The Relationship Between Concentric and Isometric Strength of Knee Flexor and Extensor Muscles and Postural Stability in Mild Stage Multiple Sclerosis Patients

by

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Abstract

Background: Multiple sclerosis (MS) affects muscle strength and postural stability. However, the relationship between concentric and isometric strength of knee flexors and extensors and postural stability in mild stage MS is not well known. The aim of the study was to examine the relationship between concentric and isometric strength of knee flexors and extensors and postural stability in mild stage MS patients.

Materials and Methods*:* The study included 21 mild-stage MS patients with an EDSS score of 4 or less and 21 healthy controls. The concentric and isometric strength of knee flexors and extensors was measured with the Biodex System 4 Dynamometer, and postural stability with the Biodex Balance System under eyes-open and eyes-closed conditions on a rigid surface.

Results: Mild stage MS patients had reduced concentric strength of knee extensors and flexors and increased postural sway compared with healthy controls ($p<0.05$). Isometric strength of knee extensors and flexors in mild stage MS patients were similar to healthy controls ($p>0.05$). There was a moderate positive correlation between concentric strength of knee extensors and flexors and isometric strength of knee flexors and open-eye postural stability indexes in mild stage multiple sclerosis patients ($p<0.05$).

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***Conclusions**:* While isometric strength of knee extensors and flexors was preserved, concentric strength of knee extensors and flexors was decreased, and postural stability was adversely affected in mild stage MS patients. The increase in the strength of the knee muscles was associated with an increase in their postural sway in mild stage MS patients.
Keywords: Multiple sclerosis, muscle strength, postural balance

1. Introduction

MS is the most prevalent neurological disorder among young adults which influences the central nervous system, leading to challenges in muscle strength and balance [1]. MS patients exhibit a decrease in isometric [2, 3, 4] and concentric [5, 6, 7] strength of knee extensors and isometric [3, 8] and concentric [6, 7] strength of knee flexors along with postural stability and balance problems [7, 8, 9, 10]. Knee extensor [11, 7] and flexor [12, 13, 14] muscle weakness and postural control impairments [15, 16] significantly impact gait function and speed in MS patients. Furthermore, disturbances in postural control are recognized as a significant factor contributing to an increased risk of falls [17, 18]. Additionally, disability levels in patients with multiple sclerosis (MS) were found to be inversely correlated with lower extremity muscle strength, indicating that as muscle strength in the lower extremities decreases, the severity of disability tends to increase [3]. Although it is well known that postural control problems and reductions in knee flexor and extensor muscle strength in MS contribute to functional impairments such as reduced walking speed, increased fall risk and disability levels, there is limited research on the relationship between knee flexors and extensors muscle strength and postural stability [7], 8]. Yahia at al. [7] observed significant

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correlations between the concentric peak torque of the hamstrings and postural sway, particularly under eyes-closed conditions, but found no such correlation between quadriceps concentric muscle strength and postural sway. Cıtaker at al. [8] found an association between isometric strength of knee flexors and extensors and balance during one-legged standing in people with MS. The relationship between different types of muscle contractions (isometric and concentric) and postural control has not been sufficiently investigated. Understanding the relationship between the isometric and concentric strength of the knee extensors and flexors and postural control is crucial for designing targeted exercises that minimize energy expenditure, especially considering the fatigue commonly experienced in MS. Designing exercises targeting the type of contraction that affects postural stability may lead to more effective exercise planning in MS patients.

It was hypothesized that MS patients would perform worse than healthy controls in postural stability and isometric and concentric strength of knee flexors and extensors. It was also hypothesized that there might be a negative correlation between isometric and concentric strength of knee flexors and extensors and postural stability indexes in mild stage MS patients. The high postural stability indexes indicates that the deviation from the target center has increased, and the loss of postural control is high. Since isometric muscle strength is required for maintaining static posture, we hypothesize that the relationship between isometric muscle strength and postural stability may be more pronounced. The objective of this study was to compare isometric and concentric strength of knee flexors and extensors and postural stability in healthy controls and mild MS

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patients and to investigate the correlation between isometric and concentric strength of knee flexors and extensors and postural stability indexes.

