Original Article

Effect of Neuromuscular Exercises on Strength, Proprioceptive Receptors, and Balance in Females with Multiple Sclerosis

Abstract

Background: Multiple sclerosis (MS) is the third most common cause of adult neurologic disabilities. The aim of this study was to determine the effect of 8 weeks of neuromuscular exercises on strength, proprioceptive receptors, and balance of women with MS. **Methods:** In this randomized controlled trial study, 20 female volunteers with relapsing-remitting MS were randomly assigned into the experimental group (n = 10) and control group (n = 10). Maximum muscular strength of knee extensor and flexor muscles, knee joint proprioceptive error (Biodex), and balance (Berg Balance Scale) was measured at baseline and after 8 weeks of neuromuscular exercise. The data were analyzed using paired t-test and independent t-test. **Results:** The results showed a significant improvement ($P < 0.05$) in the quadriceps strength, hamstring strength, proprioceptive receptor error, and the balance in the experimental group, but not in the control group. A significant difference was evident between the experimental and control groups in terms of strength, balance, and proprioceptive receptor error ($P < 0.05$). **Conclusions:** Neuromuscular exercise training is effective in improving balance, strength, and reducing the proprioceptive error in people with MS, and it could be recommended as modalities for these patients.

Keywords: *Balance, maximum strength, multiple sclerosis, neuromuscular exercises, proprioceptive error*

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Introduction

Multiple sclerosis (MS) is described as a neurodegenerative disorder of the central nervous system (CNS).[1] Affecting nearly 2.5 million adults around the world, it is recognized as the third most important cause of neurological problems among adults.[2] The annual prevalence of MS has increased by almost 10,000 people worldwide.[3] According to recent studies,[4] MS has a relatively high prevalence in Iran and the Middle East. The average age of MS onset is 27 years old, and more than 40,000 patients are diagnosed with this disorder in Iran. Symptoms including imbalance, muscle weakness, spasticity, sensory disorders, and visual impairment are considered as important manifestations of MS.[5] MS seems to majorly affect the lower limbs.[6] Balance-related problems in MS are not only associated with neuromuscular changes resulting in declined leg strength, but also adverse effects on sensory processes involved in optimal balance control (i.e., vestibular, visual, and proprioceptive).[7] According to the World Health Organization, sensory disorders are common MS symptoms. In previous studies, nearly 80% of MS patients had some sensory disorders.[8] In patients with MS, noise might increase in the sensory system and accuracy level might be reduced.[9] Any weakness and disorder in proprioceptive receptors can significantly elevate the risk of injury by reducing balance, increasing the risk of falling, and impairing walking pattern.[10] Functional limitations are in direct association with poor proprioception. Poor proprioception can increase the effect of muscle weakness on functional limitations.[11] In MS, proprioceptive receptors in the lower limbs are more disturbed compared with those of the upper limbs.[8] MS patients show weakness in proprioceptive receptors.[12-14] Similarities in the comparison of sensory modalities are in line with previous research, which solely examined the foot.[8] The knee-joint proprioceptive receptors include various neuron fibers, such as sensory neurons of the joint status and the joint motion.[11] Based on new findings, the motor activity of MS patients can be improved

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by sensory-based interventions.[8] Therefore, it is essential to examine the sensory components in the design of rehabilitation programs for MS patients. In MS patients, the advantages of exercises, including resistance training, aerobic exercises, and core stability training, have been studied. In addition, combined exercises involving aerobic, resistance, and/or balance components have been assessed in some studies.[15] A limited number of studies proposed specific exercises for proprioception and balance,[16] and there is a few research studies regarding the efficacy of combination exercise training.[15-17] Neuromuscular exercises include a combination of core stability, balance, strength, agility, and plyometric exercises. Neuromuscular training improves the ability of nervous system to generate a fast and optimal muscle-firing pattern; these exercises create compensatory changes in active muscular patterns and facilitate dynamic joint stability.[18] Neuromuscular exercises are of great importance in improving neuromuscular coordination based on strength, motion range, and proprioceptive function.[19] However, the effects of neuromuscular exercise training on proprioceptive receptors, as well as strength and balance in patients with MS are not evaluated. Investigation of MS heavily relies on data about white populations. The novelty of the present study is the evaluation of patients with mild MS according to the Expanded Disability Status Scale (EDSS score ≤ 3), with an emphasis on outcomes, including balance, strength, and proprioceptive receptors. The study location, Isfahan, is also important. This city is one of the major cities in Iran, which has shown a dramatic increase in the prevalence of MS, the highest in the Oceania and Asia.[4] Thus, the current study aimed at assessing the effects of neuromuscular training on strength and proprioceptive receptors in Iranian females with MS. It was hypothesized that an 8-week neuromuscular exercise training program would significantly improve strength, proprioception, and balance in females with MS.

