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Clin Rehabil 2004 18: 737
DOI: 10.1191/0269215504cr780oa

The online version of this article can be found at:
http://cre.sagepub.com/content/18/7/737
Effects of aerobic and strength exercise on motor fatigue in men and women with multiple sclerosis: a randomized controlled trial

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Received 15th November 2003; returned for revisions 28th January 2004; revised manuscript accepted 27th February 2004.

Objective: To investigate the effects of aerobic and strength exercise on motor fatigue of knee flexor and extensor muscles in subjects with multiple sclerosis (MS).

Design: A randomized controlled trial.

Setting: At Masku Neurological Rehabilitation Centre, Masku, and the Social Insurance Institution, Research Department, Turku, Finland.

Subjects: Ninety-five MS patients with mild to moderate disability were randomized into exercise group (n = 47) and a control group (n = 48).

Intervention: Participants in the exercise group attended in a supervised exercise period of three weeks, which was followed by a home exercise programme lasting for 23 weeks. Patients in the control group continued with their normal living.

Outcome measures: Motor fatigue of knee flexor and extensor muscles was measured during a static 30-s maximal sustained muscle contraction. The decline in force (Nm) during the 30 s was recorded, and a fatigue index (Fl) was calculated. Subjective fatigue was measured by using the Fatigue Severity Scale (FSS). The Ambulatory Fatigue Index (AFI) was calculated on the basis of a 500-m walking test. Assessment took place at baseline, at the third week (not for the control group) and at the 26th week. All outcome variables were analysed, men and women together, and some interesting contrasts were analysed by gender.

Results: Associations were observed with changes in extension Fl and Expanded Disability Status Scale (EDSS) score and mean extension torque (Nm), but not with changes in Fl and aerobic or strength exercise activity, mean AFI, mean FSS or in mean knee flexion torque. AFI was decreased in all subject groups (p = 0.007). Motor fatigue was reduced in knee flexion (p = 0.0014) and extension (ns) among female but not in male exercisers after six months of exercise. The exercise activity of women was 25% higher than that of the men.

Conclusions: Six months of exercise reduced motor fatigue in women, but not in men.
Introduction

Patients with multiple sclerosis (MS) often describe fatigue as increased weakness with exercise or as an abnormal sense of tiredness. According to questionnaire studies, the prevalence of excessive fatigue in MS is 70–90%.1–4

The aetiology of MS fatigue is probably multifactorial, and in a recent review, Schwid et al.5 suggested that components and mechanisms of fatigue should be investigated separately, and by gender6 in order to broaden the knowledge of its characteristics and severity.

For many years MS patients were advised to avoid exercise because of excessive fatigue. Inactivity, however, may promote muscle deconditioning and decrease exercise tolerance. In a survey by Freal and co-workers,1 71% of patients described increased fatigue after heavy exercise, but on the other hand, 57% of the patients in the mentioned survey perceived that moderate physical exercise was helpful in controlling fatigue. Aerobic and strength exercise may reduce fatigue in MS patients.7–10 Patients with mild to moderate physical impairment seem to benefit most from exercising.11 Currently, physical exercise is actually recommended for MS patients to improve muscle performance,11,12 and also to reduce fatigue.12

Different aspects of fatigue should be evaluated separately, both by means of subjective, self-reported questionnaires and by measuring the decline of strength during sustained muscle contraction.13,14 Schwid et al.14 found that people with MS had 12–18% higher fatigue indices than healthy subjects, when torque decline was measured during a 30-s sustained muscle contraction.

The purpose of this randomized controlled trial was to evaluate the effects of a six-month aerobic and strength exercise programme on the motor fatigue of knee extensor and flexor muscles in MS patients with mild to moderate disability.

Methods

Subjects

The design of this randomized controlled trial is shown in Figure 1. The study was approved by the Ethical Committee of the South-Western Finland District of Health Care. All of the subjects gave their written informed consent for participation in the study.

