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Elliptical exercise improves fatigue ratings and quality of life in patients with multiple sclerosis

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Abstract—Fatigue, reduced quality of life (QOL), and lower physical activity levels are commonly reported in patients with multiple sclerosis (MS). This study evaluated the effects of elliptical exercise on fatigue and QOL reports in patients with MS. Patients with MS (n = 26) completed the Fatigue Severity Scale (FSS), the Modified Fatigue Impact Scale (MFIS), and the Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) before and after completing 15 elliptical exercise training sessions. Changes in fatigue and QOL were assessed based on any changes in the fatigue and SF-36 questionnaires, and correlations between changes in each of the scales were made to determine whether a relationship was present between the fatigue and QOL measures. Results showed significant improvement in FSS, MFIS, and five SF-36 subscales as a result of elliptical exercise. The change in FSS correlated with change in two of the SF-36 subscales. Elliptical exercise for patients with MS results in significant improvements in both fatigue and QOL. These findings indicate that regular elliptical exercise could be a part of inpatient and outpatient MS rehabilitation programs.

Key words: elliptical exercise, fatigue, general health, multiple sclerosis, neurological disease, physical activity, physical function, quality of life, questionnaire, rehabilitation.

INTRODUCTION

For patients with multiple sclerosis (MS), fatigue is one of the most commonly reported symptoms and is reported by up to 90 percent of patients [1–2]. In addition, patients with MS report depressed mood and decreased quality of life (QOL) [3–5]. Fatigue, depression, and lower QOL may reflect impairments in functional ability in patients with MS [2,6].

Fatigue is described as an increased weakness with exercise or as the day progresses, as an abnormal constant and persistent sense of tiredness, or as fatigable weakness exacerbated by activity or heat [7–8]. The reported QOL level in patients with MS is lower than other persons with chronic conditions, including rheumatoid arthritis and inflammatory bowel disease [3,9–10]. Increases in structured exercise participation and increases in physical activity levels have been shown to increase QOL scores [11–13]. Currently, physical activity levels in patients with MS are significantly lower than nondisabled groups [14]. However, evidence shows that patients with MS benefit from structured exercise [15].

Abbreviations: EDSS = Expanded Disability Status Scale, FSS = Fatigue Severity Scale, MFIS = Modified Fatigue Impact Scale, MS = multiple sclerosis, QOL = quality of life, SF-36 = 36-Item Short Form Health Survey.

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For instance, endurance training has the potential to improve both fatigue [12,16] and QOL scores [17]. Motl and Gosney specifically reported that exercise training is associated with an improvement in QOL in patients with MS [17], while Snook and Motl reported that exercise improves mobility [18]. These findings are especially important since exercise is a modifiable behavior that positively affects QOL and yields other health benefits, such as reduced risk for cardiovascular diseases, type-II diabetes, obesity, and some types of cancer [17].

Different exercise modalities, however, have shown differing outcomes in fatigue and QOL improvements. For example, cycling [11] and resistance training [19] resulted in significantly improved fatigue ratings, while treadmill training [16] did not affect fatigue scores. Thus, the exercise modality that is the most effective for improving fatigue and QOL in patients with MS is not clear. Elliptical exercise offers a positive alternative to treadmill training and is performed with a piece of equipment that is fairly common and found in most workout facilities. Elliptical exercise has recently become a treatment and rehabilitation method since it provides a "walking-like" movement pattern. Elliptical trainers have been used for rehabilitation in persons who have undergone hip arthroscopy [20], anterior cruciate ligament revision surgery [21], and patellar tendonectomy [22] and in persons with patellofemoral pain syndrome [23] and diabetes [24]. Elliptical training has been shown to have similar peak oxygen uptake and heart rate as treadmill training, which indicates that the elliptical trainer is similar to the treadmill with respect to intensity [25]. However, no previous studies have outlined the result of elliptical exercise training in patients with MS. Elliptical exercise is suited for use by patients with MS; it can accommodate persons with varying levels of disease severity because of the self-paced motion and adjustable resistance levels of the machine. In addition, the elliptical machine allows the user to achieve repeated movement patterns of the lower limbs. Overall, the limitation of voluntary control of individual muscle groups predicts overall capacity to recover walking [26]. Since gait problems are so heavily reported by patients with MS, an exercise that helps improve gait by allowing for increased voluntary control of muscle activity may also help improve overall walking capacity [26]. QOL is likely to improve in patients with MS with improved overall walking capacity.

This study investigated whether 6 weeks of elliptical exercise training could affect the fatigue levels and QOL of patients with MS. We hypothesized that as a result of elliptical exercise, both fatigue levels and QOL scores would significantly improve in patients with MS. In addition, we hypothesized that improvements in fatigue ratings would correlate with improvements in QOL ratings.