Methods

This research was a randomized controlled trial study. The community-based Isfahan MS Society confirmed the diagnosis of relapsing-remitting MS in patients, who were selected by a qualified neurologist from the waiting list of a rehabilitation program. The patients were randomly assigned according to a computer-generated randomization list and were stratified by age and EDSS score to either of intervention group or control group. Neurological disability was evaluated using the EDSS questionnaire,[20] with scores ranging from 0 (normal) to 10 (MS-related death). The study included patients with mild MS symptoms and EDSS scores of 1–3. The inclusion criteria were as follows: 1) presentation of MS in the past 2 years; 2) lack of relapse in the past month; and 3) ability to exercise regularly. A prestudy checklist was completed by patients to assess their ability to exercise regularly. Patients aged between 30 and 50 who were able to exercise regularly, were recruited in the study. The Ethics Committee of University of Isfahan approved this study (IR.UI.REC.1397.070). After describing the study objectives to the participants and collecting written informed consents, they were randomly divided into experimental and control groups; they also declared their agreement after randomization. An independent academic member conducted the randomization, using shuffled, sealed envelopes containing group allocations. The experimental group undertook 8 weeks of neuromuscular exercise training, while the control group received no interventions, and they were asked to maintain normal daily activities during the 8-week intervention.

Outcome measurement

Biodex system 3 proisokinetic dynamometer was used to assess the maximum muscular strength of knee extensors and flexors. The volunteers sat on the special chair of the device at a 90° hip angle and special belts were fastened to prevent body motion and fix the considered limb. After providing standard training on the device for volunteers, they performed three repetitions of maximal isometric voluntary contraction for the extensor muscles and knee flexors at a 70° angle for 5 s. Between each contraction, more than 30 s of resting time was given. The volunteers received verbal and visual feedback during the contractions.[21]

To evaluate the proprioceptive senses,[22] an angular reconstruction method was employed by Biodex isokinetic dynamometer and the target angle was 60°. The volunteers sat on the special chair of the device at a hip angle of 90°, and the special belts were fastened to prevent body motion and fix the considered limb in place. After introducing the considered method, the volunteer brought her leg to the target angle while forwarding the leg from the starting angle of 90°. When the subject's leg reached the target angle, the device fixed the leg and held it in this position for 5 s. Then, the subject's leg returned to the starting point. Afterward, the person was asked to close her eyes and restore the target angle, and when she placed her leg in that angle, she pressed the device control key. Similar verbal feedbacks were used for all of the subjects.

Balance was evaluated using the Berg balance scale (BBS), a clinical measure including 14 balance tasks. The minimum score for each task is 0 and the maximum score is 4. If the total score of the patient is ≤20, she requires a wheelchair. If the total score of the patient is >20 or ≤40, she requires a walking aid. Patients that got a score of 40 can walk independently.[23] All of our patients had a score of over 40, showing that they could walk independently. All patients were assessed by expert trained assessors who did not know about the classification of patients into intervention and control groups during the assessment.