The inclusion criteria were: age between 30 and 54 years, definite diagnosis of MS,15 Expanded Disability Status Scale (EDSS) score of 1.0–5.5,16 willingness to participate and to exercise at home according to instructions. The exclusion criteria were: a cardiovascular disease or a musculoskeletal disorder that would hinder the patient from completing the exercise programme, relapse in MS less than one month before the baseline, intensive and regular physical exercise – at least five times a week, at least 30 min each time – during the preceding three months, and any medical, psychological or other reason indicating that the patient would not be able to complete the intervention programme.

After having confirmed their eligibility by telephone interview, the subjects were stratified by gender and randomized to an exercise or a control group. The randomization procedure was done by the project statistician with SAS software (version 8.2, SAS Institute, Inc, Cary, NC, USA).

At the baseline, the two groups were similar for anthropometric characteristics, EDSS scores, disease duration, Fatigue Severity Scale (FSS) scores and Ambulatory Fatigue Index (AFI) (Table 1).

The supervised exercise programme

Five supervised resistance and five aerobic exercise sessions were carried out during the three-week rehabilitation course. Aerobic exercises were conducted in a pool and on alternate days with resistance exercise.

The aerobic programme included varying forms of gymnastic exercises in shoulder-deep water (temperature approx +28°C). The workout schedule in the pool was as follows: 5–7 min warming up, 20–25 min aerobic exercises, 5–8 min cooling down. The targeted exercise intensity was 65–70% of age-predicted maximal heart rate. If a patient was unable to take part in the aquatic programme, it was replaced by an ergometry exercise session of 30–35 min.

The resistance exercise programme was of circuit type. After about 10 min of warming up, the patients performed 10 exercises with 10–15 repetitions in two sets. The total circuit consisted of the following exercises: (1) scapular adduction, (2) hip extension, (3) arm pull down, (4) seated abdomen,
(5) hip abduction, (6) triceps push, (7) seated back, (8) leg curl, (9) biceps brachii curl, (10) knee extension.

The exercises were performed using pressurized air resistance machines (exercises 1, 4, 5, 7, 8, 10), or weight stack machines (exercises 3, 6, 9) or against gravity (exercise 2). The load was 50–60% of the maximum load lifted at one time (i.e., one-repetition maximum, 1RM). After the third session, the loads were re-evaluated individually and, if needed, decreased or increased. Rest periods of 1 min between the exercises were applied. Both circuits were followed by a 4-min pause. The pause after the second circuit was followed by a cool-down period consisting of muscle stretching.

**The home exercise programme**

The patients were instructed to continue exercising for 23 weeks at home. The patients were
Table 1  Baseline characteristics of the female and male exercising and control MS groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise group (n=47)</th>
<th>Control group (n=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women (n=30)</td>
<td>Men (n=17)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>43±6</td>
<td>45±6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165±5</td>
<td>177±6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65±12</td>
<td>77±12</td>
</tr>
<tr>
<td>Years since diagnosis</td>
<td>6±6</td>
<td>6±7</td>
</tr>
<tr>
<td></td>
<td>(0–22)</td>
<td>(1–23)</td>
</tr>
<tr>
<td>EDSS</td>
<td>2.0±0.8</td>
<td>2.9±1.2</td>
</tr>
<tr>
<td></td>
<td>(1–4.0)</td>
<td>(1–5.5)</td>
</tr>
<tr>
<td>FSS</td>
<td>4.6±1.6</td>
<td>4.6±1.6</td>
</tr>
<tr>
<td></td>
<td>(1.2–6.7)</td>
<td>(1.4–6.2)</td>
</tr>
<tr>
<td>AFI</td>
<td>4.1±7.1</td>
<td>7.0±10.4</td>
</tr>
<tr>
<td></td>
<td>(–16.7–21.7)</td>
<td>(–10.7–32.3)</td>
</tr>
<tr>
<td>Relapsing-remitting course (n)</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>Primary progressive course (n)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Secondary progressive course (n)</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

EDSS, Expanded Disability Status Scale; FSS, Fatigue Severity Scale; AFI, Ambulatory Fatigue Index. Values are means ±SD, range or number of subjects.

provided with an individual progressive exercise programme instructed by a physiotherapist during the rehabilitation course. The weekly number of exercise sessions was four during weeks 1–17 and five during the last six weeks (18–23). The main aim of the home exercise programme was to improve muscular strength. The knee extensor and flexor muscles were exercised to an equal extent.