METHODS

Patients with MS

The study comprised 26 patients with MS (mean age 45.5 ± 10.5 yr) (**Table 1**). Inclusion criteria for the patients with MS included cognitive competency to give informed consent, age ranging from 19 years to 65 years, an Expanded Disability Status Scale (EDSS) score 1.0 to 6.0, and the ability to walk 25 feet. Exclusion criteria included inability to give informed consent, an EDSS score ≥6.5, inability to walk 25 feet, pregnancy, breast-feeding, within 3 months postpartum at the initiation of the study, any other neurological or vestibular disorder, or any other comorbid conditions that would make participation in exercise unsafe. Some examples of comorbid conditions include myocardial infarction, chest pain or angina, congestive heart failure, cardiac dysrhythmia, or actively symptomatic chronic obstructive pulmonary disease. No restrictions were placed on the type of MS subjects had, but any subjects with relapsing disease pattern needed to be stable for at least 60 days before beginning the exercise program. No subjects experienced any symptom exacerbations while enrolled in the study. No consideration was given to symptom-managing medications or disease-modifying medications. No subjects changed or stopped any current medications while enrolled in the study.

Table 1.
Demographic information for patients with MS (n = 26). Data presented as mean ± standard deviation or n.

Variable	MS Patients
Sex (M/F)	5/21
Age (yr)	45.5 ± 10.5
Baseline EDSS	2.7 ± 0.9
Height (cm)	166.0 ± 6.7
Weight (kg)	78.5 ± 16.0
TUG Score (s)	
Pretraining	11.1 ± 10.8
Posttraining	9.7 ± 5.6

EDSS = Expanded Disability Status Scale (score), F = female, M = male, MS = multiple sclerosis, TUG = Timed "Up and Go" Test.

Fatigue and QOL Measures

Fatigue

Measures of fatigue were obtained with the Fatigue Severity Scale (FSS) and the Modified Fatigue Impact Scale (MFIS).

FSS. The FSS is a method of evaluating fatigue in patients with MS and other conditions, including chronic fatigue immune dysfunction syndrome and systemic lupus erythematosus [27]. The FSS is designed to differentiate fatigue from clinical depression, since both share some of the same symptoms. The FSS questionnaire is composed of nine statements related to the patients' subjective perception of fatigue and its consequences on everyday activities. Patients are asked to rate their level of agreement (toward 7) or disagreement (toward 0) with the nine statements. The FSS has been validated for use in patients with MS, where the scale demonstrated high internal consistency with a Cronbach alpha of 0.81 [27].

MFIS. The MFIS is a modified form of the Fatigue Impact Scale based on items derived from interviews performed in patients with MS [28]. The scale assesses the effect of fatigue in terms of physical, cognitive, and psychosocial functioning with a 21-item questionnaire. The MFIS has been validated for patients with MS by Kos et al., who found the overall Cronbach alpha was 0.92 and the Cronbach alphas for the physical, cognitive, and psychosocial subscales were 0.88, 0.92, and 0.65, respectively [7,28].

QOL: SF-36

Measures of health-related QOL were obtained using the Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) questionnaire. Eight health domains are assessed with the SF-36: Physical Function, Limitation due to Physical Health (Role Physical), Limitation due to Emotional Problems (Role Emotional), Energy, Mental Health, Bodily Pain, General Health, and Social Function. The SF-36 has been used extensively to evaluate and differentiate between groups of varying health status [29–30], has previously been used for patients with MS [31–33], and has shown good responsiveness for use in patients with MS [34].

Change in FSS, MFIS, QOL

To assess the change in fatigue and QOL as a result of elliptical training, we subtracted the pretraining score from the posttraining score for each questionnaire. For example, the change in FSS score is represented as

$$FSS_{change} = FSS_{posttraining} - FSS_{pretraining}.$$

The change in each variable due to elliptical exercise was calculated in this fashion.

Exercise Training Protocol

All 26 patients with MS completed 15 sessions of elliptical exercise training. The elliptical training took place at the recreation facility of the University of Nebraska at Omaha campus. The elliptical machines (EFX 546, Precor; Woodinville, Washington) were housed in a section of the workout room that was accessible only by the investigators of this study. Each subject was monitored for the duration of the exercise training on the elliptical machine via a standard, commercially available heart rate monitor (Polar Electro Inc; Lake Success, New York); heart rate was taken every 3 minutes. Each session consisted of 30 minutes of training on the elliptical trainer. This time period for this exercise intervention (15 sessions over 6 weeks) was within the range of time periods previously used for resistance and aerobic training in patients with MS [12,16,35–36].