Exercise program

In total, the exercise protocol took 60 min. the beginning of each training session, the patients warmed up for 10 min by performing stretching and proper movements. The duration of the main exercise was considered 45 min as well as 5 min for cool down. In order to increase the effectiveness of the exercises during the training period, the overload principle (increasing the number of repetitions and seconds, the color of therabands, and the type of exercises) was used. The exercises were performed in a group three times a week for 2 months and each session took 60 min. Neuromuscular exercises included activities focused on core stability, resistance, balance, and agility in each session, and in the last 2 weeks, plyometric exercises were added with different intensities. In a circuit class format, each patient performed a set of 8 to 12 or 15 repetitions of a particular movement, and then, rotated to a different exercise station. Throughout the training sessions, a movement technique was emphasized and a neutral spinal position was encouraged. The exercises were performed in three sets with a 1 min resting period. The Borg's scale was used to rate the exertion perceived during exercising. The exercises were performed with very low intensity in the first and second weeks; then continued with low intensity in the third to fifth weeks, and finally with slightly high intensity (perceived exertion rate 9–13) in the weeks 6–8. It should be noted that all the experimental group members had a similar exercise program, which included motions derived from several instructions recommended to improve strength, proprioceptive receptors, and balance of patients with MS and osteoarthritis Table 1.[21,24,25] All protocols were performed by qualified sport science expert.

Data analysis

Continuous data have been presented as mean ± SD. Normality of continuous data was evaluated using

Table 1: Neuromuscular exercises protocol

Exercise type	Week	set	Repetition
1- Core stability exercises			
Supine abdominal draw in	1	3	8
Pelvic tilt with double knee tuck	1	3	8
Abdominal draw in with knee to chest	2	3	8 and 12
Supine butt lift with arms at side	3-4	3	8 and 12
Quadruped with leg lift	4-5	3	8 and 12
Quadruped opposite arm/leg	5-6	3	10 and 12
2- Strength exercises			
Shoulder and hip flexion with theraband (red, green, blue, and black)	1-5	3	8 and 12
Abduction of shoulder and hip with theraband (red, green, blue, and black)	1-5	3	8 and 12
Extension of shoulder and hip joint with theraband (red, green, blue, and black)	1-5	3	8 and 12
Flexion of hip with theraband (red, green, blue, and black)	1-5	3	8 and 12
Flexion of knee with theraband (red, green, blue, and black)	3-6	3	8 and 12 and 15
Semisquat motion	7-8	3	8 and 12 and 15
3- Balancing exercises			
Static lunge with support	1	3	8
Tandem stance	1-2	3	8 and 10
Static lunge without support	2	3	8 and 12
Tandem stance on the foam with support	3-4	3	8 and 12 and 15
Tandem stance on the foam without help	4-5	3	8 and 12 and 15
Toe stand	6	3	8 and 12
Single leg stance	7	3	8 and 12
4- Agility exercises			
Sit to stand	1-2	3	8 and 12 and 15
Walking between two cone obstacles	1-2	3	3
Walk diagonally between two obstacles	2-3	3	3
Zigzag walking between obstacles	3-4	3	3
Fast walking between two cone obstacle	4-5	3	3
Fast walking between two obstacles diagonally	5	3	3
Zigzag running between obstacles	6	3	3
Fast running between obstacles diagonally	6-7	3	3
5- Pylometric exercises			
Dynamic lunge with return	6-7	3	8 and 12
Side step up (low height)	7-8	3	8 and 12
Vertical jump	7	3	8 and 12
Pair jump at specified locations	8	3	3
Hopping (jumping from one leg to the same leg) at specified locations	8	3	3

Kolmogorov–Smirnov test, all variables had a normal distribution. Independent *t*-test was carried out to compare the baseline characteristics between the groups. The data were analyzed using paired samples *t*-test to identify within group differences. Independent samples Student's *t*-test was used to detect differences between groups. All the analyses were performed with SPSS version 18 (SPSS Inc, Chicago, IL). *P* value < 0.05 was considered to be statistically significant.