2. Materials and Methods

This study was performed at X University X Hospital with 21 MS patients and a control group which consists of 21 healthy controls with matching age, height, weight, and body mass index. All participants who agreed to take part in the study were given informed consent. Ethical approval was obtained from the X University Ethics Committee before the study was conducted. (04.03.2020-59). All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

The conditions for inclusion in the study for the MS patients are as follows, being 18 years old or older and having a confirmed diagnosis of MS in accordance with the McDonald criteria [19]not having experienced any relapses in the last three months, and EDSS score equal to or below 4. The conditions for inclusion in the study for the healthy controls are as follows: being 18 years old or older and not having any diagnosed disease. The exclusion criteria for both groups were: having chronic diseases such as diabetes, hypertension, heart diseases, neurological diseases in addition to MS, cognitive disorders, severe arthritis of the knee or hip, being pregnant.

The Expanded Disability Status Scale (EDSS) was used to assess the functional status of MS patients. The scale includes a sequential rating system that spans from 0 (indicating normal neurological status) to 10 (representing death because of MS) [20]Scores above 4.5 are heavily influenced by the individual's ability to walk, especially

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the ability to walk certain distances and the need for aids such as wheelchair support. Above this score, strength and balance deficits are more pronounced and well known [21]. Mild MS patients with EDSS score equal to or below 4 were included in the study.

2.1 Muscular strength

Knee muscle strength was evaluated using the Biodex System 4 Dynamometer (Biodex Corp, Shirley, NY). Individuals warmed up on a horizontal bike for 5 minutes before testing. Concentric peak torque (Nm), concentric total work (joule) of knee flexor and extensor muscles was measured at 90˚/sec with 10 repetitions [6]. The isometric peak torque (Nm) of knee flexor and extensor muscles was measured in the knee fixed position at 90° flexion with 5 repetitions. A maximal contraction was performed and maintained for approximately 3 seconds, followed by a 30-second rest period [4] . Peak torque was defined as the highest torque achieved during a single attempt. For the analysis, the result represents the average torque from the two attempts with the highest recorded values. A 5-minute rest period was provided between the concentric and isometric measurements. All measurements were applied to the dominant leg. The participant's dominant leg was identified by observing which leg they used to kick a ball.

2.2 Postural Stability

Postural stability was assessed with the Biodex Balance Systems (Biodex Medical Systems, Shirley, NY, USA). Trials were performed prior to evaluations. Evaluations were made on bare feet. Postural stability was assessed with both eyes open and closed while the platform's mobility level was set at 12 (when the platform was fixed) and on a

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firm surface. Individuals were positioned with their legs shoulder-width apart and hands crossed at chest level. During the test with eyes open, the screen of the device was turned off and they were asked to look at the poster fixed on the wall two meters away. The participants were asked to continue the test for 30 seconds while maintaining their starting position, and the test was performed 3 times with rest intervals of 10 seconds. The test was repeated in the same position with eyes closed. Postural stability was scored in the anteroposterior and mediolateral direction during measurements. The overall stability index is determined by averaging these two scores. Mediolateral, anteroposterior, and overall stability index values represent fluctuations around a zero-point determined before the test while the platform is running. The high score suggests that the deviation from the target center has increased, and loss of postural control is high [22].

2.3 Statistical analysis

Data was analysed using IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Based on power analyses conducted using the correlation coefficient, a minimum sample size of 42 participants is required for the study, with 21 patients diagnosed with Multiple Sclerosis (MS) and 21 controls. The expected power of the test is determined to be 80.2%. Descriptive statistics are reported as number of units (n), percentage (%), mean ± standard deviation ($\bar{x} \pm SD$), median (M), minimum (min) and maximum (max) values. The normality of numerical variables was assessed using the Shapiro-Wilk test for normality. Data from the two groups were compared using

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the independent samples t-test when the data were normally distributed and the Mann-Whitney U test when the data were not normally distributed. Spearman's rho coefficient was used for comparing numerical variables because the data were not normally distributed. A p-value of less than 0.05 was considered statistically significant.

Results

Demographic data, EDSS, and MS onset data are presented in Table 1. The groups were similar in terms of age (p=0.146), height (p=0.454), weight (p=0.572) and BMI (p=0.266).

