Physical Therapy
Journal of the American Physical Therapy Association and de Fysiotherapeut
Royal Dutch Society for Physical Therapy

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PHYS THER. 1994; 74:1017-1026.

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Endurance Training in Patients With Multiple Sclerosis: Five Case Studies

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Background and Purpose. *The purpose of this report is to describe how patients with multiple sclerosis increased the isokinetic peak torque of their knee flexors and perceived well-being after an endurance training program.* ***Subjects and Methods.*** *Five patients trained for 4 to 6 weeks using an endurance program for the lower extremities. Before and after training, the subjects performed 50 repeated maximum knee flexions, with simultaneous recording of surface electromyographic activity of two knee flexors, on 3 separate days using an isokinetic dynamometer. Throughout the tests, the subjects rated their perception of peripheral muscle fatigue. Visual analog scales (VAS) were used to rate different aspects of well-being.* ***Results.*** *Both the perception of peripheral fatigue and the different VAS ratings had changed positively after training. Three patients achieved higher peak torque levels throughout the posttraining endurance test.* ***Conclusion and Discussion.*** *Based on these positive results, the authors conclude that more comprehensive studies of exercise prescription in patients with multiple sclerosis are desirable. [Svensson B, Gerdle B, Elert J. Endurance training in patients with multiple sclerosis: five case studies. Phys Ther. 1994;74:1017–1026.]*

Key Words: *Endurance, Multiple sclerosis, Physical therapy, Strength, Training.*

Patients with multiple sclerosis (MS) exhibit various symptoms such as weakness, ataxia, increased reflex activity, and sensory disturbances depending on the site of the pathological processes in the central nervous system (CNS).[1,2] The onset of MS often occurs between the ages of 20 and 30 years.[3] Even though these patients are often young and initially exhibit barely perceptible symptoms, there will be a decrease in optimal physical activity.[4] General fatigue is a dominating problem for the majority of patients with MS.[5,6] This fatigue is believed to have a central origin.[5] Using electrical stimulation[7] or ^{31}P magnetic resonance spectroscopy,[8] however, it has been found that patients with upper motoneuron injury have peripheral changes in their muscles that also could contribute to the perception of general fatigue.

Decreases in isokinetic peak torque of single or repeated knee flexions in patients with MS have been reported by several authors.[9,10] Patients who have positive Babinski signs as their only symptom will have generally increased reflex activity after exertion and will need a longer period of time to recover after fatigue as compared with subjects with no known neurological impairment.[11] Patients with increased reflex activity in the lower extremities will have difficulty relaxing their extensor muscles and activating their flexor muscles after exertion.[10] Delisa et al[1] proposed that the physical training of patients with MS should be submaximal to avoid fatigue reactions. The clinical experience of endurance training for patients with MS, however, is often positive. The day-to-day variation in the actual symptoms reported by patients with MS makes it difficult to devise generalized training studies

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The study was approved by the head of the Department of Neurology, University of Umeå.

This article was submitted January 21, 1993, and was accepted June 17, 1994.

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and physical therapy regimens. Moreover, Delisa et al,[1] based on their clinical experience, stated that the fatigue is not decreased by strengthening exercise in these patients. In contrast, Gehlsen at al[12] investigated the effects of an aquatic program on the isokinetic force production and endurance of patients with MS and generally reported positive changes in force production, fatigue, work, and power. Positive experiences after training or rehabilitation in activities such as climbing stairs, dressing, and transferring have also been reported for patients with severe MS.[13]

Some physical training studies[14,15] have demonstrated that exercise can induce positive mood changes in healthy subjects and that exercise has antidepressant effects in depressed patients. It would be interesting to investigate whether such positive changes also occur in patients with MS.

In several endurance studies,[16–20] isokinetic dynamometry has been combined with electromyographic (EMG) recordings of the muscle group under investigation. The mean power frequency (MPF) shift of the EMG signal toward lower frequencies has been extensively used to indicate the development of peripheral fatigue.[21,22] Gerdle and colleagues[18,23] have found that the behavior of the MPF generally predicts the mechanical performance (ie, peak torque or work) of upper- and lower-limb muscles in healthy subjects. By combining dynamometry and MPF, the origin (central or peripheral) of the decrease in mechanical performance can be determined. Hence, a decrease in mechanical output without a shift in MPF toward lower frequencies is most likely to be of central origin.

This study of endurance training in patients with MS was intended primarily to answer the following questions:

1. Will endurance training of the knee flexors of patients with MS lead to increased mechanical output throughout repetitive isokinetic contractions?

2. Will endurance training lead to a decreased perception of fatigue throughout a standardized endurance test?

3. Are positive changes in the subjective reports concerning physical well-being and fatigue parallel to changes in mechanical performance (peak torque) and MPF of repeated isokinetic knee flexions?

Method

Subjects

Five patients with the diagnosis of MS volunteered for the study. They were selected from the neurological department of the university hospital of Umeå, Sweden. It was 6 to 20 years since they were first diagnosed. The patients were graded according to the Kutzke Expanded Disability Scale (EDSS).[24] The EDSS is a functional disability scale designed to evaluate the ambulatory status of patients with MS. The scale is graded from 0 to 10. Grade 0 denotes no disturbances; grade 5 denotes the patient is ambulatory without help or resting for 200 m, but the disturbance restricts the patient's activity throughout the day; and grade 7 denotes that the patient is able to walk about 5 m but needs assistance.[24] Different definitions of spasticity exist; for the purposes of our study, we used the definition given by Lance:

> [Spasticity] a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyperexitability of the stretch reflex, as one component of the upper motor neurone syndrome.[25]

The degree of hypertonia of the legs was classified according to the modified Ashworth scale (0–4),[26] which is a standardized scale for documenting resistance to passive movements. Grade 0 denotes no increase in muscle tone, and grade 4 denotes that the affected body part is rigid in flexion or extension. Each subject was positioned supine during the grading of the tonus of the lower limb. The tonus was registered for the limb that showed the most reflex activity. The following descriptions of the subjects include the clinical signs observed when they moved freely.

Subject A. This subject (age=39 years, weight=54 kg, height=168 cm) had known her diagnosis for 6 years and was in a stable state throughout the test period. She was graded 2 according to the EDSS. Her walking capacity was more than 1,000 m. Beyond this distance, however, feelings of general fatigue and stiffness in the right leg increasingly occurred and restricted her walking. No symptoms were visible when she was walking and moving in a general manner, but running or walking quickly induced increased tonus, mostly in the right leg. Her tonus was graded 0 in the right leg according to the modified Ashworth scale. The subject was prescribed 100 mg of thiamine chloride daily.

Subject B. This subject (age=41 years, weight=74 kg, height=176 cm) had known his diagnosis for 10 years. He was in a stable state throughout the study. His clinical symptoms were graded 4 according to the EDSS. This subject had increased tonus (hyperactive reflexes) in the lower limbs, which was more pronounced in the right leg. His walking capacity was approximately 1,000 m. He could not run, presumably due to increased extensor tonus in the limbs. The tonus in the right leg was graded 1 according to the modified Ashworth scale. The subject received 10 mg of baclofen two times per day.

