastric nerve as sympathetic nerve which supplies to trigonum vesicae and prostatic urethra. At the supraspinal level, connections from the cerebral cortex and hypothalamus to the potine micturition center are poorly understood. Lapides, classified into five types, uninhibited neurogenic bladder, reflex or automatic neurogenic bladder, autonomous neurogenic bladder, motor paralytic bladder, and sensory paralytic bladder. After stroke, uninhibited neurogenic bladder was most frequent. In spite of small volume of urine, detrusor muscle worked overactive. So, micturition became frequent. Generally they were used anticholinergic drugs for relaxation of a detrusor and inhibition of pelvic nerve activation. Recently, the effect of therapeutic electrical stimulation was reported. We applied TES on sacral lesion. The effect of transcutaneous electrical stimulation of sacral region for neurogenic bladder has already reported, but that mechanism has not been well understood. We tested cystmetry with TES on sacral region at real time and found decreasing intravesical pressure. We reported this case with some preliminary considerations.

PATIENT AND METHODS

A 72 year-old-man admitted the Hokkaido University Hospital suffering from imcomplete paraparesis and pollakisuria on April 1999. He received a C3 cervical injury by a traffic accident at 72 years old. Cervical vertebral body compressed the spinal cord. He underwent the laminoplasty. (Fig.1) .Although he recovered. and could take a dinner by himself, but needed help to change clothes or take a bath ever after 7 month of the accident. He admitted to our hospital for rehabilitation. Neurologically, cranial nerve was normal. Muscle strength of right side was normal. But that manual muscle testing demonstrated 3 level on the left arm,and 4 level on the left leg.Hyperreflexia and pathological reflex(Babinski and chadock) were also shown on the left side. He complained incontinece and pollaskiuria(18 times/day).

Transurethrally cystometry(by Manson Co,USA) was performed, using a 12 F double-lumen catheter at a continuous filling rate of 40ml/min to evaluate bladder capacity and detrusor activity. The patient put on surface electrodes (Fig.2)connected to electrical stimulator (ENRAF NONIUS Co. ENS 911)over the S2 to S3 level. After the patient felt maximum desire of void, we started TES. The electrical stimulation was applied with a pulse duration of 150 μsec, a frequency of 20 Hz and with the maximum strength maintained below the patient's pain threshold. We monitored the pressure of internal bladder on real time during transcutaneous TES.

RESULTS

First desire of void was recognized at 168ml. Maximum desire of void was recognized at 253ml. Capacity of bladder was 253ml. After the patient felt maximum desire of void, we started TES. With strength of the electrical stimulation 50mV first, but the pressure of internal bladder indicated no change. So we increased the strength to 60mV. After that, the pressure of internal bladder started to decrease and showed almost 0 cmH_2O. At that time, patient's subjective sign improved. To check the effect of TES, we performed TES for 10 minutes more, but the pressure of internal bladder didn't increase. After 10 minutes, we finished cystometry. (Fig.3)

CONCLUSIONS

The TES for neurogenic bladder was reported in 1963 by Caldwell et al. They implanted electrodes into the pelvic floor for the patients with incontinece of detrusor instability and increase intraurethral pressure by contraction external urethral sphinctor. Therefore, they cured for incontinence by training for weak sphinctor. Methods of TES are transcutaneus, anal, vaginal and intrapelvic electrode. Transcutaneus electrode put on perinium or hypogastric lesion and , plug electrude stimulate vaginal or anal and implantation electrode place in pelvic floor surgically. Tanscutaneus stimulation was not invasive like surgery, used easily but there was the following three disadvantages① Because of high amplitude and current stimulation, patient felt discomfort, pain and exposed to danger of burn. ② It was difficult to stimulate selective nerve or muscle individually . ③ Effective of stimulation was unstable. The purpose was training sphinctor and inhibition for overactive bladder by stimulating pelvic floor muscle. Fall and Lindstrom reported that ① Hypogastric nerve was activated by electrical stimulation at small bladder volumes;② At bladder filling, electrical stimulation inhibited pelvic nerve activation ;i.e. Electrical stimulation worked for collection of urine by spinal reflex pathway. Electrical stimulation applied for incontinence caused by instability detrusor rather than stress urinary incontinence.

It should be unclear which spinal level was associate with reflex pathway of electrical stimulation in sacral lesion. We suggested electrical stimulation might inhibited activation of detrusor via pelvic nerve because intravesical pressure decreased just after electrical stimulation. It was reported that the effect was enhanced by increase of the intensity of stimulation,and carried on the effect after the stimulation (which was called "carry over effect") We thought transcutaneus TES in sacral lesion was useful for patient in home care patient, because devise was simple and not invasive enough to do home treatment