Table 1. Demographic data of groups

Variables	**MS Patients** (*n*=21)	**Healthy Controls** (*n*=21)	**p value**
Gender, *n* (%)			-
Male	8 (38.1)	7 (33.3)	
Female	13 (61.9)	14 (66.7)	
Dominant Leg, *n* (%)			-
Right	20 (95.2)	19 (90.5)	
Left	1 (4.8)	2 (9.5)	

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EDSS	1 (n:4) 2 (n:1) 2.5 (n:6) 3 (n:2) 3,5 (n:5) 4 (n:3)	-	-
MS Onset, (*year*) $\bar{x}$±*sd* *Median* (*min-max*)	 7.21±5.13 5 (1-23)	-	-
Age, (*year*) $\bar{x}$±*sd* *Median (min-max)*	 38.57±10.27 36 (19-56)	 34.14±9,04 32 (21-50)	0.146
Height, (*cm*) $\bar{x}$ ±*sd* *Median (min-max)*	 166.81±7.77 167 (155-181)	 165.0±7.72 165 (151-177)	0.454
Weight, (*kg*) $\bar{x}$ ±*sd* *Median (min-max)*	 70.59±11.31 72 (53.3-93.1)	 68.43±13.16 67.3 (49.3-97.3)	0.572
BMI, (kg/cm^2) $\bar{x}$ ±*sd* *Median (min-max)*	 26.39±4.16 25.86 (19.11-35.2)	 25.01±3.75 23.9 (20.28-33.68)	0.266

Abbreviations: $\bar{x}$, mean; sd, Standard deviation; EDSS, The Expanded Disability Status Scale; BMI, Body Mass Index; MS, Multiple sclerosis; min, minimum; max, maximum

Table 2 shows the group differences in knee strength. Concentric peak torque and concentric total work values of knee extensors were lower in the MS patients than in the healthy controls ($p<0.05$). Knee extensors isometric peak torque values were similar in the MS patients and the healthy controls ($p=0.126$). Concentric peak torque and concentric total work values of knee flexors were lower in the MS patients than in the

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healthy controls ($p<0.05$). Isometric peak torque values of knee flexors were similar in the MS patients and the healthy controls ($p=0.062$).

Table 2: Group Differences in Knee Strength

	Groups		**Test Statistics**
	MS Patients $\bar{x}\pm sd$ *M* (*min-max*)	**Healthy Controls** $\bar{x}\pm sd$ *M* (*min-max*)	**p value**
Knee Extensors			
Concentric Peak Torque (*Nm*)	90.44±36.49 86.2 (20-185.4)	125.77±49.70 111 (55.6-217.6)	**0.012***
Concentric Total Work (*Joule*)	367.21±153,39 321.9 (44.7-650.3)	483.30±193.42 433.5 (221.5-858.1)	**0.035***
Isometric Peak Torque (*Nm*)	118.18±50.74 110 (20.6-243.4)	147.01±64.06 124.5 (63.7-274.9)	0.126
Knee Flexors			
Concentric Peak Torque (*Nm*)	38.0±18.31 36.8 (8.5-81)	57.46±24.02 45.8 (26.4-104.6)	**0.010***
Concentric Total Work (*Joule*)	146.46±85.35 133.2 (9.9-317.5)	234.14±106.32 208.9 (95-431.1)	**0.005***
Isometric Peak Torque (*Nm*)	42.76±17.91 41.8 (15.5-78.6)	55.88±22.39 45.9 (24.8-95.2)	0.062

$\bar{x}$, mean; *sd*, Standard deviation; *M*: Median; MS, Multiple sclerosis; min, minimum; max, maximum; Nm, Newton-metre; *Statistically significant value at the level of $p<0.05$.

Group differences in postural stability are presented in Table 3. Anteroposterior, mediolateral, and overall stability index values were higher in the MS patients than in the healthy individuals when the eyes were open and closed ($p<0.05$).