Subject C. This subject (age=30 years, weight=67 kg, height=174 cm) had known his diagnosis for 10 years. He had grade 6 on the EDSS. His walking capacity was 200 m. For longer distances, he used a wheelchair. When he walked, an increase in extensor tonus in both legs (more pronounced in the right leg) was observed. This increase in tonus appeared to impair his gait. He also showed slight ataxia when walking.

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The tonus in both legs was graded 1 on the modified Ashworth scale. The subject received 20 mg of baclofen daily.

Subject D. This subject (age=44 years, weight=67 kg, height=162 cm) had known her diagnosis for 14 years and was in a stable state throughout the test period. She was graded 6 on the EDSS. She had increased tonus in the extensors of the right leg and experienced difficulty in activation of the dorsal extensors of the right foot. Her walking capacity was approximately 100 m. When ambulating, an orthosis for the right foot and the support of a crutch were used. Tonus in the right leg was graded 1 according to the modified Ashworth scale. The subject received 25 mg of amitriptyline hydrochloride twice per day and 1 mg of estradiol once per day.

Subject E. This subject (age=37 years, weight=57 kg, height=168 cm) had known her diagnosis for 20 years. She was graded 7 on the EDSS. She was able to take a few steps with support, but with an increased tonus in the lower limbs and with more marked hypertonus in the right leg. The subject also exhibited increased tonus in her right arm. For ambulation, she was dependent on a wheelchair, which she could handle herself even outdoors. Her tonus was graded 2 in the right leg according to the modified Ashworth scale. The subject received 25 mg of maprotiline hydrochloride twice per day.

Ten female subjects without known neurological impairment, aged 25 to 40 years ($\bar{X}$=33, SD=4) performed the same isokinetic endurance tests at one occasion and served as a control group. The results from these tests are reported in detail elsewhere.[27]

Data from these subjects are presented to give the reader a representative picture of how the investigated variables will change throughout repeated isokinetic contractions (ie, the pattern). Similar patterns for the investigated variables have described elsewhere.[16–20,23] The absolute levels of peak torque were not comparable because the two groups were not matched with respect to age, gender, anthropometric data, and so forth.

Pretraining and Posttraining Tests

Each subject performed 50 repeated maximum knee flexions of the limb with the most pronounced symptoms (ie, the limb with most reflex activity) using an isokinetic dynamometer.* This procedure was repeated at the same time of the day three times before and three times after the training period, with 1 day of rest in between.

Each subject was seated in a specially designed chair. The subject was seated with the trunk, the hips, and the noninvestigated thigh fixated with straps to enable adequate and comfortable stabilization of the investigated thigh. Great care was taken to align the flexion-extension axis of the knee joint with the movement axis of the dynamometer and to ensure that the position was maintained throughout the entire test. The lever arm of the dynamometer was fixed at the ankle of the tested leg (see Gerdle et al[28] for details). The passive part of the contraction cycle (ie, the knee extension) was performed manually (ie, against gravity) by the test leader (BS). This was done with the purpose of avoiding an increased tonus in the extensors, which could have reduced the ability for force development in the flexors.[29] No rest was allowed between the active and passive parts of the contraction cycle. The angular velocity was 1.57 rad·s^{-1} (90°/s), and the range of motion (ROM) was from 5 to 90 degrees of flexion. A relatively low angular velocity was chosen because patients with increased reflex activity have difficulty performing fast and force-demanding exercises.[30]

Electromyographic signals, using surface electrodes† (center-to-center distance=20 mm), were obtained from the maximum bulges of the semitendinosus and biceps femoris muscles. For both muscles, the electrode placement was 20 cm (SD=1) proximal from the knee joint. Before the electrodes were attached, the skin area was dry shaved and rubbed with alcohol and ether (4:1). After surface electrodes had been applied, the impedance was checked and only values below 2 kΩ were accepted. A four-channel preamplifier‡ and a multichannel EMG amplifier‡ (frequency range=10 Hz–4 kHz [−3 dB]) were used to register the EMG activity. The amplifier was equipped with an adjustable gain, and the gain was individually adjusted in semilogarithmic steps to levels suitable for recording. To avoid the influence of artifacts (eg, from cable movements), the lower cutoff frequency of 10 Hz was used. An oscilloscope and an xy-recorder were used continuously to check the signals from the muscles and the dynamometer. The two raw EMG signals, the angle and the torque signals, were simultaneously recorded on a seven-channel, frequency-modulated tape recorder§ with a tape speed of 4.75 cm·s^{-1} and a frequency range of DC to 1.25 kHz.

The signals were analyzed on a computer (Masscomp 5500)‖ using a specially designed program. The EMG signals were sampled at a frequency of 4 kHz and analogue-to-digital converted with 12-bit accuracy over the signal range of ±5 V. The signals were pretreated by mean and trend removal and by Hamming windowing. Linear drift from the mean during the time window must be removed, otherwise both linear trend and mean

*Cybex, Div of Lumex Inc, 2100 Smithtown Ave, Ronkonkoma, NY 11779.

†Medicotest, Ølstykke, Denmark.

‡Made by the Department of Work Physiology, National Institute of Occupational Health, Umeå, Sweden.

§TEAC Corp, Tokyo, Japan.

‖Massachusetts Computer Corp.