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AUTHORS INDEX

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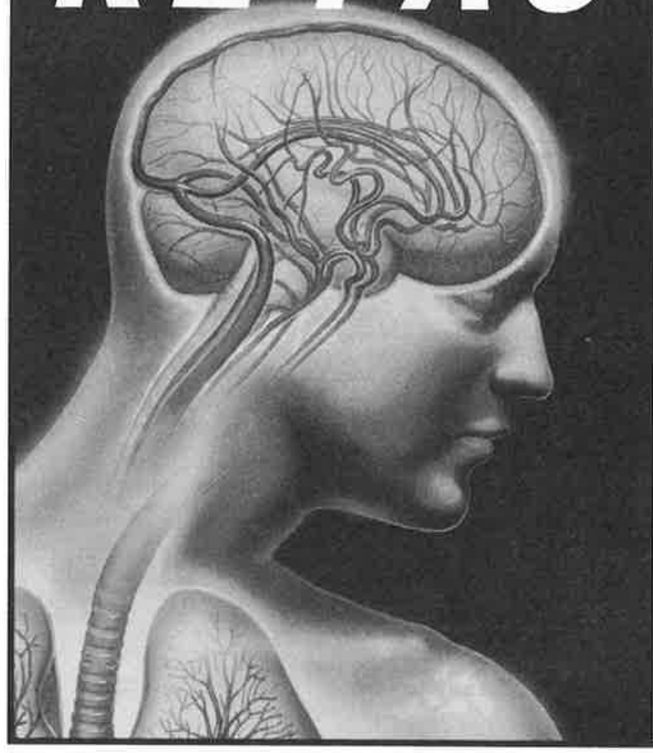

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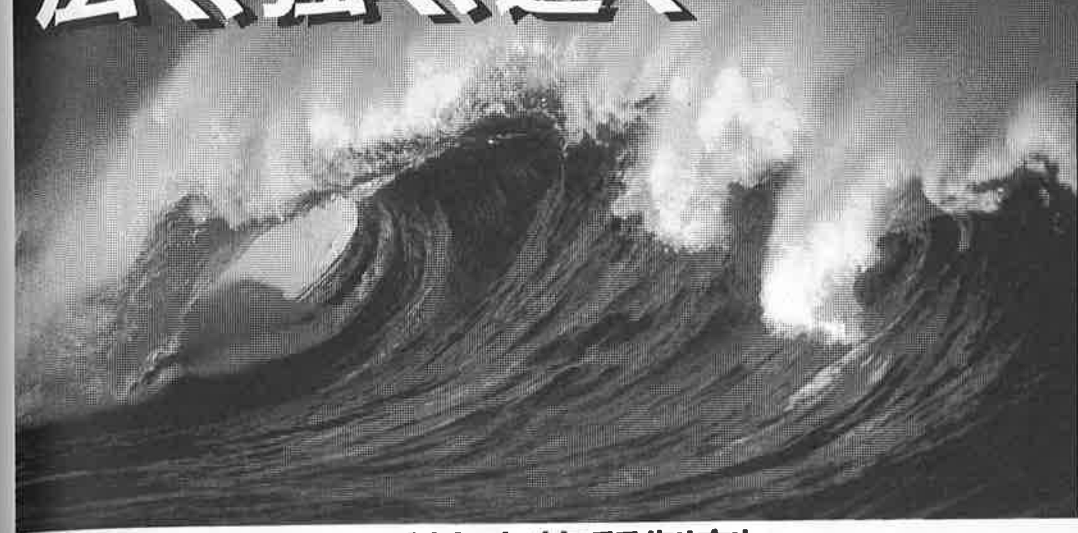

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効能・効果

ブドウ球菌属、レンサ球菌属、腸球菌、ペプトストレプトコッカス属、ブランハメラ・カタラーリス、大腸菌、シトロバクター属、クレブシエラ属、エンテロバクター属、セラチア属、プロテウス属、モルガネラ属、プロビデンシア属、シュードモナス属、インフルエンザ菌、アシネトバクター属、バクテロイデス属、プレボテラ属のうち本剤感性菌による中等症以上の下記感染症
○敗血症　○外傷創感染、手術創感染　○咽後膿瘍、扁桃周囲膿瘍、慢性気管支炎、気管支拡張症（感染時）、慢性呼吸器疾患の二次感染、びまん性汎細気管支炎、肺炎、肺化膿症、膿胸　○腎盂腎炎、複雑性膀胱炎（難治性を含む）、前立腺炎　○胆のう炎、胆管炎、肝膿瘍　○腹膜炎　○骨盤腹膜炎、ダグラス窩膿瘍　○子宮付属器炎、子宮内感染、子宮旁結合織炎（骨盤死腔炎を含む）　○髄膜炎　○角膜潰瘍、眼窩感染、全眼球炎　○中耳炎、副鼻腔炎、化膿性唾液腺炎（耳下腺炎、顎下腺炎）

用法・用量

本剤の使用に際しては、投与開始後3日をめやすとしてさらに継続投与が必要か判定し、投与中止又はより適切な他剤に切り替えるべきか検討を行うこと。さらに、本剤の投与期間は、原則として14日以内とすること。

成人：通常、成人には塩酸セフォゾプランとして1日1〜2g(力価)を2回に分けて静脈内注射又は点滴静脈内注射する。なお、年齢、症状に応じて適宜増減するが、**難治性又は重症感染症**には1日4g(力価)まで増量し、2〜4回に分けて投与する。

小児：通常、小児には1日40〜80mg(力価)/kgを3〜4回に分けて静脈内注射又は点滴静脈内注射する。なお、**難治性又は重症感染症**には1日160mg(力価)/kgまで増量し、3〜4回に分けて投与する。髄膜炎には1日200mg(力価)/kgまで増量できる。ただし、成人における1日最大用量4g(力価)を超えないこととする。