During the first exercise session, subjects initiated exercise at their self-selected pace with the instruction that they would need to complete 30 minutes of exercise and could take as many breaks as necessary. All subjects started the exercise session with the elliptical machine set at an incline of 0 (no incline) and a resistance of 1 (lowest possible resistance). Progression of exercise intensity was achieved by increasing the resistance level of the elliptical machine and/or by increasing the subject's steps per minute (stepping speed was controlled by the subject and not the elliptical machine). We increased exercise intensity based on the patient's age-predicted heart rate maximum measured with the heart rate monitor. The first exercise session's intensity was dictated by the patient's level of motivation, ability to perform, spasticity, and fitness level; thus, no minimum percentage of age-predicted heart rate was required. The heart rate during each exercise session was continually monitored in a log and tracked as a percentage of the age-predicted heart rate maximum to ensure that subjects were progressing in exercise intensity as their fitness level improved. To ensure that all subjects were progressing in the exercise protocol, we increased exercise intensity every 3 to 4 sessions.

Statistical Analysis

To investigate any changes that occurred in the fatigue and general health perceptions of patients with MS as a result of elliptical training, we used paired *t*-tests to compare questionnaire scores from pre- to posttraining. All variables showed normal distribution according to the Shapiro-Wilks test except the SF-36 Role Emotional and Energy subscales. For these two variables, the nonparametric Wilcoxon signed ranks test was used to compare pre- and posttraining scores. To examine the relationship between the change in fatigue scores and the change in QOL scores, we used Pearson correlations. The correlations between FSS and MFIS and the SF-36 Role Emotional and Energy subscales were performed with Spearman correlations. All analyses were performed with SPSS 16.0 statistical software (SPSS Inc; Chicago, Illinois) and tested at $\alpha = 0.05$.

RESULTS

Fatigue Measures

The scores of the FSS significantly decreased from 4.89 ± 1.32 to 4.32 ± 1.57 ($p = 0.008$; effect size = 0.43), indicating a significant improvement in fatigue ratings in patients with MS. The scores of the MFIS also significantly decreased from 43.7 ± 15.8 to 35.4 ± 14.3 ($p < 0.001$; effect size = 0.58), indicating a significant improvement in fatigue ratings in patients with MS (**Table 2**).

SF-36

The Physical Function subscale score significantly increased from pre- to posttraining ($p = 0.013$; effect size = 0.33), indicating an improvement in perception of physical function ability. The Role Emotional subscale significantly increased from pre- to posttraining ($p = 0.015$; effect size = 0.58), indicating an improvement in perception of emotional problems and the limitations that those problems cause. The Energy subscale significantly increased from pre- to posttraining ($p < 0.001$; effect size = 0.54), indicating an improvement in the energy level of patients with MS following the elliptical training. The Social Function subscale significantly increased from pre- to posttraining ($p = 0.009$; effect size = 0.51), indicating an improvement in the limitation in social function. Finally, the General Health subscale significantly increased from pre- to posttraining ($p = 0.048$; effect size = 0.25), indicating an overall improvement in general health perception in patients with MS following elliptical training (**Table 2**).

Correlations

Change in FSS due to elliptical exercise significantly correlated with change in SF-36 Physical Function subscale ($R = -0.42$; $p = 0.043$). In addition, change in FSS correlated ($R = -0.52$) with change in SF-36 Role Physical subscale ($R = -0.52$; $p = 0.009$) (**Table 3**). These correlations are moderate. Change in MFIS did not correlate with change in any of the SF-36 subscales (**Table 3**).

DISCUSSION

The results of this study indicate that 6 weeks of elliptical exercise training significantly improve fatigue and

Table 2.
Averaged scores for each fatigue scale and for each component of Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) for patients with multiple sclerosis. Data presented as mean ± standard deviation.

Questionnaire Scale	Pretraining	Posttraining	*p*-Value
Fatigue Severity Scale	4.89 ± 1.32	4.32 ± 1.57	0.008*
Modified Fatigue Impact Scale	43.7 ± 15.8	35.4 ± 14.3	<0.001*
SF-36			
Physical Function	60.0 ± 21.8	67.1 ± 23.6	0.01*
Role Physical	38.5 ± 38.2	55.8 ± 42.0	0.07
Role Emotional	46.1 ± 43.3	68.0 ± 32.3	0.02†
Energy	43.4 ± 19.8	54.0 ± 19.6	<0.001†
Mental Health	62.0 ± 22.5	66.9 ± 18.3	0.10
Social Function	60.2 ± 26.5	72.6 ± 24.0	0.009*
Bodily Pain	67.8 ± 22.3	72.9 ± 21.8	0.13
General Health	48.3 ± 19.3	53.1 ± 19.9	0.048*

*Significant group difference by paired *t*-test, $p < 0.05$.
†Significant group difference by Wilcoxon signed ranks test, $p < 0.05$.