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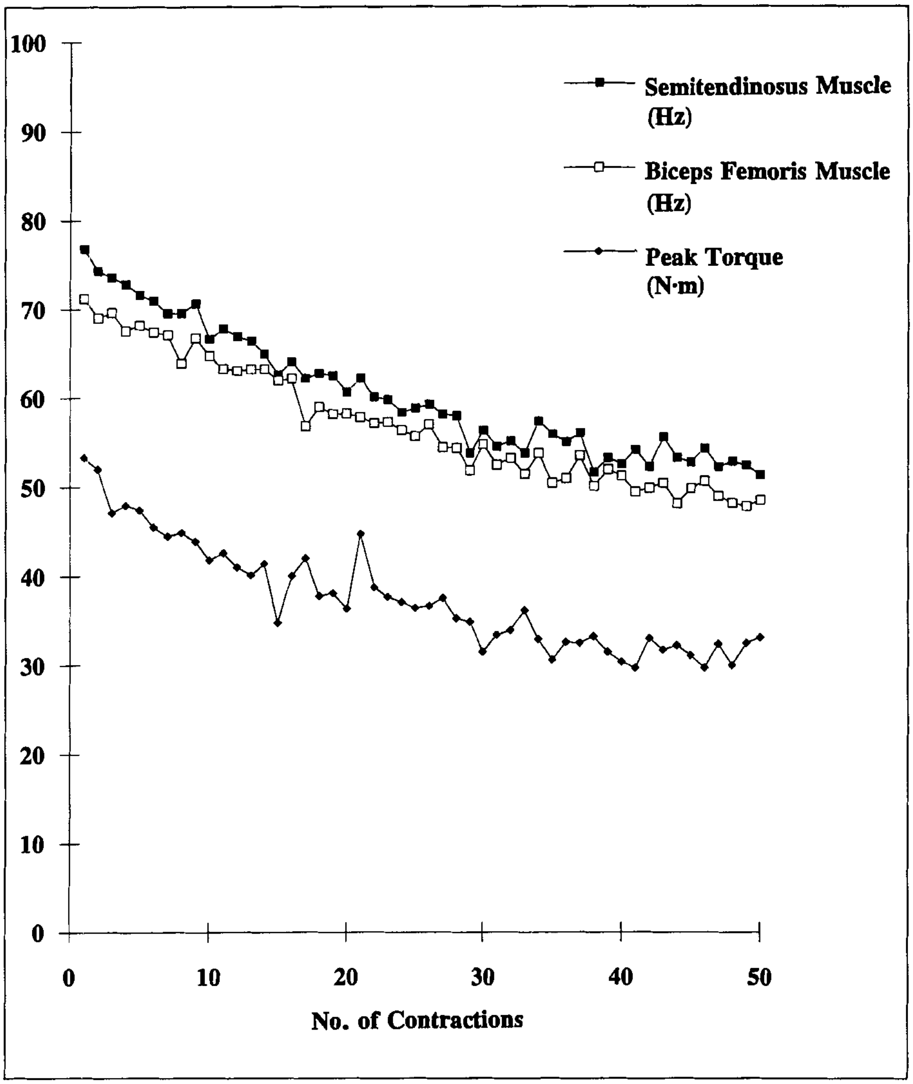

Figure 1. *Relationship between number of contractions and peak torque (in newton-meters) and mean power frequency (in hertz) of the semitendinosus and biceps femoris muscles of control group subjects (n=10) without neurological impairments.*

will appear as strong components of the low-frequency part of the spectrum.[31] The power spectral density function (PSDF) was obtained (time window=256 milliseconds, bandwidth=10–500 Hz) using the fast-Fourier transform (FFT) technique; a 1,024-point FFT yielded a spectral resolution of approximately 4 Hz. The MPF (mean spectral frequency) was computed. The program also determined peak torque (ie, the peak value of the torque curve throughout the ROM compensated for gravitational torques) as the mechanical variable, and the MPF was calculated from the EMG signals of each contraction. For details concerning the method of analysis, see Gerdle et al.[32]

For the purposes of this study, we defined *strength* as the mean value of the peak torque of the first contraction of the three tests done before and after training, respectively. *Endurance* was defined as the peak torque level of the 50 repeated knee flexions of each test. The mean values of the three tests done before and after training, respectively, were calculated. The isokinetic dynamometer has been used in a number of studies for investigating strength and endurance,[33] and several studies[16,34,35] have examined the reliability and validity of isokinetic peak torques recorded during single or repeated contractions. Surface EMG is widely used, and questions such as normalization, test-contractions, and EMG-force relationships have been extensively discussed by others.[36,37] The use of EMG (signal amplitude and MPF) during isokinetic contractions has been tested for reliability and validity.[16,38,39]

For every fifth contraction of the endurance test, the subject rated the perception of peripheral fatigue of the knee flexors using a 10-point graded scale described by Borg.[40] This scale is recommended for subjective symptoms such as aches, pain, and so on.[40] Ratings of peripheral fatigue using this scale throughout repeated plantar flexions and shoulder flexions have generally shown a good correlation with peak torque throughout the initial 40 to 50 maximum isokinetic contractions.[18,23]

One day before and 1 day after the training period, the subjects rated psychological and physical well-being (satisfaction) in the following areas: general fatigue, general health, physical fitness, somatic health, and mood. These items were chosen as relevant for patients with MS. For these ratings, visual analog scales (VAS) were used. Each of these scales had a total length of 100 mm. The following endpoints were used: for general fatigue, "no fatigue" and "continuous fatigue," respectively; for general health, "very good" and "very bad," respectively; for physical fitness, "very good" and "very bad," respectively; for somatic health, "very healthy" and "very sick," respectively; and for mood, "not at all depressed" and "very depressed," respectively. In this report, the distances (in millimeters) from the negative endpoints are presented. When completing the VAS posttraining, the subjects were not allowed to see their pretraining responses. Two of these scales (somatic health and mood) were identical to scales used in studies of patients with chronic pain.[41] A discussion of the reliability of these two scales is presented by Johansson.[41] Hence, three new scales were included in this pilot experiment

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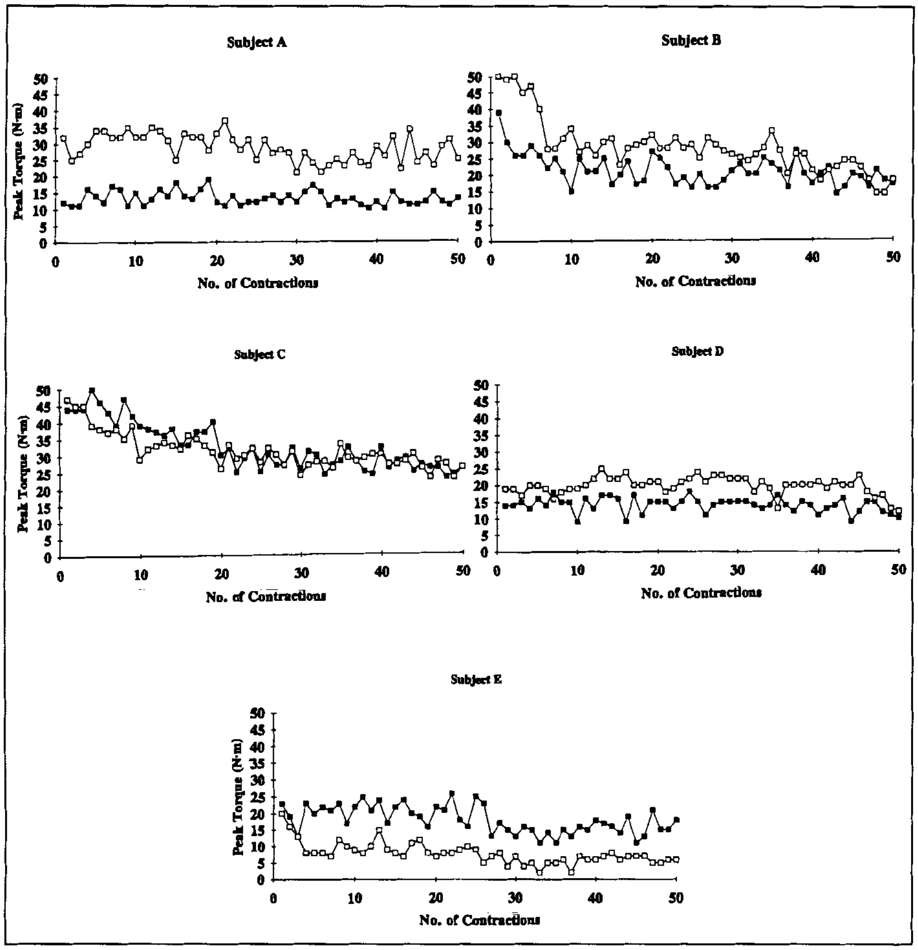

Figure 2. *Peak torque (in newton-meters) pretraining (■—■) and posttraining (□—□) throughout 50 repetitive maximum knee flexions of five patients with multiple sclerosis.*

without any reliability or validity studies.