Table 3: Group Differences in Postural Stability Indexes

	Groups		**Test Statistics**
	MS Patients $\bar{x}\pm sd$	**Healthy Controls** $\bar{x}\pm sd$	**p value**

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	M (*min-max*)	*M* (*min-max*)	
Eyes Open			
Anteroposterior Stability Index	1.17±0.69 1.0 (0.40-2.60)	0.53±0.32 0.40 (0.10-1.30)	**0.001***
Mediolateral Stability Index	0.68±0.38 0.60 (0.10-1.40)	0.36±0.22 0.30 (0.10-1.10)	**0.002***
Overall Stability Index	1.50±0.72 1.60 (0.50-3.10)	0.73±0.34 0.60 (0.20-1.40)	**<0.001***
Eyes Closed			
Anteroposterior Stability Index	1.64±1.03 1.60 (0.40-4.10)	0.96±0.53 0.90 (0.30-2.30)	**0.017***
Mediolateral Stability Index	1.16±0.79 1.0 (0.20-2.60)	0.47±0.29 0.40 (0.10-1.20)	**0.002***
Overall Stability Index	2.26±1.25 2.20 (0.50-4.70)	1.16±0.55 1.0 (0.50-2.40)	**0.003***

$\bar{x}$: mean, *sd*: Standard deviation, *M*: Median, MS, Multiple sclerosis; Min, minimum; Max, maximum; *Statistically significant value at the level of $p<0.05$.

Correlation analysis of knee muscle strength and postural stability indexes in MS patients is presented in Table 4. There was a moderate positive correlation between concentric peak torque and concentric total work values of knee extensors and anteroposterior and overall stability index when the eyes were open ($p<0.05$). There was a moderate positive correlation between concentric peak torque value of knee flexors and anteroposterior and overall stability index values, between concentric total work value of knee flexors and anteroposterior and overall stability index values, and between isometric peak torque value of knee flexors and anteroposterior and overall stability index values in the MS group with eyes open ($p<0.05$). In other cases, no correlation was found ($p>0.05$).

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Table 4: Correlation Between Knee Muscle Strength and Postural Stability Indexes in MS patients.

Postural Stability Indexes	**KE-CPT**	**KE-CTW**	**KE-IPT**
Eyes Open			
Anteroposterior Stability Index	rho=0.595 p=**0.006**	rho=0.537 p=**0.015**	rho=0.425 p=0.070
Mediolateral Stability Index	rho=0.188 p=0.426	rho=0.147 p=0.537	rho=0.100 p=0.684
Overall Stability Index	rho=0.570 p=**0.009**	rho=0.499 p=**0.025**	rho=0.392 p=0.097
Eyes Closed			
Anteroposterior Stability Index	rho=0.269 p=0.252	rho=0.205 p=0.385	rho=0.230 p=0.343
Mediolateral Stability Index	rho=-0.178 p=0.452	rho=-0.200 p=0.398	rho=-0.333 p=0.163
Overall Stability Index	rho=0.096 p=0.686	rho=0.042 p=0.860	rho=-0.011 p=0.966
Postural Stability Indexes	**KF-CPT**	**KF-CTW**	**KF-IPT**
Eyes Open			
Anteroposterior Stability Index	rho=0.614 p=**0.004**	rho=0.557 p=**0.011**	rho=0.554 p=**0.014**
Mediolateral Stability Index	rho=0.080 p=0.737	rho=-0.026 p=0.912	rho=0.208 p=0.394
Overall Stability Index	rho=0.562 p=**0.010**	rho=0.461 p=**0.041**	rho=0.542 p=**0.016**
Eyes Closed			
Anteroposterior Stability Index	rho=0.297 p=0.204	rho=0.273 p=0.245	rho=0.135 p=0.582
Mediolateral Stability Index	rho=-0.223 p=0.345	rho=-0.274 p=0.242	rho=-0.327 p=0.172
Overall Stability Index	rho=0.086 p=0.719	rho=0.047 p=0.842	rho=0.003 p=0.991

rho, Spearman rho coefficient; KE-CPT, knee extensors concentric peak torque; KE-CTW, knee extensors concentric total work; KE-IPT, knee extensors isometric peak torque; KF-CPT, knee flexors concentric peak torque; KF-CTW, knee flexors concentric total work; KF-IPT, knee flexors isometric peak torque

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3. Discussion

This study found that there was a decrease in concentric strength of knee extensors and flexors but no change in isometric strength of knee flexors and extensors in mild stage MS patients. Impaired static postural stability with eyes open and closed was also found in mild stage MS patients. There was a moderate positive correlation between concentric strength of knee extensors and flexors and isometric strength of knee flexors and postural stability indexes with eyes open, but not eyes closed, in mild stage MS patients. The increase in the strength of the knee muscles was associated with an increase in their postural sway. No correlation was found between isometric strength of knee extensors and postural stability indexes in mild MS patients.