Table 3.
Relationship between changes of scores of fatigue (FSS and MFIS) and quality of life (SF-36 subscales).

Correlated Parameter	*R*	R^2	*p*-Value
FSS			
MFIS	0.12	0.01	NS
SF36-PF	–0.42	0.17	0.043*
SF36-RP	–0.52	0.27	0.009*
SF36-RE†	–0.06	0.00	NS
SF36-E†	–0.14	0.02	NS
SF36-MH	–0.30	0.09	NS
SF36-SF	–0.30	0.09	NS
SF36-BP	–0.28	0.08	NS
SF36-GH	–0.11	0.01	NS
MFIS			
SF36-PF	–0.21	0.04	NS
SF36-RP	–0.26	0.07	NS
SF36-RE†	–40.39	0.15	NS
SF36-E †	–0.22	0.05	NS
SF36-MH	–0.24	0.06	NS
SF36-SF	–0.38	0.14	NS
SF36-BP	–0.31	0.09	NS
SF36-GH	–0.11	0.01	NS

*Significant correlation between parameters.
†Nonparametric correlation performed.
BP = Bodily Pain, E = Energy, FSS = Fatigue Severity Scale, GH = General Health, MFIS = Modified Fatigue Impact Scale, MH = Mental Health, NS = nonsignificant, PF = Physical Function, RE = Role Emotional, RP = Role Physical, SF = Social Function, SF-36 = 36-Item Short Form Health Survey.

QOL in patients with MS. These results are in agreement with the original hypotheses. In addition, significant correlations were found between improvements in fatigue ratings and reported physical function limitations, which are also in agreement with the original hypotheses. To our knowledge, no other reports examine the effect of elliptical training on fatigue and QOL in patients with MS.

Importantly, the pre- and posttraining FSS scores were above 4.0, which is traditionally the cutoff score for FSS because only 5 percent of nondisabled control subjects were reported to have scores above this level [27]. This result indicates that at pretraining, the patients in this study did report fatigue according to both the FSS and MFIS at levels similar to those reported in previous studies [7,37].

Our data show a significant improvement in both the FSS score and MFIS score in patients with MS after a relatively brief 6 weeks of elliptical exercise training, which indicates that elliptical exercise training has a beneficial effect on MS fatigue. The positive effect of elliptical exercise on fatigue is an important finding because fatigue is reported as one of the most disabling symptoms of MS [38]; reported fatigue may be due to a decrease in voluntary effort or motor control capabilities [39]. Fatigue may occur as a result of sustained force production (peripheral fatigue), which would occur in an individual regardless of disease status if the task was sustained for a significant amount of time. Alternatively, fatigue may occur if there is a failure to sustain the required neural drive to create muscle force production (central fatigue) [39]. The existence of central fatigue is likely the source of fatigue in patients with MS, because the decline in neural drive could result from the loss of supraspinal and spinal contributions. It could also be due to conduction blockage in motor axons in the peripheral nerves [40–41]. Six weeks of elliptical training may have allowed for improved axonal conduction and therefore improved supraspinal contribution to motor control. While this idea is only speculative, inclusion of a gait-simulating exercise may have helped to improve muscle firing patterns and increase supraspinal input. To verify this idea, researchers could measure somatosensory-evoked potentials to investigate whether spinal conduction speeds improved. In animal models of spinal cord injury, exercise has been shown to increase the release of brain-derived neurotrophic factor, which promotes reflex normalization [42], and to increase action of microRNAs, which help regulate apoptosis after injury [43]. Fisher et al. showed that when neurologically damaged rats were exposed to treadmill training, their walking performance returned to the level of nondisabled control subjects within 30 days [44]. These results speak to the widespread effects that exercise may have in patients with neurological disease. While patients with MS are not spinal cord injury patients, the characteristic brain and spinal cord lesions present in patients with MS cause motor and sensory problems similar to spinal cord injury [38]. In patients with MS, the repetitive elliptical training tested in this study could allow for increased muscle activation and increased physical activity levels while training. An increase in neural drive could then result in the improvements in fatigue reports seen in this study. However, these hypotheses need to be verified with biomechanical studies that explore the neuromuscular adaptations that occur after elliptical training.