Training Program

The general aim of the training program was to increase the absolute level of peak torque of the knee flexors throughout repeated maximum knee flexions. We wanted to design a program that avoided feelings of exhaustion during the training sessions but still resulted in better muscular output. Thus, the principle of the program was to have low-load, relatively long pauses of rest between the exercises and at least 1 day of rest between the training sessions. The intention was to perform three sets of exercises, with 10 repetitions of each exercise per set, at each training session (3×10). The subjects rested for 1 minute between each set of exercises and for 3 minutes between new exercises. Each training session ended with 10 minutes of rest, with the subjects lying down.[42] Each training session lasted 40 to 90 minutes including shorter pauses. With the purpose of having a high degree of similarity between pretraining and posttraining tests, the training programs of all subjects consisted of at least one exercise that involved maximum knee flexions in the sitting position. Two subjects performed this exercise using a pulley apparatus, and the other three subjects performed this exercise using the Orthotron®,* an isokinetic training dynamometer.

The training was performed using weight cuffs, the pulley apparatus, isokinetic dynamometers, and in some instances manual assistance. If the subjects managed to perform the exercises against resistance, the load throughout the training was 40% to 50% of 1 repetition maximum (RM), defining 1 RM as the maximum load a subject was able to sustain throughout the ROM.[43,44] One RM was determined when the individual training program was designed. If a subject was unable to perform the movement with this load, he or she performed the exercise against the gravitational torque of the limb itself. If the subjects wanted to increase the general load in the training program, they were allowed to do that by increasing the number of repetitions and decreasing the duration of the pauses. When using the Orthotron®, angular velocities between 1.05 and 1.57 rad·s^{-1} (60°–90°/s) were used and the subject was instructed to perform maximal contractions. The reason for choosing the lower angular velocity (ie, 1.05 rad·s^{-1}) was that each subject had to perform a whole contraction cycle, and some subjects were not able to do this at the higher angular velocity (ie, 1.57 rad·s^{-1}) (probably due to reflex activity). The training of knee flexion in the pulley apparatus was designed according to the same principle as the other exercises when using resistance (ie, using 40%–50% of 1 RM).

Training schedule of subject A.

Subject A trained 15 times during 6 weeks with at least 1 day between training sessions. She trained both legs. The knee flexors were trained in the Orthotron® at the speed of 1.05 rad·s^{-1} for the right leg and 1.52 rad·s^{-1} for the left leg and in the prone position using the pulley apparatus with the load 50% of 1 RM. The hip flexors were also trained in the pulley apparatus in a standing position with a load of 50% of 1 RM. Hip abduction was performed lying on the side and hip extension was performed lying in the prone position with weight cuffs on the ankles with a load of 50% of 1 RM. The trunk muscles were trained by using the pulley apparatus or in the prone and supine positions using the weight of the trunk as resistance. From the sixth

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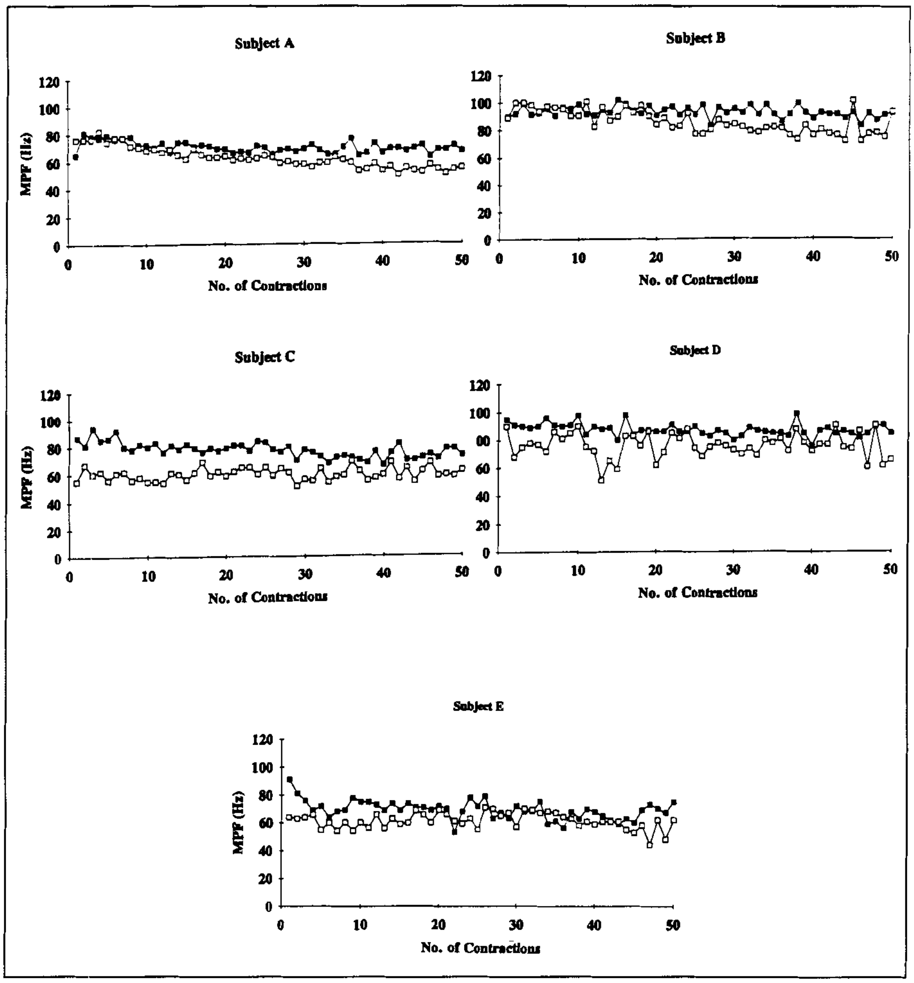

Figure 3. *Mean power frequency (MPF) (in hertz) of the semitendinosus muscle pretraining (■—■) and posttraining (□—□) throughout 50 repetitive maximum knee flexions of five patients with multiple sclerosis.*

training session, the subject increased the repetitions from three sets of 10 repetitions each to three sets of 15 repetitions each for all exercises, except for the isokinetic training of the knee flexors and the training of the hip flexors.

