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Original Research

Effects of Gluteus Maximus Muscle Strength on Ataxia, Gait, and Equilibrium in Multiple Sclerosis

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ABSTRACT

Objective: Multiple sclerosis (MS) is an autoimmune disease that causes scar tissue in the nervous system and seriously affects the quality of life of people. Muscle weakness, spasticity and coordination problems are seen primarily in the lower extremities. Strengthening exercises improve muscle strength in people with multiple sclerosis, but there is no consensus on their effect on walking capacity.

Methods: To determine the relationship between gluteus maximus muscle strength, ataxia, balance and walking capacity in Multiple Sclerosis. An experimental study design was applied. Gluteus maximus muscle strength was measured using a dynamometer. Walking capacity was determined by the 6-minute walk test (6MWT) and dynamic gait index (DGI). Balance was evaluated with the one-leg standing test (SLS). The severity of ataxia was measured with the International Ataxia Rating Scale (ICARS). Fatigue was evaluated with VAS and quality of life of all patients with SF36 short form.

Results: EDSS mean of the study = 3.39 ± 1.4; 2 men and 16 women with mean age = 37.17 ± 9.16 years were included. 6MWT, DGI, ALS, ICARS, VAS were different before and after treatment ($p<0.05$). There was no significant difference other than physical function and general health among the sub-parameters of SF36 ($p>0.05$). Correlation of muscle strength with ataxia, gait and balance was not significant ($p>0.05$)

Conclusion: In individuals with MS, the fact that the treatment program consists of modalities that include balance and sensory exercises as well as muscle strengthening exercises increases the success of rehabilitation.

Key words: multiple sclerosis, muscle strenght, balance, gait

INTRODUCTION

Multiple Sclerosis (MS); It is a chronic, autoimmune, demyelinating and degenerative disease that occurs in the central nervous system. MS affecting the central nervous system is a highly heterogeneous disease and may present with very variable clinical signs and symptoms, including motor, sensory, autonomic, and cognitive impairments, depending on the region of the central nervous system[1]. Motor symptoms are generally seen in the form of muscle weakness, coordination problems, spasticity, spasticity-related pain, cramps and spasms in the lower extremities and cause a decrease in mobility and physical activity. Walking problems are one of the most frequently reported problems in MS[2]. In addition to symptoms such as muscle weakness, spasticity, and ataxia, visual and oculomotor disorders may also cause walking difficulties[3]. The contribution of muscle weakness to walking, seen even in the early stages of the disease, is undeniable. Muscle weakness is a modifiable factor[4]. There are important studies examining gait patterns in MS patients[5]. Previous evidence has shown that foot and knee muscle function is associated with gait performance[6]. However, just strengthening the foot and knee muscles is not enough to normalize gait in MS[7].

Strengthening exercises for people with MS are typically part of a comprehensive physical therapy plan[7]. However, while strengthening exercises have consistently been shown to improve muscle strength and endurance in people with MS, they have not consistently resulted in significant improvements in gait performance[7]. Although conditions such as insufficient exercise dose and poor quality study design have been cited as the reason[8,9], another reason that is not overemphasized is that the muscles that may have the greatest impact on gait performance are not prioritized[8].

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Table 1. Exercise Training Program

Hafta / **Setler**	1st week	2nd week	3th week	4th week	5th week	6th week
1st set	10 max. repeat	12 max. repeat	12 max. repeat	15 max. repeat	15 max. repeat	15 max. repeat
2 minutes rest						
2nd set	10 max. repeat	12 max. repeat	12 max. repeat	15 max. repeat	15 max. repeat	15 max. repeat
2 minutes rest						
3th set	10 max. repeat	12 max. repeat	12 max. repeat	15 max. repeat	15 max. repeat	15 max. repeat
2 minutes rest						
4th set				15 max. repeat	15 max. repeat	15 max. repeat

Table 2. Participant characteristic

Characteristics	**MS patients (N=18)**
Age, years (mean±SD)	9.167 ± 37.17
Gender Female/male, n (%)	18/2.18(88.89/11.11)
EDSS	3.39±1.42

EDSS: Expanded Disability Status Scale, SD: Standard Deviation, MS: Multiple Sclerosis, $p < 0.05$.