新生児(低出生体重児を含む)：通常、新生児(低出生体重児を含む)には、1回20mg(力価)/kgを0日齢(生後24時間未満)は1日1〜2回、1(生後24時間以降)〜7日齢は1日2〜3回、8日齢以降は1日3〜4回静脈内注射又は点滴静脈内注射する。なお、**重症又は難治性感染症**には1回40mg(力価)/kgまで増量できる。

〈静脈内注射の場合〉
日局「注射用水」、日局「生理食塩液」又は日局「ブドウ糖注射液」に溶解して、緩徐に静脈内に注射する。

〈点滴静脈内注射の場合〉
糖液、電解質液又はアミノ酸製剤などの輸液に加えて、30分〜2時間かけて静脈内に点滴注射する。

〈キットの場合〉
キットSは添付の生理食塩液に、キットGは添付の5%ブドウ糖注射液にコネクターを介して溶解し、30分〜2時間かけて静脈内に点滴注射する。

〈用法・用量に関連する使用上の注意〉
1. 高度の腎障害(例えばクレアチニンクリアランス値:30mL/分以下等)のある患者には、投与量・投与間隔の適切な調節をするなど慎重に投与すること。
2. 本剤の使用にあたっては、耐性菌の発現等を防ぐため、原則として感受性を確認し、疾病の治療上必要な最少限の期間の投与にとどめること。

使用上の注意

●**慎重投与**(次の患者には慎重に投与すること)

静注用及びキット共通
(1)ペニシリン系抗生物質に対し過敏症の既往歴のある患者
(2)本人又は両親、兄弟に気管支喘息、発疹、蕁麻疹等のアレルギー症状を起こしやすい体質を有する患者
(3)高度の腎障害のある患者　(4)高度の肝障害のある患者
(5)高齢者　(6)経口摂取の不良な患者又は非経口栄養の患者、全身状態の悪い患者

5%ブドウ糖注射液添付のキットGのみ
(1)カリウム欠乏傾向のある患者　(2)糖尿病の患者　(3)尿崩症の患者　(4)腎不全の患者

生理食塩液添付のキットSのみ
(1)心臓、循環器系機能障害のある患者 (2)腎障害のある患者

●**重要な基本的注意**
(1)**ショック**があらわれるおそれがあるので、十分な問診を行うこと。なお、事前に皮膚反応を実施することが望ましい。
(2)**ショック発現時に救急処置のとれる準備をしておく**こと。また、投与後患者を安静の状態に保たせ、十分な観察を行うこと。
(3)本剤投与前に感受性の確認が行えなかった場合、本剤投与開始後3日をめやすとして本剤に対する感受性を確認し、本剤投与が適正であるか判断すること。なお、本剤に感受性が認められない場合、速やかに他の薬剤に変更すること。
(4)患者の状態などから判断して、7日以上にわたって本剤を投与する場合には、その理由を常時明確にし、発疹の出現や肝機能異常等の副作用に留意し、漫然とした継続投与は行わないこと。
(5)**新生児(低出生体重児を含む)**に投与する場合は、**日齢に応じた1日投与回数にすること。**

●**相互作用：併用注意**(併用に注意すること)
利尿剤　フロセミド等

●**副作用**
承認時までの調査では、2,548例中447例(17.5%)に、市販後の使用成績調査(1998年8月時点)では、3,803例中345例(9.1%)に臨床検査値の異常を含む副作用が認められている。以下の副作用は上記の調査あるいは自発報告等で認められたものである。

重大な副作用
1)**ショック**(0.1%未満)を起こした例があるので、観察を十分に行い、不快感、口内異常感、喘鳴、眩暈、便意、耳鳴、発汗等の異常が認められた場合には投与を中止し、適切な処置を行うこと。
2)**急性腎不全等の重篤な腎障害**(0.1%未満)があらわれることがあるので、定期的に検査を行うなど観察を十分に行い、異常が認められた場合には投与を中止し、適切な処置を行うこと。
3)**顆粒球減少**(0.1〜5%未満)、また、**無顆粒球症**(0.1%未満)があらわれることがあり、また、他のセフェム系抗生物質で**溶血性貧血**があらわれることが報告されているので、異常が認められた場合には、投与を中止するなど適切な処置を行うこと。
4)**偽膜性大腸炎等の血便を伴う重篤な大腸炎**(0.1%未満)があらわれることがある。腹痛、頻回の下痢があらわれた場合には直ちに投与を中止するなど適切な処置を行うこと。
5)発熱、咳嗽、呼吸困難、胸部X線異常、好酸球増多等を伴う**間質性肺炎、PIE症候群**(0.1%未満)等があらわれることがあるので、このような症状があらわれた場合には投与を中止し、副腎皮質ホルモン剤の投与等の適切な処置を行うこと。
6)**皮膚粘膜眼症候群**(Stevens-Johnson症候群)、**中毒性表皮壊死症**(Lyell症候群)(0.1%未満)があらわれることがあるので、観察を十分に行い、異常が認められた場合には投与を中止し、適切な処置を行うこと。
7)腎不全の患者に大量投与すると**痙攣**(頻度不明)等を起こすことがある。
8)**DIC**(0.1%未満)があらわれることがある。

■使用上の注意の詳細および取扱い上の注意等については、添付文書をご参照ください。

FIRSTCIN®

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(9903)