Training schedule of subject B. Subject B trained 15 times throughout 8 weeks and rested at least 1 day between training sessions. He trained both legs. Knee flexors were trained in the prone position and hip flexors were trained in the standing position using the pulley apparatus with a load of 40% to 50% of 1 RM. The knee flexors were trained at a speed of 1.05 rad·s^{-1} for the right leg and 1.52 rad·s^{-1} for the left leg in the Orthotron®. Hip abduction was performed lying on the side and hip extension was performed lying prone with the weight cuff on the ankles. The load was 50% of 1 RM. During the five initial training sessions, this subject performed three sets of 5 repetitions each and thereafter three sets of 10 repetitions each of all exercises, except for training of the knee flexors using the Orthotron®, where he managed to perform three sets of 10 repetitions each throughout the whole training period.

Training schedule of subject C. This subject trained two or three times a week throughout 6 weeks at a rehabilitation center and continued in a training department near his home for 1 week (ie, the last 3 sessions). He trained for a total of 20 sessions with the specially designed program. At the rehabilitation center, for the days between training sessions, the subject performed balance exercises that were not part of the specially designed program. He trained both legs. Knee flexors were trained in the sitting position and in the prone position using the pulley apparatus (50% of 1 RM). The subject also used the pulley apparatus to train the hip flexors (in the standing position). The load was 50% of 1 RM. Hip abduction was performed in a side-lying position and hip extension was performed in a prone position with the weight cuff on the ankles. The load was 50% of 1 RM. The trunk was trained in prone and supine positions, with the trunk itself as resistance. The program initially consisted of three sets of 10 repetitions each for all exercises, and from the 10th training session the subject increased to three sets of 15 repetitions each. This subject was very dependent on the temperature in the training room. At a high temperature (ie, >22°C), he felt more exhausted and had difficulty performing the training. During the fourth week, his status was somewhat poorer with more reflex activity, which reduced the training intensity (reduction of repetitions and loads).

Training schedule of subject D. Subject D trained at a rehabilitation center for 4 weeks for a total of 12 training sessions, with at least 1 day of rest between training sessions, using a specially designed program that concentrated on the right leg. She trained the knee flexors in a sitting a position using the pulley apparatus. The load was 50% of 1 RM. She also trained the knee flexors and hip extensors in a prone position and the hip abductors in a side-lying position without any weights. The abdominal muscles were trained by sit-ups in a supine position. The subject performed three sets of 10 repetitions each of all the exercises, except during the first week of the training period when she performed three sets of 5 repetitions each of the hip extension exercises. On the days between training sessions, she performed light, nonspecific aquatic exercises.

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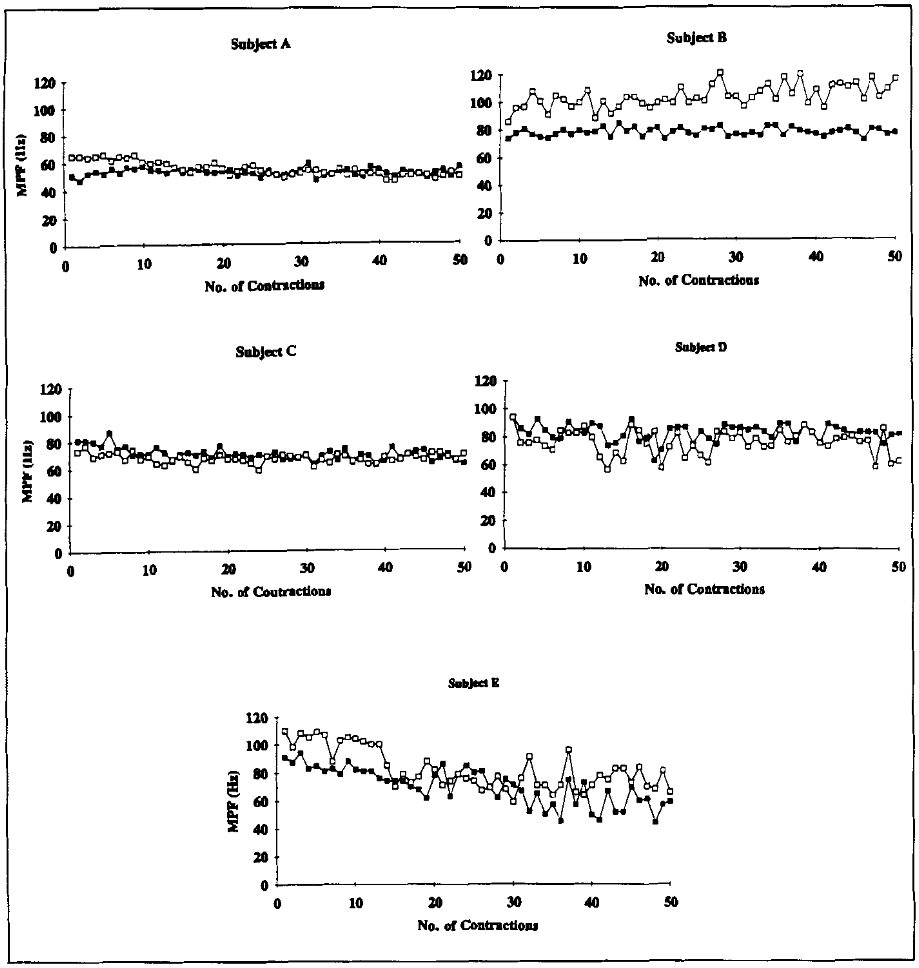

Figure 4. *Mean power frequency (MPF) (in hertz) of the biceps femoris muscle pretraining (■—■) and posttraining (□—□) throughout 50 repetitive maximum knee flexions of five patients with multiple sclerosis.*

Training schedule of subject E. Subject E trained at a rehabilitation center for 5 weeks, for a total of 15 sessions, with the specially designed program concentrated on the right leg. Knee flexors were trained in the Orthotron® at 1.52 rad·s^{-1}, and eccentric contractions were done in the prone position. She needed manual assistance to flex the knee to the position of 90 degrees to be able to perform the eccentric movement. She trained her hip flexors and abductors in the side-lying position and performed the exercises with manual assistance. Hip extension was performed in the prone position with manual assistance. All exercises consisted of three sets at 10 repetitions each. The subject also needed manual assistance when she trained her left leg, but not as much as for the right leg. She trained every second day. On the days between training sessions, she performed light, nonspecific aquatic exercises.

Subjects A and B performed their training at the physical therapy department of the university hospital of Umeå, Sweden. Subjects C, D, and E trained at a rehabilitation center that mainly specialized in progressive neurological disorders, located 20 km from the university hospital.

Data Analysis

Our primary intention was to evaluate the subjects individually. For all repeated recordings and ratings of a specific subject, the mean value of the three tests, pretraining and posttraining, respectively, were used in the analyses.