Results

A total of 30 out of 60 female MS patients, who were randomly assigned in the study, were randomly assigned to the experimental and control groups (15 patients per group). Nevertheless, for personal reasons, five patients from the control group and five patients from the experimental group were eliminated. The experimental group completed the training sessions. Patients with relapse or comorbidities during the intervention (or both) were excluded [Figure 1]. A total of 20 female patients (experimental group, $n = 10$; control group, $n = 10$) participated in this study. Mean age for the experimental group was 38.7 ± 7.2 and 40.1 ± 5.6 in the control group [Table 2]. There were no significant differences at baseline between the two groups in terms of age, height, weight, EDSS, and disease duration (*P* > 0/05).

The quadriceps muscular strength improved significantly ($P < 0.05$) in the experimental group, but not in the control group ($P > 0.05$). A significant difference ($P < 0.05$) in muscular strength was evident between the experimental and control groups [Table 3].

The muscular strength in the hamstring muscles improved significantly ($P < 0.05$) in the experimental group, but not in the control group ($P > 0.05$). A significant difference ($P < 0.05$) in muscular strength was evident between experimental and control groups [Table 3].

The proprioceptive error decreased significant ($P < 0.05$) in the experimental group, but not in the control group ($P > 0.05$). A significant difference ($P < 0.05$) in proprioceptive error was evident between the experimental and control group [Table 3].

The balance score improved significantly ($P < 0.05$) in the experimental group, but not in the control group ($P > 0.05$). A significant difference ($P < 0.05$) in balance score was evident between the experimental and control groups [Table 3].

Discussion

The current study aimed at evaluating the effect of neuromuscular exercises on muscle strength, proprioceptive receptors, and balance in female patients with MS compared with a control group in Isfahan, Iran. The study results showed a significant increase in muscle strength of the quadriceps and hamstrings and balance after

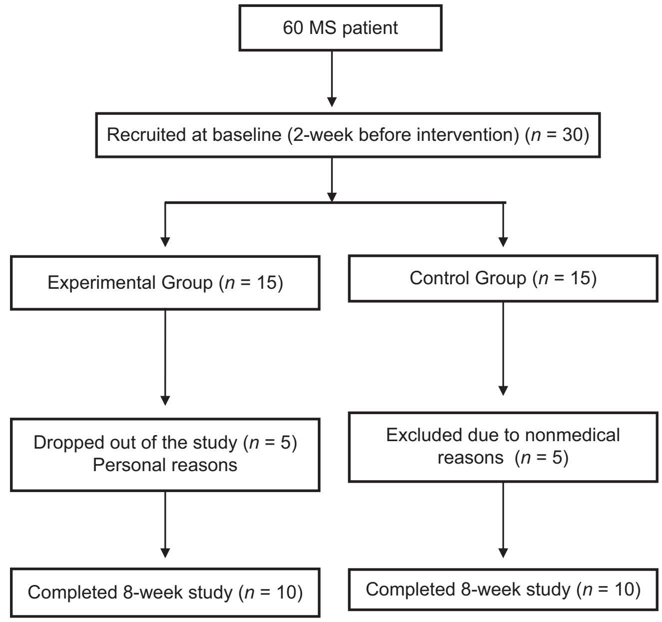

Figure 1: CONSORT flow diagram of patients' recruitment

Table 2: Demographic and clinical features between the two groups (mean±SD)

Variables	Experimental group (*n*=10)	Control group (*n*=10)	*P*
Age (years)	38.7±7.24	40.1±5.64	0.61
Height (cm)	156±5.84	158±6.04	0.60
Weight (kg)	46.1±9.87	48.5±11	0.58
EDSS (arbitrary unit)	1.75±0.71	1.85±0.66	0.71
Disease duration (year)	4.2±2.1	4.4±2.0	0.72

SD=Standard deviation. *P* values derived from independent Student *t*-test

neuromuscular exercises, and a significant reduction was observed in proprioceptive error.