The home exercise programme included eight resistance exercises for the same muscle groups that were trained during the first three weeks. The subjects were equipped with two elastic bands (Theraband®, Akron, Ohio, USA), one for the lower, one for the upper extremities. During weeks 1–5 patients performed each exercise in two sets of 10–12 repetitions. In the sixth week, the number of repetitions was increased to 12–15. In week 12, they were given new, stiffer elastic bands, and the number of repetitions was decreased to 10–12 for the rest of the exercising period. For the duration of the exercise period, six months was deemed appropriate to achieve training effects.17,18

The proportions of strength exercise and aerobic exercise of all home exercises were 75% and 25%, respectively. The patients in the control group did not participate in any exercise programme, instead, they were asked to continue with their normal living.

Exercise activity

Subjects kept a daily diary in which they recorded the duration and intensity of exercise, level of general condition (before and after the exercise), and any symptoms following the exercise. During the home exercise period the subjects were contacted four times by phone to allow the research staff to monitor their adherence and progress, to answer any questions, and provide individual feedback and encouragement.

Measurements

Leg flexor and extensor torque and motor fatigue were measured by using a knee muscle dynamometer (Ab HUR®; Oy, Kokkola, Finland). The measurement methods have been described previously.19 Participants in the exercise group were assessed at the baseline, at three weeks and at six months. The control group was assessed at the baseline and at six months. All outcome variables were analysed men and women together, and some interesting contrasts were analysed by gender.
**Torque (Nm) during the 30-s fatigue measurement**

The decline in mean torque of 1 s (Nm) was calculated in 1-s intervals from the time point of maximum value of the muscle torque (TPM) to the end of the recording (30 s). The highest mean value of 1 s during the period 0–5 s was chosen as the TPM.

**Fatigue Index (FI)**

The area under force curve (AUFC, where force (F) is giving the moment, Nm) calculation starts from the TPM during the first 5 s. The AUFC from this point to the end of the contraction (30 s) is divided by the hypothetical AUFC that would be obtained if the patient sustained the same maximal force (F) until the end of the 30 s. 19 Fatigue index (FI) is given as:

\[
FI = 100\% \times \left[ 1 - \frac{(AUFC_{TPM-30})}{(F_{max, 0-5} \times (TPM - 30))} \right]
\]

This FI has proven to be a reliable method of assessing motor fatigue in MS patients. 19

**Fatigue Severity Scale (FSS)**

Perceived fatigue was measured by the FSS developed and validated by Krupp and co-workers. 20

**Ambulatory Fatigue Index (AFI)**

The patients’ ambulatory ability was assessed by means of a 500-m walking test. 21 The test was carried out on a 50-m course. The patients were asked to walk at their maximum speed instead of ‘comfortable pace’. The time was recorded for the first and the final lap, and AFI was calculated by dividing the velocity during the final 50-m lap by the velocity during the initial 50-m lap. 14,21

**Statistical analysis**

Multivariate analysis with repeated measures was used to examine potential changes in FI, AFI and FSS. Group (exercise versus control) and gender were used as between-subject factors and time and side as within-subject factors. The EDSS score, AFI and FSS were used as fixed covariates and the duration of aerobic and strength exercise activity in the exercise group, and the maximal and mean torque (Nm) values were used as variable covariates to find out the associations of these variables with the FI. The results from the three-week supervised period were also analysed to establish possible learning effects related to the measurement; this analysis was done only for the exercise group. Validity of the models was evaluated by means of residual analysis. The results are presented in baseline FI(%) (mean ± SEM) and mean changes (±SEM) with 95% confidence intervals (CI). The analyses were based on the torque measured from the right leg (there were no differences between right or left leg). The Pearson correlation coefficients were used to describe the association between the FI in flexion and extension and FSS, AFI and EDSS. P-values of less than 0.05 were considered to indicate statistical significance. SAS statistical software was used in all statistical calculations (version 8.2, SAS Institute, Inc, Cary, NC, USA).