Results

The subjects without neurological impairments exhibited a decrease of peak torque during the initial 25 contractions followed by a more or less stable level of peak torque during the rest of the test (Fig. 1). For the patients with MS, this clear pattern did not exist (Fig. 2). Hence, during the initial 25 contractions, a great variability in peak torque was found and no marked decrease in peak torque was found for the majority of patients with MS either pretraining or posttraining. Only subjects C and D had patterns of peak torque throughout the test that was to some degree similar to the patterns of peak torque of the control subjects. Three of the patients (subjects A, B, and D) achieved higher peak torque levels throughout the endurance tests after the training. Subject C did not exhibit any change, and subject E showed a decrease in peak torque throughout the posttraining tests (Fig. 2).

The decreases in MPF seen in the subjects without neurological impairments throughout the initial 25 to 30 contractions (Fig. 1) were generally not found in the patients with MS (Figs. 3 and 4). The control subjects generally had lower initial MPFs in both muscles than did the patients with MS during the pretraining test. Lower MPFs throughout the posttraining test compared with the pretraining test were found for the semitendinosus muscle of all subjects (Fig. 3). No definite change in MPF of the biceps femoris muscle was found when comparing the pretraining and posttraining data (Fig. 4). The changes concerning the endurance test between the pretraining and posttraining conditions have been summarized in Table 1.

All subjects demonstrated improvements on the VAS scale concerning the different aspects of perceived physical and mental health, except for subject D, who reported no change in perceived general health (Tab. 2).

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Table 1. *Changes in Peak Torque, Mean Power Frequency, and Rating on the Borg Scale Throughout the Endurance Tests*[a]

Subject	Kutzke Expanded Disability Scale[24]	Peak Torque	Mean Power Frequency: Semitendinosus Muscle	Mean Power Frequency: Biceps Femoris Muscle	Borg Scale Rating
A	2	↑	↓	—	↓
B	4	↑	↓	↑	↓
C	6	—	↓	—	↓
D	6	↑	↓	↓	–
E	7	↓	↓	—	↓

[a] ↑ denotes increased absolute value posttraining compared with pretraining; ↓ denotes decreased absolute value posttraining compared with pretraining; — denotes no definite change.

Both before and after training, more or less linear increases in the perception of fatigue throughout the endurance test were found (Fig. 5). As shown in Figure 5, the perception of fatigue posttraining was generally lower compared with the pretraining condition; only subject D did not show any definite change. Subjects B and C reached maximal ratings in the perception of fatigue both pretraining and posttraining. Their maximal levels (≥10), however, were reached after a greater number of contractions posttraining.

Discussion

The instability of the clinical picture often seen in patients with MS often makes it difficult to evaluate the effect of training. The patients with MS in this study, however, did not show any changes in their clinical status throughout the training period (except for one subject who had a 1-week period with increased reflex activity). The training and the special design of the program appeared to be well suited for these patients because the effects of training were generally positive from the subjective rating (VAS) point of view. Moreover, the subjects reported such positive experiences whether they had been training alone at a physical therapy department or whether they had been at a rehabilitation center that specialized in progressive neurological disorders.

Clear positive effects were not found in the different physiological variables measured even though a majority (three out of five) of the subjects had increased their strength and endurance (Fig. 2), which indicates a physiological improvement as well. It is reasonable to assume that, from the patient's point of view, the aspect of primary importance is to feel better; it is only of secondary importance if this feeling is accompanied by physiological improvements. In the future, research with more subjects must be conducted before making definite statements about the physiological effects of this kind of training program in patients with MS. The fact that muscular endurance increased is consistent with the study of Gehlsen and co-workers,[12] who investigated the effects of an aquatic program and reported generally positive changes in force production, fatigue, power, and work.

These physiological improvements are probably of peripheral origin. Hence both biochemical and electrophysiological studies of patients with upper neuron lesions suggest biochemical changes in the investigated muscles of the lower limb.[7,8] These changes are probably due to the long-term disuse or altered use of the muscle fibers, as suggested recently by Lenman and co-workers.[7] One of the authors (BS) often has contact with the subjects who participated in this study, and four of them reported that they were able to perform more demanding daily functional activities involving the lower limbs after the training period. Even though subject B did not report any functional improvements, he both rated better on the VAS and exhibited improvements in the endurance/strength test. Another possibility is that the observed increased functional capacity may only be a reflection of increased general well-being or self-confidence.[45] This increased sense of well-being or self-confidence in turn may make the subjects more willing to try and succeed in functional activities near the limit of their capacity. Our belief in the subjects' absolute capacity may also have influenced their functional capacity in a positive way.

The patients with MS did not exhibit the same clear pattern of an initial

Table 2. *Differences (in Millimeters) Between Posttraining and Pretraining Ratings on Visual Analog Scale*[a]

Subject	General Fatigue	General Health	Physical Fitness	Somatic Health	Mood
A	28	26	21	23	13
B	29	25	25	28	24
C	40	30	75	5	21
D	31	0	75	26	34
E	23	11	61	20	7

[a] Positive value denotes improvement.

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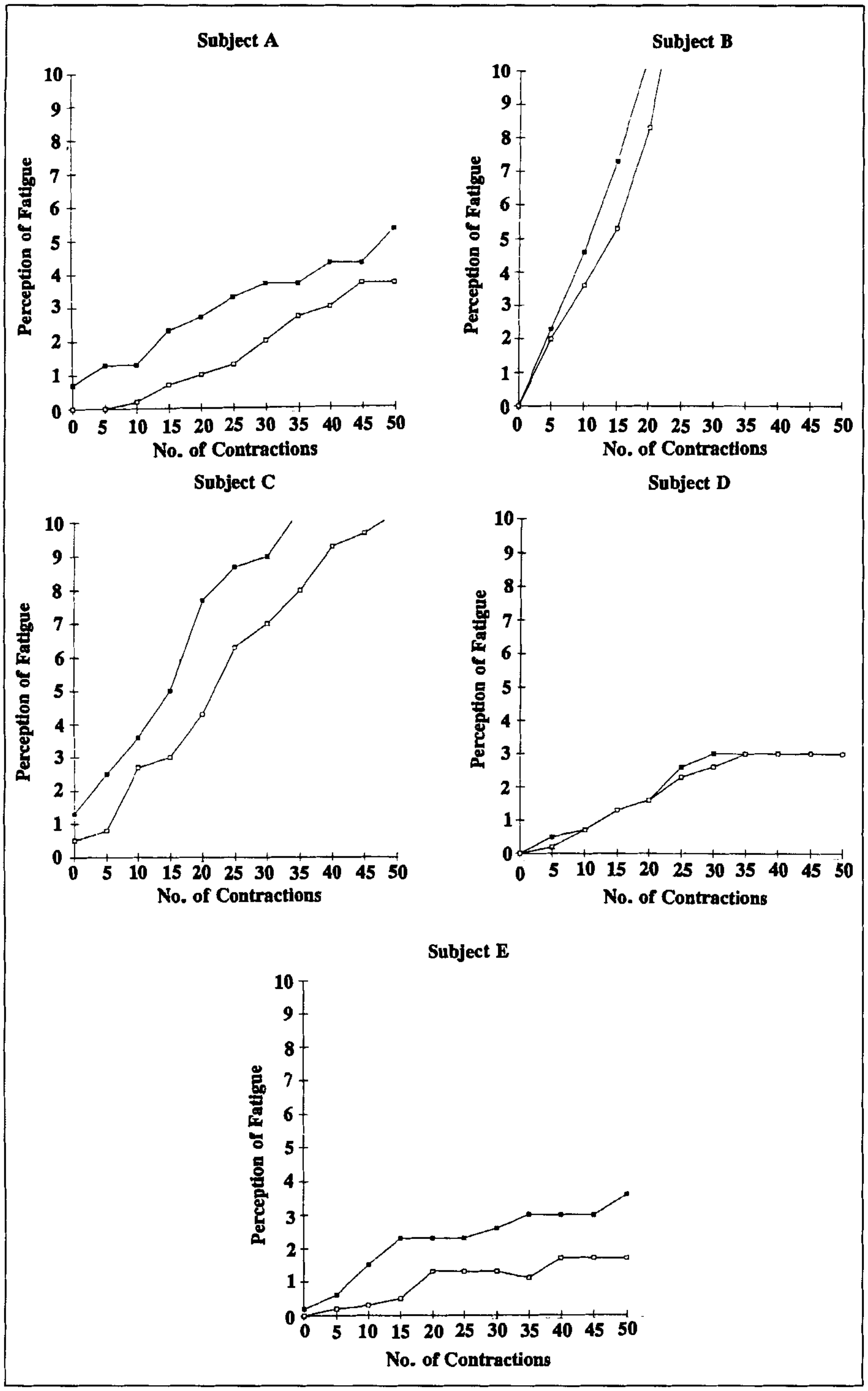