There are also different studies investigating the effect of muscle strength on gait performance in MS. However, only a small number of muscle groups were examined at the same time in these individual studies[10]. Although proximal stabilization muscles are very important for normal lower extremity in people with MS, little is known about the relationship between gait performance and hip extension[10,11].

The gluteus maximus (Gmax), which makes up 16% of the cross-sectional area of the hip, is the largest muscle of the hip[12]. Gmax, which takes part in many functional activities such as walking, running and weight lifting, takes part in providing pelvic stability. Gmax muscle weakness causes a decrease in pelvic rotation and hip extension. In this study, gluteus maximus muscle strength will be associated with ataxia, gait and balance.

Main Points:

- Balance and gait problems in MS affect the quality of life of individuals.
- Balance and gait disturbances are associated with muscle weakness.
- Muscle strength should be evaluated for the effectiveness of treatment in balance and gait problems in MS

METHODS

Approval for this study was obtained from our local ethics committee (Decision No: 2021/3408) and written consent was obtained from individuals with MS, and it was conducted in accordance with the Declaration of Helsinki.

Subjects

Thirty remission MS patients who were diagnosed according to the 2010 McDonald criteria and presented to the MS outpatient clinic of a university hospital were evaluated. Ten patients did not meet the inclusion criteria. Two patients refused to particiipate13,14. Eighteen ambulatory type (16 female, 2 male) patients received exercise training between 16 March and 27 April 2022.

Table 3. Comparison of lower extremity muscle strength and ataxia, gait and balance in patients with Multiple Sclerosis

Assesments	**Right** **Mean±SD**	**Left** **Mean±SD**	
Muscle Strenght Pre-treatment Post-treatment P value	15.72±3.64 20.39±4.50 **.000**	14.83±2.97 20.67±5.64 **.000**	
Ataxia Pre-treatment Post-treatment P value	2.44±1.29 1,33±1.08 **.000**	2.17±1.33 1.06±0.99 **.000**	
The Single leg Stance Test (open eyes) Pre-treatment Post-treatment P value	14.11±9.05 19.50±9.76 **.000**	12.94±8.36 18.89±9.56 **.000**	
The Single leg Stance Test (close eyes) Pre-treatment Post-treatment P value	2.51±2.97 6.06±5.56 **.000**	2.61±3.23 5.50±4.95 **.000**	
Assesments	**Pre-treatment**	**Post-treatment**	P value
DYİ	16.28±5.39	19.17±4.89	**.000**
6MWT	403.64±106.182	465.67±79.01	**.000**
VAS	4.28±2.10	1.33±1.57	**.000**
SF-PF P value	51.39±26.27	60.83±24.57	.123
SF-RP P value	39.44±4566	72.22±33.08	**.007**
SF-RF	62.11±15.49	65.33±18.15	.507
SF-BP P value	66.61±2246	74.83±20.18	.058
SF-GH P value	45.83±14.87	69.72±17.94	**.001**

SF-SF P value	63.00±24.81	70.11±21.48	.265
SF-RE P value	44.17±36.06	70.11±34.15	.507
SF-VT P value	48.89±21.25	48.89±20.69	.981
*p < 0.05, **p < 0.001. VAS: Visual Analog Scale, SF: Short Form 36, PF: Physical Functioning, RP: Role Physical, BP: Bodily Pain, GH: General Health, SF: Social Functioning, RE: Role Emotional, VT: Vitality			

Inclusion Criteria
without any orthopedic disability,

Exclusion Criteria
-diabetes mellitus,
-defect of vision,
-cognitive and orthopedic problems,
-Patients with acute MS attacks (3 months before the study) or who were treated with corticosteroids (1 month before the study) were excluded from the study.

Progressive Resistance Training
Participants were instructed to perform all exercises in a moderate pace concentric and eccentric phase (Table 1)

Outcome Measures
Gluteus Maximus Isometric Muscle Strength
Six clinical measures were used to assess strength, coordination, gait, and balance performance. Gluteus maximus Lafayette -01165 (Lafayette Instrument Company, Lafayette IN, USA) was measured with a manual dynamometer [15]. Subject's position and dynamometer placement were standardized according to Bohannon[16]. Subjects were recorded for the weight of the exercise by measuring a maximum repetitions in Newtons.