Studies have shown a decrease in isometric [2, 3, 4] concentric [5, 6, 7] strength of knee extensors and isometric [3, 8] and concentric [6, 7] strength of knee flexors measured by isokinetic dynamometer in MS patients. Consistent with our findings Chung at al. [5] showed that the concentric strength of knee extensors decreased, while the isometric strength of knee extensor muscles remained similar between the MS and control groups. This result indicates that the loss of strength in knee extensors varies depending on the type of contraction in MS patients, and it is seen that the loss of strength occurs at high speeds. In support of our results, impairments in muscle strength were shown to be most pronounced during maximal, moderate-to-rapid dynamic contractions of lower extremity muscles [3, 23]. According to DelMastro et al. [3] study, as disability level and age

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increase, particularly in women, a decline in isometric strength of knee flexor and extensor muscles has been observed. In the present study, relatively young individuals with low disability levels were included. Therefore, isometric muscle strength might have been found to be comparable to that of healthy individuals.

Postural instability is considered one of the most disabling symptoms of the disease, as it impairs mobility and functional independence, increases the likelihood of injury and falls, and significantly reduces overall quality of life [24]. Similar to the present results, it has been shown in previous studies that MS patients have balance and postural stability problems [5, 7, 8, 9, 10]. Maintaining balance is achieved by integrating visual, somatosensory and vestibular inputs [25]. It is known that these systems are affected in MS patients. Maintaining or changing posture requires the coordination of multiple sensory and motor processes, rather than being a simple automatic reaction [26]. It is important to define and measure postural control deficiencies, since one of the reasons why people with MS often fall is postural control problems. The EDSS includes static and dynamic balance assessment through clinical tests such as the Romberg test and tandem walking, but these tests may not be sensitive enough to detect the risk of mild balance disorders [27]. The previous study showed that static posturography is more sensitive than the traditional Roberg test and may also have prognostic value in people with MS [28]. We utilized static posturography in this study because patients had mild MS.

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In this study, there was a moderate positive correlation between concentric strength of knee extensors and flexors and isometric strength of knee flexors and postural stability indexes with only eyes open. This result shows that increasing muscle strength increases postural sway evaluated with eyes open. According to our hypothesis, we expected a negative correlation between postural control and strength of flexor and extensor knee muscles, particularly emphasizing a more pronounced effect in isometric muscle strength. Karst et al. showed that pressure center displacements were significantly reduced during bending and reaching in MS patients [29]. It was also reported that MS patients changed their center of mass far and less rapidly and tended to return to their stability limits rapidly [30]. According to the results of this study, the reason for the increase in postural sway as muscle strength increases in MS patients can be interpreted as that MS patients who have stronger lower extremity muscles do not tend to return to their stability limits quickly, perhaps because they have less fear of falling. It was suggested that, with the eyes open, an increase in muscle strength leads to greater postural sway, while the presence of the visual system may reduce the fear of falling.

Chung et al. [5] found a relationship between knee extensor strength asymmetry and standing balance in MS patients. Since the present study only evaluated the dominant extremity and there was no data on asymmetry, a comparison between two studies is difficult. Another study found a relationship between isometric strength of knee flexors and extensors and balance during one-legged standing in people with MS[8] . This study assessed balance on one leg; therefore, it was difficult to make comparisons with our study in which we assessed postural sways on two legs. However, Yahia at all [7] studies

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had a similar design to our study. It was reported that there was a negative relationship between concentric muscle strength of the knee flexors and postural sway, particularly under eyes-closed conditions, in contrast to our results. It was also reported that there was no relationship between concentric strength of knee extensors and postural stability. In that study, concentric muscle strength was measured at an angular velocity of 60°/sec. In our study, the measurements were performed at an angular velocity of 90°/sec. Measurement of muscle strength at different angular velocities or different clinical characteristics and disease duration of MS patients may have affected the results. Additionally, the Biodex Balance System utilizes different parameters and procedures compared to other types of posturography, making it challenging to quantitatively compare its results with those obtained from other devices. Our study is significant as it is the first to examine the relationship between the isometric and concentric strength of the knee flexors and extensors and postural stability assessed using the Biodex Balance System. However, more studies are needed to elucidate the relationship between muscle strength and postural sway in MS patients.