Figure 5. *Perception of fatigue in the working muscles according to the 10-point graded Borg scale pretraining (■—■) and posttraining (□—□) throughout 50 repetitive maximum knee flexions for five patients with multiple sclerosis. Note that subjects B and C reached maximal ratings in the perception of fatigue both pretraining and posttraining. Their maximal levels (≥10), however, were reached after a greater number of contractions posttraining.*

decrease in mechanical output as the control subjects. We have proposed that the initial decrease in mechanical performance during repeated maximal isokinetic contractions in subjects without neurological impairments reflects fatigue mainly of the type II motor units (fibers).[16,23] Consistent with this suggestion, the MPF of the two muscles investigated remained relatively stable throughout the endurance tests for the patients with MS. Thus, even though the patients experienced peripheral fatigue, it was not accompanied by an MPF shift. These findings are consistent with fatigue of mainly central origin, as expected (ie, the frequency spectrum of the EMG signal was dominated by the effects of the upper motoneuron dysfunction). An additional explanation for the stable MPF throughout the endurance tests in the patients with MS could be that due to the pathological changes in the CNS, these patients had difficulties in recruiting their type II motor units (associated with decreased strength) and relied primarily on the type I fibers. Some studies indicate that a primary reliance on type I muscle fibers will be associated with a stable MPF.[23] Type II fiber atrophy, without any change in the proportion of the two main fiber types, has also been reported in morphological studies.[46,47] Other studies,[48,49] however, have shown an increased proportion of type II fibers without any signs of fiber atrophy. Such morphological findings could be consistent with the higher initial MPF of the patients with MS in our study because MPF is positively correlated with the proportion of type II muscle fibers.[28,50] The findings of Edström and co-workers,[46,47] however, are not consistent with such an explanation for the higher MPF in patients with MS.

Conclusion

Our report indicates that patients with MS generally experience increased well-being in different areas. The physiological variables examined, however, did not show such a consistent picture for all patients. Our report indicates potential beneficial effects of endurance training even though research with more patients must be conducted before definite conclusions can be drawn.

Acknowledgments

We thank Majken Rahm and Monika Edström, who assisted during the tests

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and who also performed the EMG analyses. We also thank Maj-Lis Nordström, Sara Wiik, and Anne Wikström at Björkgärden, who supervised the training for three of the patients.

References

1 Delisa JA, Hammond MC, Mikulic MA, Miller RM. Multiple sclerosis, part I: common physical disabilities and rehabilitation. *Am Fam Physician.* October 1985:157–163.

2 Kraft GH, Freal JE, Coryell JK. Disability, disease duration, and rehabilitation service needs in multiple sclerosis: patient perspectives. *Arch Phys Med Rehabil.* 1986;67:164–168.

3 Mc Alphine D. *Course and Diagnosis in Multiple Sclerosis: A Reappraisal.* London, England: Churchill Livingstone; 1972:197–223.

4 Madonna MG, Holland NJ, Wiesel-Levison P. The value of physical therapy improving gait in multiple sclerosis: a research design. *Rehabilitation Nursing.* September–October 1985: 32–34.

5 Freal JE, Kraft GH, Coryell JK. Symptomatic fatigue in multiple sclerosis. *Arch Phys Med Rehabil.* 1984;65:135–137.

6 Ericsson RP, Lie MR, Wineinger MA. Rehabilitation in multiple sclerosis. *Mayo Clin Proc.* 1989;64:818–828.

7 Lenman AJR, Tulley FM, Vrbova G, et al. Muscle fatigue in some neurological disorders. *Muscle Nerve.* 1989;12:938–941.

8 Miller RG, Green AT, Moussavi RS, et al. Excessive muscular fatigue in patients with spastic paraparesis. *Neurology.* 1990;40:1271–1274.

9 Armstrong LE, Wiandt DM, Swasey PR, et al. Using isokinetic dynamometery to test ambulatory patients with multiple sclerosis. *Phys Ther.* 1983;63:1274–1279.

10 Dunchan P. The effect of a prior quadriceps contraction on knee flexor torque in normal subjects and multiple sclerosis patients with spastic paraparesis. *Physiotherapy Practice.* 1987;3:11–17.

11 Benecke R, Condrad B. Evaluation of motor deficits in patients suffering from multiple sclerosis. In: Bauer HJ, Posers S, Ritter G, eds. *Progress in Multiple Sclerosis Research.* Berlin, Federal Republic of Germany: Springer-Verlag; 1980:589–595.

12 Gehlsen G, Grigsby S, Winant DM. Effects of an aquatic fitness program on the muscular strength and endurance of patients with multiple sclerosis. *Phys Ther.* 1984;64:653–657.

13 Greenspun B, Steinemann M, Agru R. Multiple sclerosis and rehabilitation outcome. *Arch Phys Med Rehabil.* 1987;68:434–437.

14 Steinberg H, Sykes EA. Introduction to symposium on endorphins and behavioral processes: review of literature on endorphins and exercise. *Pharmacol Biochem Behav.* 1985;23:857–862.

15 LaFontaine TP, DiLorenzo TM, French PA, et al. Aerobic exercise and mood: a brief review, 1985–1990. *Sports Med.* 1992;13:160–170.