Coordination
The validity and reliability of the International Cooperative Ataxia Rating Scale (ICARS), which has psychometric properties for balance assessment, has been proven. It contains a kinetic function subscale that assesses coordination[17]. The total score of the lower extremity kinetic functions section is 8. Evaluation was made out of 8 points.

Gait
Walking performance has commonly been evaluated in people with MS using 6-minute walk test (6MWT). Individuals with MS who are successful in the 6MWT have a more successful ambulation in the community[18].

Dynamic Gait Index (DGI)
It is used in the evaluation of functional walking. It was created to evaluate postural control during walking. It consists of eight steps including walking at different walking speeds, walking with horizontal and vertical head movements, turning during walking, walking over obstacles, turning around the obstacle, and going up and down stairs. The activity in each section is evaluated between 0 (severe disorder)-3 (normal)[19].

The Single Leg Stance Test (SLS, EC-EO)
Which lower extremity is dominant, which foot would you use to hit the ball?" was determined by the question. How long the patients could stand on one leg was recorded in seconds. When the patient lost his balance and the foot touched the ground, the chronometer was stopped. No verbal stimulus was given during the evaluation[20,21].

Quality of life (SF-36)
The SF-36 has been validated for use in individuals with neurological diseases and the Turkish translation has been validated[22]. Te Short Form Health Survey (SF-36) questionnaire measures health status, taking into account physical functioning and exercise, emotional and physical role functioning, mental health in general, social role functioning, body pain and general health.

Statistical Analysis
All data were analyzed using the Statistical Package for the Social Sciences (SPSS, Chicago, version 21, SPSS Inc. Chicago, IL). Data were expressed as mean ± standard deviations for numerical variables and numerically for categorical variables. Wilcoxon test was performed to determine the changes that occurred after treatment. Significant differences in the values of EDSS 4 above and below the tests were made with the Mann-Whitney U Test. Statistical significance level was accepted as p <0 .05.

RESULTS
There were 16 female and 2 male patients with a mean age of 9.167 ± 37.17 years between the range of 25 and 53 years (Table 2).

Ataxia, gait and balance were evaluated before and after muscle strengthening training.

Lower extremity ataxia in individuals with MS, the results before and after treatment are significant (pright=0.000, pleft=0.000) (Table 2). When gait is evaluated, the difference between DGI and 6MWT before and after treatment is significant (pDGİ=0.000,

Table 4. The relationship between EDSS 4 and above values ataxia gait and balance

Evaluation Parameters	EDSS Level	N	Mean	p value	(z value)
Muscle Strength	EDSS 4 below	13	21.26	0.251	–1.148
	EDSS 4 above	5	18.60		
$VAS_{fatigue}$	EDSS 4 below	13	1.01	0.108	–1.607
	EDSS 4 above	5	2.20		
ICARS	EDSS 4 below	13	0.80	**0.012***	–2.511
	EDSS 4 above	5	2.20		
6DYT	EDSS 4 below	13	494.77	**0.015***	–2.424
	EDSS 4 above	5	390		
DYİ	EDSS 4 below	13	14.20	**0.008***	–2.634
	EDSS 4 above	5	19.17		
SLS_{EO}	EDSS 4 below	13	23.03	**0.007***	–2.72
	EDSS 4 above	5	9.02		
SLS_{EC}	EDSS 4 below	13	7.61	**0.004***	–2.424
	EDSS 4 above	5	1.00		

p<0.05, z: Mann Whitney-U Test; ICARS:International Cooperative Ataxia Rating Scale, 6MWT:Six-Minute Walking Test; DYI:Dynamic Gait Index; SLSGA: The Single leg Stance Test (eyes open); SLSGK: The Single leg Stance Test (eyes closed)

p6MWT=0.000) (Table 3). The results were significant in the The Single leg Stance Test with eyes open and closed before and after treatment (peyes open=0.000, peyes closed=0.000) (Table 2). The difference in VAS fatigue evaluated before and after 6MWT walking was significant (p=0.000, p=0.000, respectively) (Table 3).