〈薬価基準収載〉

筋・張・緩・和

指定医薬品
要指示医薬品：注意ー医師等の処方せん・指示により使用すること

筋緊張改善剤

ミオナール®

錠 50mg／顆粒 10%

塩酸エペリゾン製剤

ミオナールは中枢神経系と血管平滑筋の双方に作用して、筋緊張緩和作用と血流改善作用を発揮する薬剤です。
ミオナールは、これらの作用により“コリ↔痛みの悪循環”を多面的に断ち、頸肩腕症候群等に伴う肩こり・頸部痛、腰痛を改善します。
また安全性の面では、臨床報告 12,315 例中、嘔気 62 件 (0.50%)、食欲不振50件 (0.41%)、脱力感53件 (0.43%)など、416 例(3.38%)に副作用が認められています。(1991 年 12 月)
また重大な副作用としてショックを起こすことがあります。

効能・効果

・下記疾患による筋緊張状態の改善
頸肩腕症候群、肩関節周囲炎、腰痛症
・下記疾患による痙性麻痺
脳血管障害、痙性脊髄麻痺、頸部脊椎症、術後後遺症 (脳・脊髄腫瘍を含む)、外傷後遺症 (脊髄損傷、頭部外傷)、筋萎縮性側索硬化症、脳性小児麻痺、脊髄小脳変性症、脊髄血管障害、スモン (SMON)、その他の脳脊髄疾患

用法・用量

錠 50mg： 通常成人には1日量として 3 錠 (塩酸エペリゾンとして 150mg) を 3 回に分けて食後に経口投与する。
なお、年齢、症状により適宜増減する。

顆粒10%： 通常成人には1日量として 1.5g(塩酸エペリゾンとして 150mg) を 3 回に分けて食後に経口投与する。
なお、年齢、症状により適宜増減する。

使用上の注意

禁忌 (次の患者には投与しないこと)
本剤の成分に対し過敏症の既往歴のある患者

1. 慎重投与 (次の患者には慎重に投与すること)
(1) 薬物過敏症の既往歴のある患者
(2) 肝障害のある患者
〔肝機能を悪化させることがある。〕

2. 重要な基本的注意
本剤投与中に脱力感、ふらつき、眠気等が発現することがあるので、その場合には減量又は休薬すること。なお、本剤投与中の患者には自動車の運転など危険を伴う機械の操作には従事させないように注意すること。

3. 相互作用
併用注意 (併用に注意すること)

薬剤名等	臨床症状・措置方法	機序・危険因子
メトカルバモール	類似薬の塩酸トルペリゾンで、眼の調節障害があらわれたとの報告がある。	機序不明

4. 副作用
総症例 12,315 例中、416 例 (3.38%) の副作用が報告されている。(再審査終了時)
(1) 重大な副作用 (頻度不明)
ショック　ショックを起こすことがあるので、観察を十分に行い、異常が認められた場合には投与を中止し、適切な処置を行うこと。

hhc ヒューマン・ヘルスケア企業　Eisai エーザイ株式会社
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1998年1月新様式第1版　●その他の使用上の注意につきましては添付文書をご参照ください。資料請求先：医薬部ミオナール係　G-H₂99.07-1

骨粗鬆症の治療に！

週1回投与で骨量改善

骨粗鬆症の適応症が認められた
初のカルシトニン製剤

特性

1. 天然ウナギカルシトニンのS-S結合をC-C結合に変えた合成ウナギカルシトニン誘導体の骨粗鬆症治療剤です。
2. 20単位週1回の投与により骨粗鬆症に対して、骨量改善効果を示します。
3. 骨吸収抑制作用を示し、骨粗鬆症の骨吸収亢進状態を改善します。(in vitro, in vivo)
4. 骨形成促進作用を有することが示唆されています。(in vitro, in vivo)
5. 副作用発現例は、総症例10,323例中367例で、発現頻度は3.56%でした。
主な副作用症状は、悪心、嘔吐等の消化器症状 129例 (1.25%)、顔面潮紅、熱感等の循環器症状 119例 (1.15%) 等でした。(承認時～1997年12月迄の集計)
重大な副作用はショック、テタニー、喘息発作を起こすことがあるとの報告があります。

【禁忌(次の患者には投与しないこと)】
本剤の成分に対し過敏症の既往歴のある患者

■効能・効果／骨粗鬆症
■用法・用量／通常、成人には1回エルカトニンとして20エルカトニン単位を週1回筋肉内注射する。
■使用上の注意(抜粋)
1. 慎重投与(次の患者には慎重に投与すること)
(1) 発疹(紅斑、膨疹等)等の過敏症状を起こしやすい体質の患者
(2) 気管支喘息又はその既往歴のある患者［喘息発作を誘発するおそれがある。］
2. 重要な基本的注意
(1) 本剤の適用にあたっては、厚生省「老人性骨粗鬆症の予防及び治療法に関する総合的研究班」の診断基準(骨量減少の有無、骨折の有無、腰背痛の有無などの総合による)等を参考に、骨粗鬆症との診断が確立した患者を対象とすること。
(2) 本剤はポリペプチド製剤であり、**ショック**を起こすことがあるので、アレルギー既往歴、薬物過敏症等について十分な問診を行うこと。
(3) ラットに1年間大量皮下投与した慢性毒性試験において、下垂体腫瘍の発生頻度の増加がみられたとの報告があるので、長期にわたり漫然と投与しないこと。[「9.その他の注意」の項参照]
3. 相互作用
併用注意(併用に注意すること)