16 Fugl-Meyer AR, Gerdle B, Eriksson BE, Jonsson B. Isokinetic plantar-flexion endurance: reliability and validity of output/excitation measurements. *Scand J Rehabil Med.* 1985;17: 47–52.

17 Gerdle B, Hedberg R, Jonsson B, Fugl-Meyer AR. Mean power frequency and integrated electromyogram of repeated isokinetic plantarflexions. *Acta Physiol Scand.* 1987;130: 501–506.

18 Gerdle B, Elert J, Henriksson-Larsén K. Muscular fatigue during repeated isokinetic shoulder forward flexions in young females. *Eur J Appl Physiol.* 1989;58:666–673.

19 Elert J, Gerdle B. The relationship between contraction and relaxation during fatiguing isokinetic shoulder flexions: an electromyographic study. *Eur J Appl Physiol.* 1989;59:303–309.

20 Tesch PA, Dudley GA, Duvoisin MR, et al. Force and EMG signal patterns during repeated bouts of concentric or eccentric muscle actions. *Acta Physiol Scand.* 1990;138:263–267.

21 Basmajian JV, Deluca CJ. *Muscles Alive: Their Functions Revealed by Electromyography.* 5th ed. Baltimore, Md: Williams & Wilkins; 1985.

22 Lindström L, Petersen I. Power spectra of myoelectric signals: motor unit activity and muscle fatigue. In: Stålberg E, Young R, eds. *Clinical Neurophysiology.* London, England: Butterworth & Co (Publishers) Ltd; 1981:66–87.

23 Gerdle B, Fugl-Meyer AR. Is the mean power frequency shift of the EMG a selective indicator of fatigue of the fast-twitch motor units? *Acta Physiol Scand.* 1992;145:129–138.

24 Kutzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability scale (EDSS). *Neurology.* 1983;33:1444–1452.

25 Lance JW. Symposium synopsis. In: Felman RG, Young RR, Koella WP, eds. *Spasticity: Disordered Motor Control.* Chicago, Ill: Yearbook Publishers; 1980:485–494.

26 Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther.* 1987;67:206–207.

27 Lindström B, Gerdle B. The Interrelationship between, EMG, peak torque, and perceived fatigue during repeated maximum isokinetic knee flexion with and without active knee extension. *Physiotherapy Theory and Practice.* 1994;10:17–25.

28 Gerdle B, Wretling ML, Henriksson-Larsén K. Do the fibre type proportion and the angular velocity influence the mean power frequency of the electromyogram? *Acta Physiol Scand.* 1988;134:341–346.

29 Knutsson E, Måansson A. Effects on maximal voluntary dynamic muscle strength in spastic patients by the inflow from reciprocal muscles. In: Kondrad B, Bennecke R, Bauer HJ, eds. *Die Klinischer Wetrtung der Spastizitet.* Stuttgart, Federal Republic of Germany: FK Schattauer Verlag GmbH; 1984:147–153.

30 Chen WY, Person FM, Burnett C. Force-time measurement of knee muscle function of subjects with multiple sclerosis. *Phys Ther.* 1987;67:934–946.

31 Marple SL Jr. Digital spectral analysis with applications. In: Oppenheim AV, ed. *Prentice-Hall Signal Processing Series.* Englewood Cliffs, NJ: Prentice-Hall Inc; 1987:227.

32 Gerdle B, Eriksson NE, Hagberg C. Changes in the surface electromyogram during increasing isometric shoulder forward flexions. *Eur J Appl Physiol.* 1988;57:404–408.

33 Elert J. *The Pattern of Activation and Relaxation During Fatiguing Isokinetic Contractions in Subjects With and Without Muscle Pain.* Umeå, Sweden: Arbete och Hälsa, Vetenskaplig Skriftserie; 1991:47. Dissertation.

34 Cabri JMH. Isokinetic strength aspects of human joints and muscles. *Crit Rev Biomed Eng.* 1991;19:231–259.

35 Baltzopoulos V, Brodie DA. Isokinetic dynamometry applications and limitations. *Sports Med.* 1989;8:101–116.

36 Järvholm U. *On Shoulder Muscle Load: An Experimental Study of Muscle Pressures, EMG, and Blood Flow.* Gothenburg, Sweden: University of Gothenburg; 1990. Dissertation.

37 Petrovsky JS Glaser RM, Chandler P, Philips A. Evaluation of the amplitude and frequency components of the surface EMG as an index of muscle fatigue. *Ergonomics.* 1982;25:213–223.

38 Öberg T. *Trapezius Muscle Fatigue and Electromyographic Frequency Analysis.* Linköping, Sweden: Linköping University; 1992. Dissertation.

39 Shankar S, Gander RE, Brandel BR. Changes in myoelectric signal (MES) power spectra during dynamic contractions. *Electroencephalogr Clin Neurophysiol.* 1989;73:142–150.

40 Borg G. Psychosocial basis of perceived exertion. *Med Sci Sports Exerc.* 1982;14:377–381.

41 Johansson F. *Patients With Chronic Pain: A Clinical, Pharmacological, and Biochemical Study.* Umeå, Sweden: Umeå University; 1982. Dissertation.

42 Russel R. Disseminated sclerosis: rest exercise therapy—a progress report. *Physiotherapy.* 1967;66:77.

43 McCartney N, Moroz D, Garner SH, McComas A. The effects of strength training in patients with selected neuromuscular disdorders. *Med Sci Sports Exerc.* 1987;20:362–367.

44 Saltin B. Muskulär anpassning till styrketräning. In: Forsberg A, Saltin B, eds. *Styrketräning.* Stockholm, Sweden: Idrottens Forskningsråd, Sveriges Riksidrottsförbund, Folksam; 1985:74–81.

45 Morgan PW. Affective beneficence of vigorous physical activity. *Med Sci Sports Exerc.* 1984;17:94–100.

46 Edström L. Selective changes in size of red and white muscle fibres in upper motor lesions and parkinsonism. *J Neurol Sci.* 1970;11: 537–550.

47 Edström L, Grimby L, Hannerz J. Correlation between recruitment order of motor units and muscle atrophy pattern in upper lesions: significance of spasticity. *Experimentia.* 1973; 29:560–561.

48 Landin S, Hagenfeldt L, Saltin B, Wahren J. Muscle metabolism during exercise in hemiparetic patients. *Clin Sci R Molecular Med.* 1977; 53:257–269.

49 Sjöström M, Fugl-Meyer AR, Nordin G, Wählby L. Poststroke hemiplegia: crural muscle strength and structure. *Scand J Rehabil Med Suppl.* 1980;7:53–67.

50 Moritani T, Gaffney FD, Carmichael T, Hargis J. Interrelationships among muscle fiber types, electromyogram and blood pressure during fatiguing isometric contraction. In: Winter DA, Norman RW, Wells RP, et al, eds. *Biomechanics, IX-A.* Champaign, Ill: Human Kinetics Publishers Inc; 1985:5a:287–292.

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PHYS THER. 1994; 74:1017-1026.

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