In order to evaluate the efficacy of the treatment, the SF36 test was applied to individuals with MS before and after the treatment. No significant changes were found in other parameters except mental function and general health, which are sub-parameters of SF36 (p<0.05).

As a result of the correlation analysis, no significant relationship was found between muscle strength and ataxia, gait and balance (p<0.05).

According to Wilxon analysis performed by dividing EDSS 4 into two groups as below and above, it was seen that EDSS and 6MWT, ataxia and balance were positively correlated (p>0.05), while there was no significant correlation with muscle strength and fatigue (p>0.05) (Table 4).

DISCUSSION

In this study investigating the effectiveness of isolated gluteus maximus exercises on ataxia, gait and balance in MS patients, positive improvements were obtained in ataxia, gait and balance after treatment compared to before. However, as a result of the correlation analysis, no significant relationship was found between muscle strength and ataxia, gait and balance. The reason for this is thought to be related to the low number of people in the evaluated MS group and the mild EDSS level. There are studies examining lower extremity gait pattern compensations for people with MS[23], and previous studies have shown that ankle and knee muscle function is associated with walking performance in people with MS[24]. However, improving ankle and knee muscle function through resistance training alone is probably not sufficient to optimize gait in people with MS[25]. Proximal muscle function should also be considered, as it provides the stability necessary for effective lower extremity movement during walking[26]. In a study by Broekmans et al. the relationship of knee flexion and extension muscle strengths at 45°, 60° and 90° with the 2 Meter Walking Test (2MWT) was examined in individuals with mild ambulatory dysfunction, and isometric knee extensor measured at 45°. no significant correlation was found except for the strength. The lack of robust associations between maximal muscle strength and walking tests may be related to the mild subgroup performing almost as well as healthy subjects[27]. The lack of a significant relationship between muscle strength and fatigue in the study can be explained by the fact that fatigue is not dependent on the EDSS level and the study group mainly consists of individuals who are mildly affected. In the study conducted by Schwid et al., it was stated that fatigue was not related to muscle strength, and that fatigue in individuals with MS was at 500 m. reported that it affects walking distance[28]. In the study, it was observed that exercise improved coordination. However, the lack of significant difference in the correlation can be explained by the small number of the study group. In the study of Salcı et al., individuals with MS were divided into three groups. While balance exercise was given to one of the groups, balance exercise and chorea stabilization exercises were given

to one of the other two groups, and task-oriented exercise was given to the other with balance exercises. While the ataxia kinetic functions section of ICARS improved in the group given chorea stabilization and balance exercises, no significant difference was observed in the group given only balance exercises[2]. In the study conducted by Brookmans et al., significant improvements were obtained in muscle strength and balance in the group given progressive resistance exercises compared to the group given electrical stimulation[29]. In the study, significant improvements in physical role and general health were obtained from the sub-parameters of SF-36. In the study conducted by Huisinga et al. 26 people with MS exercised with an elliptical device for 6 weeks and fatigue and quality of life were evaluated before and after the treatment[30]. Significant improvements in physical function, emotional state, energy, social function and general health were obtained after treatment. The difference between this study and ours can be attributed to the large number of people participating in the treatment and the elliptical exercise being a type of exercise that works the whole body.

Our results should be evaluated in light of the following limitations. Although the threshold values used in this study are supported by the previous literature, there is no standard threshold for mild to moderate disability in the EDSS. We did not have any follow-up to assess fatigue and quality of life and to monitor whether improvements were sustained weeks or months after the end of this study. The aim of this study was to present the effectiveness of isolated gluteus maximus exercises to MS patients independent of this research protocol. In addition, the short duration of this study, such as 6 weeks, was so short that significant changes in disease status were not expected in the MS group. However, a control MS group with a standard treatment such as physical therapy, with exercise performed for a longer period of time, for example 12 weeks, may also be important.

CONCLUSION

Isolated gluteus maximus exercise alone is not sufficient to improve ataxia, walking performance and balance in MS patients. The treatment approach should be multimodal considering the complex mechanism of MS. Isolated gluteus maximus exercise in addition to classical exercise provides better rehabilitation results. Randomized studies are needed to evaluate the effectiveness of this study.

Suggestions: More objective and precise results can be obtained with larger sample groups and randomized controlled studies in future studies.

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