**Results**

Women completed 62% (29 h) and men 53% (23 h) of the pre-planned strength exercise sessions (75 times) at home (with elastic bands). When aerobic and strength exercise sessions were combined, 98% (63 h) of women and 85% (53 h) of men completed the targeted amount of exercise sessions (75 +24 times). The realized proportion of strength exercises were 46% (29 h of 63 h) in women, and 43% (23 h of 53 h) in men. The most frequent aerobic exercises (number of sessions) were: walking (n =42), cycling (n =35), swimming (n =17) and cross-country skiing (n =10). One woman showed exceptionally high aerobic exercise frequency (266% of the targeted exercise frequency). When her data were omitted the aerobic and strength exercise frequency in women was 92% (59 h). In the exercise groups no association was observed between FI and the amount of aerobic or strength exercise as covariate.

In knee extension, the FI was −3.3% lower in female exercisers after six months of exercising, while the controls showed an increase of 4.3% (Table 2). There were no differences in the changes of FI in knee extension between male exercisers and male controls. In both groups the FI tended to increase from baseline by six months (Table 2).
Table 2  Fatigue at baseline and change at 26 weeks assessed by fatigue index (FI) and fatigue index covariates (FI cov)

<table>
<thead>
<tr>
<th></th>
<th>Extension</th>
<th>Flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FI (%)</td>
<td>FI cov (%)</td>
</tr>
<tr>
<td><strong>Female exercise group (n=30)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>27.3±2.6</td>
<td>28.3±2.1</td>
</tr>
<tr>
<td>mean ±SEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>-3.3±2.5 ( -8.2, 1.6)</td>
<td>-3.0±1.5 ( -6.0, 0.1)</td>
</tr>
<tr>
<td>mean ±SEM (CI) at 26 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Female control group (n=31)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>22.4±2.6</td>
<td>25.9±2.1</td>
</tr>
<tr>
<td>mean ±SEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>4.3±2.5 ( -0.7, 9.4)</td>
<td>1.8±1.5 ( -1.2, 4.9)</td>
</tr>
<tr>
<td>mean ±SEM (CI) at 26 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Male exercise group (n=17)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>24.9±3.7</td>
<td>23.2±3.1</td>
</tr>
<tr>
<td>mean ±SEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>2.0±3.6 ( -5.1, 9.1)</td>
<td>3.7±2.3 ( -0.8, 8.2)</td>
</tr>
<tr>
<td>mean ±SEM (CI) at 26 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Male control group (n=17)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>25.3±3.5</td>
<td>24.2±2.9</td>
</tr>
<tr>
<td>mean ±SEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>1.8±3.3 ( -4.8, 8.4)</td>
<td>1.5±2.0 ( -2.5, 5.5)</td>
</tr>
<tr>
<td>mean ±SEM (CI) at 26 weeks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant change (p<0.05).

The baseline FI and change at 26 weeks were measured for female and male exercise and control groups, using a 30-s static fatigue test of knee extension and flexion. The percentage (%) values are given as mean ± SEM and 95% confidence interval (CI). The adjusted covariates were EDSS score, and mean torque (Nm) of 1 s during the first 5 s.

However, in knee extension the group*gender*time interaction was not significant, which reflects that the changes were statistically equivalent in men and women. Statistically significant covariates were EDSS score (p = 0.04), maximal torque (p = 0.001) and mean torque (p = 0.0004). Changes in FI with these adjustments are also shown in Tables 2 and 3.

The exercising men reached the maximal torque level faster than the exercising women did in knee extension and flexion torques (Nm) at six months. Additionally, the torque decline after the TPM was greater and faster in men than in women.

In knee flexion, the group*gender*time interaction was significant (p = 0.0140). The difference between the female exercisers and controls was even greater than in knee extension, with less fatigue in exercisers (−1.9%) and significantly increased fatigue (5.3%) in controls (Table 2). There were no differences in the changes of flexion fatigue between male exercisers and controls (Table 2). In flexion no association between FI and covariates was observed. The effects of side (left or right leg) were not significant either in extension or in flexion.