薬剤名等	臨床症状・措置方法	機序・危険因子
ビスホスホン酸塩系骨吸収抑制剤 パミドロン酸二ナトリウム等	血清カルシウムが急速に低下するおそれがある。高度の低カルシウム血症があらわれた場合には投与を中止し、注射用カルシウム剤の投与等適切な処置を行うこと。	両剤のカルシウム低下作用により、血清カルシウムが急速に低下するおそれがある。

4. 副作用
総症例10,323例中、367例(3.56%)に副作用が認められた。その主なものは、悪心、嘔吐等の消化器症状129例(1.25%)、顔面潮紅、熱感等の循環器症状119例(1.15%)等であった。(承認時～1997年12月迄の集計)
(1)重大な副作用
1)**ショック**(頻度不明)　ショックを起こすことがあるので、観察を十分に行い、症状があらわれた場合には投与を中止し、適切な処置を行うこと。
2)**テタニー**(頻度不明)　低カルシウム血症性テタニーを誘発することがあるので、症状があらわれた場合には投与を中止し、注射用カルシウム剤の投与等適切な処置を行うこと。
3)**喘息発作**(頻度不明)　喘息発作を誘発することがあるので、観察を十分に行い、症状があらわれた場合には投与を中止し、適切な処置を行うこと。[「1.慎重投与」の(2)の項参照]
(2)その他の副作用

分類＼頻度	0.1～5%未満	0.1%未満	頻度不明
過敏症注)	発疹	蕁麻疹	
循環器	顔面潮紅、熱感	胸部圧迫感、動悸、血圧上昇	血圧低下
消化器	悪心、嘔吐、腹痛	食欲不振、下痢、口渇、胸やけ、口内炎	
神経系	ふらつき	めまい、頭痛、耳鳴、視覚異常(かすみ目等)	
肝臓	GOT、GPTの上昇		
電解質代謝		低リン血症	低ナトリウム血症
注射部位	疼痛	発赤、腫脹	
その他	瘙痒感、全身倦怠感	指先のしびれ、発汗、頻尿、浮腫、咽喉部異和感(咽喉部ハッカ様爽快感等)、発熱、悪寒、脱力感	

注)発現した場合には、投与を中止すること。
＊その他の使用上の注意等につきましては、添付文書をご参照ください。

骨粗鬆症治療剤　薬価基準収載

Elcitonin エルシトニン®注20S

劇薬、指定医薬品　(エルカトニン注射液)

製造販売元 旭化成工業株式会社
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H11.11

旭化成

1回30日間分の
投薬可能

厚生省告示第90号により、
平成10年4月1日より適用。

慢性関節リウマチ治療の新しい流れ。

【禁忌(次の患者には投与しないこと)】
(1) 本剤に対し重篤な過敏症の既往歴のある患者
(2) 白血球数3,000/mm³以下の患者[骨髄機能抑制を増悪させ、重篤な感染症、出血傾向等が発現するおそれがある。]
(3) 妊婦又は妊娠している可能性のある婦人[「使用上の注意 5.妊婦、産婦、授乳婦等への投与」の項参照]

【効能・効果】
1.腎移植における拒否反応の抑制
2.原発性糸球体疾患を原因とするネフローゼ症候群(副腎皮質ホルモン剤のみでは治療困難な場合に限る。また、頻回再発型のネフローゼ症候群を除く)
3.ループス腎炎(持続性蛋白尿、ネフローゼ症候群または腎機能低下が認められ、副腎皮質ホルモン剤のみでは治療困難な場合に限る)
4.慢性関節リウマチ(過去の治療において、非ステロイド性抗炎症剤さらに他の抗リウマチ薬の少なくとも1剤により十分な効果の得られない場合に限る)

【用法・用量】
1.腎移植における拒否反応の抑制
通常、体重1kg当り下記量を1日量として、1日1～3回に分けて経口投与する。
初期量としてミゾリビン2～3mg相当量
維持量としてミゾリビン1～3mg相当量
しかし、本剤の耐薬量および有効量は患者によって異なるので、最適の治療効果を得るために用量の注意深い増減が必要である。
2.原発性糸球体疾患を原因とするネフローゼ症候群(副腎皮質ホルモン剤のみでは治療困難な場合に限る。)およびループス腎炎(持続性蛋白尿、ネフローゼ症候群または腎機能低下が認められ、副腎皮質ホルモン剤のみでは治療困難な場合に限る。)
通常、成人1回ミゾリビンとして50mgを1日3回経口投与する。ただし、腎機能の程度により減量等を考慮すること。なお、本剤の使用以前に副腎皮質ホルモン剤が維持投与されている場合には、その維持用量に本剤を上乗せして用いる。症状により副腎皮質ホルモン剤の用量は適宜減量する。
3.慢性関節リウマチ
通常、成人1回ミゾリビンとして50mgを1日3回経口投与する。なお、症状により適宜増減する。ただし、腎機能の程度により減量等を考慮すること。

【用法・用量に関連する使用上の注意】
本剤は主として腎臓から排泄されるため、腎障害のある患者では排泄が遅延し、骨髄機能抑制等の重篤な副作用が起こることがあるので、腎機能(血清クレアチニン値等)及び年齢、体重等を考慮し、低用量から投与を開始するなど用量に留意して、患者の状態を十分に観察しながら慎重に投与すること[患者のクレアチニンクリアランスと本剤の消失速度との関係、またクレアチニンクリアランスを血清クレアチニン値、年齢及び体重より換算する計算式例は「薬物動態 1.吸収」の項参照]。