The reported QOL scores from the SF-36 also significantly increased as a result of elliptical training in patients with MS. The Physical Function, Energy, Social Function, and General Health subscales all significantly improved as a result of training, which indicates that elliptical training affected both the physical and mental aspect of QOL perception in patients with MS. Additionally, the improvement in SF-36 subscales for Physical Function, Energy, Social Function, and General Health indicate a perceived improvement in physical and social functioning in daily life. However, the Role Physical, Mental Health, and Bodily Pain subscales did not show significant improvement despite showing increases from pre- to post-training. Specifically, the Role Physical subscale increased by 17.3 points. This indicates that the patients with MS reported an improvement in physical functioning; however, that improvement was not statistically significant. QOL is reduced in patients with MS [5], but recent reports show that exercise training is associated with improvement in QOL [17]. This finding was supported by the present study. The improvement in QOL is likely due to the overall increase in physical activity level that training with the elliptical exercise machine provided. In general, the level of physical activity is greatly reduced in patients with MS because of multifactor causes including axonal fatigue, deconditioning, ongoing disability, and medical recommendations for limited activity [15]. Previous studies have also shown an improvement in QOL parameters related to regular physical activity in individuals with MS [11–13]. Increasing the overall physical activity level of patients with MS is also crucial to maintaining long-term health in the population despite the inherent challenges to patients with MS in sustaining an increased activity level [45]. A meta-analysis performed by Motl et al. outlined the current physical activity levels in patients with MS and found that they are less active than nondiseased populations [14]. In addition, patients with MS have lower QOL scores and lower levels of physical activity than other persons with chronic conditions [3,9–10]. Low QOL scores translate to lower physical activity levels, while increases in structured exercise participation and increases in physical activity levels have been shown to increase QOL scores [11–13]. Thus, the improvement in reported QOL in patients with MS in the present study is likely the result of the structured elliptical exercise program.

The QOL measures did not correlate with the MFIS, which specifically evaluates the effect of fatigue in terms of physical, cognitive, and psychosocial effects; the FSS examines the effect of fatigue on everyday activities in general. Interestingly, the change in fatigue according to the FSS correlated moderately only with changes in the physical components of the QOL questionnaire. Patients may have reported that their participation in an exercise program had a greater effect on the physical function aspects of their QOL because their physical function directly affects their level of central or peripheral fatigue. The improvement in FSS and the Physical Function and Role Physical subscales are then likely to all be related to an improvement in central fatigue that affects both fatigue reports and the physical functioning of patients with MS. As stated previously, central fatigue is likely the source of fatigue in patients with MS, because the decline in neural drive could result from the loss of supraspinal and spinal contributions. It could also be due to conduction blockage in motor axons in the peripheral nerves [40–41]. By participating in elliptical exercise, patients with MS may have improved their neural drive and the supraspinal and spinal contributions to motor control. Thus, fatigue was improved and the physical components of the QOL scale reflected an overall improvement in motor function. Conversely, the reported improvement in Role Emotional, Energy, Social Function, and General Health subscales may not have a specific effect on central fatigue levels, so no correlation with FSS was noted.

We must note that the disease severity level of the patients enrolled in this study was relatively low. Of the 26 subjects who completed the study, 8 worked part-time and 13 worked full-time. Of the 5 people who did not work, all were involved in other community activities including groups sponsored by the local chapter of the National MS Society. The level of community interaction that all subjects had makes it unlikely that the improvement seen in QOL was due solely to interaction with the study personnel. We should also note that patients were enrolled continuously throughout the year, not in one season alone. For this reason, it is unlikely that change in season could account for the improvements in QOL and fatigue.

Our results should be viewed in light of the following limitations. First, we did no follow-up after completion of the study to evaluate fatigue and QOL and monitor whether improvements were maintained weeks or months after the conclusion of this study. The goal of this study, however, was to introduce a new exercise modality to patients with MS that could be maintained independent of this research protocol. Elliptical exercise machines are readily available for use in recreation facilities or the home, so we hoped that patients would maintain the exercise beyond this study. We could only measure fatigue and QOL at follow-up if the patients were instructed to stop exercising. Second, we did not include a control MS group to measure changes in fatigue and QOL as a function of time and disease progression. The relatively short length of this study, 6 weeks, was short enough that significant changes in disease status were not expected in a control MS group. However, if the intervention was performed over a longer period of time, e.g., 12 or 24 weeks, a control MS group with a standardized treatment, such as physical therapy, may be important.

CONCLUSIONS

Regardless of these limitations, this study shows that a relatively short elliptical exercise training program can improve fatigue and QOL ratings in patients with MS. These findings indicate that regular elliptical exercise could be a part of inpatient and outpatient MS rehabilitation programs.

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