Women in the exercise group improved significantly their fatigue resistance in knee extension during the 23-week home exercise period. In knee flexion, the achieved improvements had
Table 3  Fatigue at baseline and change at 0–3, 3–26 and 0–26 weeks in the male and female groups assessed by fatigue index (Fl) and fatigue index covariates (Fl cov)

<table>
<thead>
<tr>
<th>Extention</th>
<th>Flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI (%)</td>
<td>FI (%)</td>
</tr>
<tr>
<td>Fl cov (%)</td>
<td>Fl cov (%)</td>
</tr>
<tr>
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</table>

Female exercise group (n=30)

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Change 0–3 weeks</th>
<th>Change 3–26 weeks</th>
<th>Change 0–26 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI (%)</td>
<td>27.3±2.2</td>
<td>26.3±2.0</td>
<td>23.9±2.0</td>
</tr>
<tr>
<td>Fl cov (%)</td>
<td>26.3±2.0</td>
<td>-1.6±1.6 (4.8, 1.6)</td>
<td>No association with the covariates was observed</td>
</tr>
</tbody>
</table>

Male exercise group (n=17)

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Change 0–3 weeks</th>
<th>Change 3–26 weeks</th>
<th>Change 0–26 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI (%)</td>
<td>24.8±3.1</td>
<td>23.5±2.9</td>
<td>21.9±2.9</td>
</tr>
<tr>
<td>Fl cov (%)</td>
<td>23.5±2.9</td>
<td>2.1±2.3 (2.4, 7.6)</td>
<td>No association with the covariates was observed</td>
</tr>
</tbody>
</table>

*Statistically significant change (p<0.05).

The baseline Fl and the changes from baseline to 3 weeks, from 3 to 26 weeks, and from baseline to 26 weeks were measured in female and male exercise groups, using a 30-s static fatigue test of knee extension and flexion. The percentage (%) values are given as mean ± SEM with 95% confidence interval (Cl). The adjusted covariates were EDSS score, and mean torque (Nm) of 1 s during the first 5 s.

Discussion

In the present study, exercising women but not men showed reduced motor fatigue after an exercise period of six months. The amount of reduction was not related to the amount of exercise. Other

already occurred during the first three weeks of exercising (Table 3). In men no improvement could be observed. In knee extension, EDSS score (p=0.01) and mean torque (p=0.0003) were statistically significant covariates. These adjustments slightly decreased the improvement observed in the exercising women.

A positive correlation was found at the baseline, between the FI in knee extension and EDSS in the male exercise group (r=0.66, p<0.01). No other correlations between the FI and AFI, EDSS or FSS were found.

The time effect was statistically significant for the AFI both in the exercise and control groups (change and confidence intervals), 2.44 (0.67–4.21), p=0.007, and nearly significant for the FSS, 0.17 (−0.02 to 0.36), p=0.07. No significant gender or group interactions were observed in AFI or in FSS.
reasons related either to MS or to individual physiology may explain the lack of exercise effect in men. It can be speculated that six months was too long for a training period and that the progression of the disease may have hidden some positive training effects, especially in men. Perhaps, if we had followed up the training effects more frequently (e.g., once a month), we might have obtained a more comprehensive picture of the training effects on motor fatigue. Morganti et al. showed in their one-year resistance training programme in healthy older women that the greatest increases in strength were achieved in the first three months.

The relapsing-remitting type of multiple sclerosis is present in 80% of MS patients, with a female predominance of approximately 60–70%. In our study, there were more subjects with a progressive course of MS among the men than among the women. Male exercisers also had a higher mean EDSS score than female exercisers, in spite of equal duration of MS. High EDSS scores and high FI values were associated in the male but not in the female exercise group. Gender differences observed in the EDSS among our subjects are in line with previous studies. In MS, disability progresses faster in men than in women. It can be speculated that deconditioning of muscles was evident only in men in our study.

Kent-Braun and co-workers studied the skeletal muscle composition, strength and enzyme activity in MS patients (mean EDSS score 4.0). They found that the MS patients’ muscles had the same characteristics as disused muscles: fewer type I (slow twitch) fibres, smaller muscle fibres, greater tendency to supply energy by anaerobic pathways and to have impaired skeletal muscle oxidative capacity. They proposed that the chronically reduced maximum discharge rates, and altered motor unit activation might induce changes in skeletal muscle characteristics.