【使用上の注意】
1.慎重投与(次の患者には慎重に投与すること) (1) 骨髄機能抑制のある患者[骨髄機能抑制を増悪させ、重篤な感染症、出血傾向等が 発現するおそれがある。] (2) 細菌・ウイルス・真菌等の感染症を合併している患者[骨髄機能抑制により、感染症を増悪させるおそれがある。] (3) 出血性素因のある患者[骨髄機能抑制により、出血傾向が発現するおそれがある。] (4) 腎障害のある患者[「用法・用量に関連する使用上の注意」の項参照] **2.重要な基本的注意** (1) 骨髄機能抑制等の重篤な副作用が起こることがあるので、**頻回に臨床検査(血液検査、肝機能・腎機能検査等)**を行うなど、患者の状態を十分に観察すること。異常が認められた場合には減量・休薬等の適切な処置を行うこと。(2) **感染症・出血傾向**の発現又は増悪に十分注意すること。患者の状態を十分に観察し、異常が認められた場合には投与を中止し、適切な処置を行うこと。(3) プリン合成阻害作用に基づく尿酸生成増加のため尿酸値の上昇があらわれることがある。ネフローゼ症候群に対する臨床試験において、尿酸値の上昇が231例中21例(9.1%)に認められ、10mg/dL以上11例、最高値13.1mg/dLであった。(4) 小児に投与する場合には、副作用の発現に特に注意し、慎重に投与すること。(5) 小児及び生殖可能な年齢の患者に投与する必要がある場合には、性腺に対する影響を考慮すること。(6) 原発性糸球体疾患を原因とするネフローゼ症候群に投与する場合には、次の事項に留意すること。1) 副腎皮質ホルモン剤のみでは十分な治療効果が認められない患者、又は副作用、合併症等により副腎皮質ホルモン剤の減量が必要な患者に限り使用すること。特に副腎皮質ホルモン剤の1日投与量がプレドニゾロン換算で20mg以上である患者には、副腎皮質ホルモン剤の減量を目的とする場合に限る。2) 頻回再発型のネフローゼ症候群を除く。3) 投与開始後6カ月を目標として、尿蛋白、腎機能等を定期的に測定し経過をみながら以降の投与継続の可否を検討する。1日尿蛋白量、クレアチニンクリアランス、血清総蛋白、その他臨床諸症状の経過を総合的に判定し、改善効果を認め投与を継続する場合には、以後も定期的に尿蛋白、腎機能等を測定しながら投与すること。また、病態の急速な進展がみられる場合には、中止又は他の治療法を考慮するなどの適切な処置を行うこと。なお、従来より投与している治療薬剤は継続して併用することが望ましい。(7) ループス腎炎に投与する場合には次の条件をいずれも満足する患者に限ること。1) 臨床的に全身性エリテマトーデス(SLE)と診断され、アメリカリウマチ協会の1982年改訂SLE分類基準の4項目以上を満たした患者 2) ループス腎炎の存在が以下の項目のうち、少なくとも1項目を持つことで確認された患者(SLE以外の原因による腎障害は除く) a.4週以上の持続性蛋白尿 b.ネフローゼ症候群 c.腎機能低下(クレアチニンクリアランス(Ccr) 70mL/分以下又は血清クレアチニン値1.5mg/dL以上) 3) 副腎皮質ホルモン剤のみでは十分な効果が認められない患者、又は副作用、合併症等により副腎皮質ホルモン剤の減量が必要な患者 (8) 慢性関節リウマチに投与する場合には、次の事項に留意すること。1) 活動性の慢性関節リウマチに対してのみ投与を考慮すること。2) 過去の治療において、非ステロイド性抗炎症剤で十分な効果が認められず、また金剤(注射用、経口用)、D－ペニシラミン、ブシラミン、ロベンザリットニナトリウム等の抗リウマチ薬を使用して、十分な効果が認められなかった患者、又は投与中止を必要とする副作用が発現した患者に限り使用すること。3) 本剤は遅効性であり、通常、効果発現まで2～4カ月間の継続投与が必要である。ただし、6カ月間継続投与しても効果があらわれない場合には、投与を中止すること。なお、従来より投与している非ステロイド性抗炎症剤は継続して併用することが望ましい。 **3.副作用** 総症例4,909例中、719例(14.65%)に副作用が認められた。その主なものは、腹痛、食欲不振等の消化器系障害244例(4.79%)、白血球減少等の血液系障害121例(2.46%)、発疹等の過敏症119例(2.42%)等であった。(承認時～1996年10月までの集計) (1) 重大な副作用 1) 骨髄機能抑制(2.42%) 白血球減少、血小板減少、赤血球減少、ヘマトクリット値の低下等があらわれることがあるので、頻回に検査を行うなど観察を十分に行い、重篤な血液障害が認められた場合には投与を中止し、適切な処置を行うこと。2) 感染症(1.28%) 肺炎、髄膜炎、敗血症、帯状疱疹等があらわれることがあるので、患者の状態を十分に観察し、異常が認められた場合には投与を中止し、適切な処置を行うこと。3) 間質性肺炎(頻度不明) 発熱、咳嗽、呼吸困難、胸部X線異常を伴う間質性肺炎があらわれることがあるので、患者の状態を十分に観察し、このような症状があらわれた場合には投与を中止し、副腎皮質ホルモン剤投与等の適切な処置を行うこと。4) 急性腎不全(0.04%) 急性腎不全があらわれることがある。腎障害のある患者(「用法・用量に関連する使用上の注意」の項参照)で尿酸値の上昇を伴ってあらわれることがあるので、定期的に検査を行うなど観察を十分に行い、異常が認められた場合には投与を中止し、血液透析等の適切な処置を行うこと。 **4.高齢者への投与** 本剤は、主として腎臓から排泄されるが、高齢者では腎機能が低下していることが多いため、排泄が遅延するおそれがあるので、腎機能(血清クレアチニン値等)及び年齢、体重を考慮し適宜減量すること[「用法・用量に関連する使用上の注意」及び「薬物動態 1.吸収」の項参照]。**5.妊婦、産婦、授乳婦等への投与** (1) 催奇形性を疑う症例報告があり、また、動物実験(ラット、ウサギ)で催奇形作用が報告されているので、妊婦又は妊娠している可能性のある婦人には投与しないこと。(2) 授乳中の投与に関する安全性は確立していないので、授乳婦に投与する場合には授乳を中止させること。