Current study found significant improvements in the quadriceps and hamstring strength after the 8-week neuromuscular exercise training program. This finding is similar to that of Dalgas *et al.*,[24] who reported significant improvements in their participant s' leg strength. Others have found more significant results using a resistance-specific intervention. Learmonth *et al.*,[17] reported no significant improvements in quadriceps strength after a 12-week group exercise training. They did not assess hamstring strength. Neuromuscular exercises, which include general and specific physical activities, are recognized as an innovative approach to improve both health aspects (i.e., muscle strength and cardiovascular endurance) and related skills (i.e., agility and balance).[26] The lower limb muscles can be strengthened via neuromuscular training through optimal alignment of the lower limbs and trunk.[27] Neuromuscular training rehabilitation programs can improve muscular strength and trigger stretch contraction, which can explain the greater balance of muscle strength

Table 3: Changes in strength, Proprioceptive receptors error, balance in experimental and control groups (n=20) before and after an 8-week neuromuscular exercise (mean±SD)

Variable	Experimental Group (n=10)			Control group (n=10)			P^b
	Pretest	Posttest	P^a	Pretest	Posttest	P^a	
Quadriceps muscle strength (N/m)	56.48±25.78	81.72±30.99	0.01	60.24±18.95	59.58±19.10	0.7	0.01
Hamstring muscle strength (N/m)	28.83±12.90	42.35±14.99	0.04	29.96±9.10	27.07±7.02	0.2	0.02
Proprioceptive receptors error (degree)	9.43±2.93	5.14±3.02	0.004	9.74±2.31	9.92±5.49	0.8	0.01
Berg Balance Scale	48.3±6.05	53.0±1.6	0.02	48.3±3.36	47.8±3.02	0.06	0.02

NOTE. Values are mean±SD, [a]Indicates within-group differences (paired samples t-test), [b]Indicates between group differences (independent samples t-test)

in the fast motion test.[28] Plyometric is an important element of neuromuscular exercises.[29] Research suggests that plyometric exercises stimulate musculoskeletal and neuromuscular adaptations.[30] Numerous studies also examined the effect of plyometric exercises on lower limb strength and showed an increase in the maximal voluntary contraction and the level of force progression under isometric exercise.[31] One of the key findings of the current study was a reduction in proprioceptive error level at the week 8 in the intervention group. Delayed proprioceptive conduction in patients with MS is related to poor postural stability.[13] The neuromuscular training programs are meant to improve sensorimotor control and achieve compensatory functional stability.[32] To rehabilitate motor patterns and prevent long-term motor disorders, an overload pattern of neuromuscular exercises is used for physiological stimulation of sensory feedback changes, and thus, improving proprioceptive and neuromuscular control mechanisms.[33] Plyometric training enhances spinal reflex activity, leading to more efficient feedback from proprioceptors.[34] Similar to the current study findings, Tarakci *et al*.[15] found a significant improvement in the BBS scores with more group exercise. On the contrary, Learmonth *et al*.[17] showed in their study that there was no significant improvement in BBS after 12-weeks community-based group exercise intervention in patients with MS. Zech *et al*.[33] showed that neuromuscular exercises had a greater effect on dynamic balance than static balance. In physiological adaptation after neuromuscular exercises, it is assumed that the change in the feedback mechanism of mechanoreceptors after joint injury leads to CNS reorganization processes in sensorimotor integration (learning) and subsequently, alterations in motor response (e.g., adaptations of neuromuscular control). Neuromuscular exercises tend to improve posture control (such as the position of the pelvis and lower limbs in relation to each other) and function (quality of functional movements) by challenging the lower limbs in functional positions.[32] Specifically, in neuromuscular exercises, it was observed that the diversity of exercises, including plyometric exercises, would challenge the nervous system of such patients. It is an important factor in boosting the training effect and maintaining patient compliance, without causing any negative effects. Our neuromuscular training program was well-tolerated by patients, improved proprioception, and some functional measures among MS patients.

This study had some limitations. First, a relatively limited number of patients, who completed the neuromuscular exercise program, were recruited. Therefore, further research with a larger sample size is needed to examine our findings over a longer period. Second, the study population only included females, and patients with EDSS scores of 1–3 were included. The clinicians preferred not to examine patients with more overt symptoms.

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Conflicts of interest

There are no conflicts of interest.

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