In our study, the EDSS and torque were associated with fatigue in knee extension, but not in flexion, in which the strength is lower. Previous studies speak both for and against an association between weakness and motor fatigue. Schwid and co-workers concluded that strength and motor fatigue are distinct features, but Djaldetti and co-workers observed that static fatigue was more pronounced when weakness was present. De Haan and co-workers proposed that fatigue can be reduced by increasing the muscle mass. According to Schwid et al., fatigue may have several forms (weakness, fatigue or both). The authors did not find any relationships between static and dynamic fatigue within the same muscle group.

The torque decline was greater and faster in male than in female exercisers after a few initial seconds of measurement in this study. A similar trend was observed in our previous paper among mild-to-moderately affected MS patients. Women's performance remained probably at a submaximal level, while men performed with maximal effort. The absolute muscle force was lower in women than in men. However, since women were performing the same relative work as men did, the oxygen demand in their working muscles may have been lower. Further, the vascular occlusion during the performance may correlate with the force of muscle contraction. With reduced vascular occlusion in muscles, the metabolic clearance should consequently be faster during a prolonged performance. Thus, both decreased oxygen demand and better metabolic clearance in women may explain the observed gender differences in fatigue.

Perceived fatigue (measured by FSS) in our study tended to increase in all subjects after 26 weeks of follow-up. Previous studies indicate that perceived fatigue is distinct from motor fatigue. Sharma and co-workers suggested that MS-related fatigue has both central and peripheral components, such as impaired metabolism and altered muscle excitation components – contraction coupling. Our finding is consistent with the study of Sharma et al., where they proposed the lack of association between perceived fatigue and FI to indicate that the origin of motor fatigue is related with dysfunction of upper motor neurons and/or muscles. Previous studies are contradictory concerning whether fatigue is of central or peripheral origin or both,

During the first three weeks, we did not observe any learning effects in the measurements, except that the exercising women improved their fatigue resistance in knee flexion. It is possible that our exercise programme was optimal for flexor muscles, because of water gymnastics and because of the fact that knee extensor and flexor muscles were
Clinical messages

- Motor fatigue can be successfully reduced in mildly impaired female MS patients by aerobic and strength exercise.
- The exercise should preferably be as specific as possible concerning the muscle group and exercise intensity for achieving reduced fatigue in knee extensor and flexor muscles in subjects with MS.

Exercised at gym with the same type of device as was used for the fatigue measurement.32

Subjects in this study were chosen from MS patients who had sent their application to participate in an inpatient rehabilitation course. This is a potential source for bias. The attitude of all of them may well have been positively turned towards physical exercise. Another limitation is that the subjects were no more than mildly or moderately disabled. Therefore, exercise intervention trials among severely affected patients are needed before generalizations concerning the entire MS population can be made.

Also, to ensure better statistical power, the male exercise group should have been larger.

Our study showed that aerobic and strength exercise can reduce motor fatigue in MS patients as has earlier been proposed by Kent-Braun et al.8 and de Haan et al.10 The exercise mode used in our study, exercises for the whole body, was perhaps not optimal for the purpose of improving fatigue resistance in knee muscles. The physiological enhancements normally achieved by exercising may not be the same in MS patients in whom different muscle groups are affected in various and unpredictable ways. Therefore, the exercise effect might have been more pronounced if the exercises had mainly focused on leg extension and flexion, and also with a greater proportion of strength exercises. Furthermore, of all aerobic exercises, walking was the most popular exercise mode, and that did probably not provide sufficient intensity to reduce fatigue in men (e.g., to achieve muscle hypertrophy).33 Further studies are needed to find out the optimal exercise mode and intensity for improving motor fatigue resistance in MS patients. The changes in ambulatory endurance (measured by AFI) were similar for all subjects. An explanation may be the relatively low reliability of AFI intraclass correlation coefficient (ICC) 0.36 in subjects with MS and 0.21 in healthy subjects).14 The reliability of the FI used in our study has been shown to be good (ICC 0.68–0.86).

In conclusion, the outcomes of the present study show that aerobic fitness and strength exercising reduces motor fatigue in MS subjects with low or moderate disability. This study indicates that the exercise mode was more feasible among the less disabled women than the more disabled men. There might also be a physiological female gender advantage.

Acknowledgements

This study was supported by a grant from the Social Insurance Institution of Finland.

References