※その他の使用上の注意の詳細については製品添付文書をご参照ください。

免疫抑制剤 薬価基準収載

ブレディニン®錠25 50

指定医薬品・要指示医薬品 Bredinin Tablets (一般名：ミゾリビン)

※注意 医師等の処方せん・指示により使用すること

資料請求先 旭化成工業株式会社
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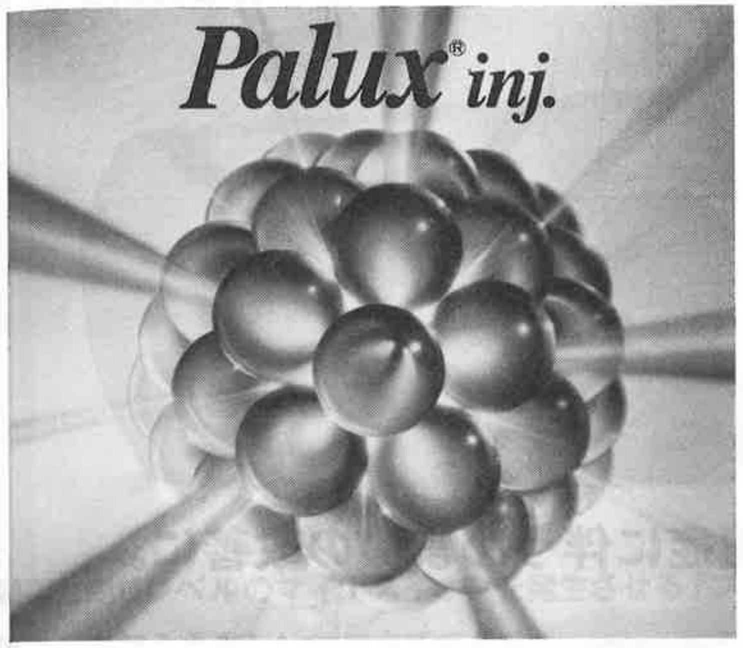
H.11.9.

プロスタグランジンDDS製剤



プロスタグランジンE1製剤 薬価基準収載

パルクス®注

劇薬・指定医薬品・要指示医薬品注) (アルプロスタジル注射液)
注) 注意－医師等の処方せん・指示により使用すること

【警告】
動脈管依存性先天性心疾患(新生児)に投与する場合には、本剤投与により無呼吸発作が発現することがあるので、呼吸管理設備の整っている施設で投与すること。

【禁忌(次の患者には投与しないこと)】
1. 重篤な心不全の患者[心不全の増強があらわれるとの報告がある。]
2. 出血(頭蓋内出血、消化管出血、喀血等)している患者[出血を助長するおそれがある。]
3. 妊婦又は妊娠している可能性のある婦人[添付文書「妊婦、産婦、授乳婦等への投与」の項参照。]
4. 本剤の成分に対し過敏症の既往歴のある患者

【効能・効果、用法・用量】

効能・効果	用法・用量
○慢性動脈閉塞症(バージャー病、閉塞性動脈硬化症)における四肢潰瘍ならびに安静時疼痛の改善 ○下記疾患における皮膚潰瘍の改善 進行性全身性硬化症 全身性エリテマトーデス ○糖尿病における皮膚潰瘍の改善 ○振動病における末梢血行障害に伴う自覚症状の改善ならびに末梢循環・神経・運動機能障害の回復	通常、成人1日1回1～2mL(アルプロスタジルとして5～10μg)をそのまま又は輸液に混和して緩徐に静注、又は点滴静注する。なお、症状により適宜増減する。
○動脈管依存性先天性心疾患における動脈管の開存	輸液に混和し、開始時アルプロスタジル5ng/kg/minとして持続静注し、その後は症状に応じて適宜増減して有効最小量とする。
○経上腸間膜動脈性門脈造影における造影能の改善	通常、成人には1回1mL(アルプロスタジルとして5μg)を生理食塩液で10mLに希釈し、造影剤注入30秒前に3～5秒間で経カテーテル的に上腸間膜動脈内に投与する。

【用法・用量に関連する使用上の注意】
(1) 本剤を輸液以外の他の薬剤と混和使用しないこと。ただし血漿増量剤(デキストラン、ゼラチン製剤等)との混和は避けること。なお、持続投与を行う場合には、ライン内での凝集を防ぐため、**必ず単独ラインで投与すること。**
(2) **経上腸間膜動脈性門脈造影に用いる場合には、凝集**・クリーミングを起こす可能性があるため、**造影剤と直接混和しないこと。また、本剤を投与した後**、カテーテル内を生理食塩液で洗浄してか**ら造影剤を投与すること。**

【使用上の注意】
1.慎重投与(次の患者には慎重に投与すること)
(1) 心不全の患者[心不全の増強傾向があらわれることがある。]
(2) 緑内障、眼圧亢進のある患者[眼圧を亢進させるおそれがある。]
(3) 胃潰瘍の合併症及び既往歴のある患者[既往のある患者に胃出血をおこすおそれがある。]
(4) 間質性肺炎の患者[間質性肺炎を増悪することがある。]
(5) 腎不全の患者[腎不全を増悪することがある。]
(6) 出血傾向のある患者[出血を助長するおそれがある。]
(7) 抗凝血剤(ワルファリン等)あるいは血小板機能を抑制する薬剤(アスピリン、塩酸チクロピジン、シロスタゾール等)、血栓溶解剤(ウロキナーゼ等)を投与中の患者[「相互作用」の項参照。]
(8) 経上腸間膜動脈性門脈造影に用いる場合、重度の食道静脈瘤が認められている患者[門脈圧を上昇させるおそれがある。]
2.重要な基本的注意
(1) 慢性動脈閉塞症(バージャー病、閉塞性動脈硬化症)、進行性全身性硬化症、全身性エリテマトーデス、振動病の患者に適用する場合には、次の事項を考慮すること。
本剤による治療は対症療法であり、投与中止後再燃することがあるので注意すること。
(2) 糖尿病における皮膚潰瘍の患者に適用する場合には、次の事項を考慮すること。
1) 糖尿病治療の基本である食事療法、運動療法、経口血糖降下剤、インスリン等の治療を行った上での適用を考慮すること。
2) 外用の糖尿病性潰瘍治療剤では十分な効果が期待されない患者に対して適用を考慮すること。
3) 本剤による治療は対症療法であり、投与中止後再燃することがあるので注意すること。
4) 投与中は経過を十分に観察し、4週間連日投与して効果が認められない場合には、他の適切な治療に切り替えること。
(3) 経上腸間膜動脈性門脈造影に適用する場合には、次の事項を考慮すること。肝硬変がある場合には、十分な造影能が得られない可能性がある。
(4) 動脈管依存性先天性心疾患の新生児に適用する場合には、次の事項を考慮すること。
1) 重篤な疾患を有する新生児への投与なので、観察を十分に行い慎重に投与すること。なお、副作用が発現した場合は、投与中止、注入速度の減速など適切な処置を講ずること。
2) 過量投与により副作用発現率が高まるおそれがあるため、有効最小量で維持すること。
3) 長期投与により長管骨膜に肥厚がみられるとの報告があるので観察を十分に行い、必要以上の長期投与は避けること。
3.相互作用
併用注意(併用に注意すること)

薬剤名等	臨床症状・措置方法	機序・危険因子
抗凝血剤 ワルファリン等	出血傾向の増強をきたすおそれがある。	本剤は血小板凝集抑制作用を有するため、これらの薬剤との併用によりその作用を増強するおそれがある。
血小板機能を抑制する薬剤 アスピリン 塩酸チクロピジン シロスタゾール等		
血栓溶解剤 ウロキナーゼ等		

4.副作用
成人対象疾患
総症例7,302例中320例(4.38%)489件の副作用が認められた。その主なものは 血管痛73件(1.00%)、注射部発赤35件(0.48%)、肝機能異常30件(0.41%)、頭痛27件(0.37%)、血管炎23件(0.31%)等であった。[再審査終了時及び効能追加時(糖尿病、経上腸間膜動脈性門脈造影)]
新生児対象疾患
総症例605例中148例(24.46%) 214件の副作用が認められた。その主なものは 無呼吸発作74件(12.23%)、発熱56件(9.26%)、低ナトリウム血症23件(3.80%)、下痢21件(3.47%)等であった。[再審査終了時]
重大な副作用
1) **ショック、アナフィラキシー様症状(いずれも頻度不明)**：ショック、アナフィラキシー様症状(呼吸困難、蕁麻疹、喉頭浮腫等)があらわれることがあるので、観察を十分に行い、異常が認められた場合には投与を中止し、適切な処置を行うこと。
2) **心不全、肺水腫、間質性肺炎(いずれも頻度不明)**：心不全(増強を含む)、肺水腫、間質性肺炎(増悪を含む)があらわれることがあるので、このような症状があらわれた場合には、投与を中止すること。
3) **脳出血、消化管出血(いずれも頻度不明)**：脳出血、消化管出血があらわれることがあるので、観察を十分に行い、異常が認められた場合には投与を中止すること。
4) **無呼吸発作(12.23%)**：新生児に投与した場合、無呼吸発作があらわれることがあるので、観察を十分に行うこと。なお、発現した場合は、減量、注入速度の減速、投与中止など適切な処置を行うこと。

※その他の使用上の注意については添付文書をご参照ください

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