There are some limitations of this study. In this study, only the dominant extremity was evaluated. The evaluation of two extremities or the weaker extremity has the potential to change the results. In addition, postural stability was evaluated only on a stable surface. The relationship between muscle strength and postural stability can be better understood when evaluated on a moving or foam surface.

4. Conclusions

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Consequently, the concentric strength of knee flexors and extensors, as well as the postural stability of MS patients, were impaired compared to healthy controls. Concentric muscle strength of knee flexors and extensors and postural stability should be considered in the follow-up of physiotherapy assessments in mild stage MS patients. More studies are needed to understand the relationship between concentric and isometric strength of knee flexors and extensors and postural stability in mild stage MS patients.

References

[1] Dobson R, Giovannoni G. Multiple sclerosis - a review. Eur J Neurol. 2019 Jan;26(1):27-40. doi: 10.1111/ene.13819.

[2] Scott SM, Hughes AR, Galloway SD, et al. Surface EMG characteristics of people with multiple sclerosis during static contractions of the knee extensors. Clin Physiol Funct Imaging. 2011 Jan;31(1):11-7. doi: 10.1111/j.1475-097X.2010.00972.x

[3] DelMastro HM, Simaitis LB, Gromisch ES, et al. Establishment of regression-based normative isometric strength values for major lower limb muscle groups in persons with multiple sclerosis. Mult Scler Relat Disord. 2023 Jul;75:104772. doi: 10.1016/j.msard.2023.104772

[4] Wens I, Dalgas U, Vandenabeele F, et al. Multiple sclerosis affects skeletal muscle characteristics. PLoS One. 2014 Sep 29;9(9):e108158. doi:10.1371/journal.pone.0108158

[5] Chung LH, Remelius JG, Van Emmerik RE, et al. Leg power asymmetry and postural control in women with multiple sclerosis. Med Sci Sports Exerc. 2008 Oct;40(10):1717-24. doi: 10.1249/MSS.0b013e31817e32a3.

[6] Ramari C, Moraes AG, Tauil CB, et al. Knee flexor strength and balance control impairment may explain declines during prolonged walking in women with mild multiple sclerosis. Mult Scler Relat Disord. 2018 Feb;20:181-185. doi: 10.1016/j.msard.2018.01.024

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[7] Yahia A, Ghroubi S, Mhiri C, et al. Relationship between muscular strength, gait and postural parameters in multiple sclerosis. Ann Phys Rehabil Med. 2011 May;54(3):144-55., doi: 10.1016/j.rehab.2011.02.004

[8] Citaker S, Guclu-Gunduz A, Yazici G, et al. Relationship between lower extremity isometric muscle strength and standing balance in patients with multiple sclerosis. NeuroRehabilitation. 2013;33(2):293-8. doi: 10.3233/NRE-130958

[9] Cusin FS, Tomaz A, Ganança MM, et al. Postural Control in Relapsing-Remitting Multiple Sclerosis., Int Arch Otorhinolaryngol. 2022;26 (4):592–604. doi: 10.1055/s-0041-1741026.

[10] Ünlüer NÖ, Özkan T, Yaşa ME, et al. Investigation of the relationship between trunk motor control and balance, functional mobility, and gait capacity in patients with multiple sclerosis. Turk Noroloji Dergisi. 2021;27(3):283–288. doi: 10.4274/TND.2021.41017

[11] Kjølhede T, Vissing K, Langeskov-Christensen D, et al. Relationship between muscle strength parameters and functional capacity in persons with mild to moderate degree multiple sclerosis. Mult Scler Relat Disord. 2015 Mar;4(2):151-8. doi: 10.1016/j.msard.2015.01.002.

[12] Pilutti LA, Sandroff BM, Klaren RE, et al. Physical Fitness Assessment Across the Disability Spectrum in Persons With Multiple Sclerosis: A Comparison of Testing Modalities. J Neurol Phys Ther. 2015 Oct;39(4):241-9. doi: 10.1097/NPT.0000000000000099

[13] Mañago MM, Hebert JR, Kittelson J, et al. Contributions of Ankle, Knee, Hip, and Trunk Muscle Function to Gait Performance in People With Multiple Sclerosis: A Cross-Sectional Analysis. Phys Ther. 2018 Jul 1;98(7):595-604. doi: 10.1093/ptj/pzy048

[14] Broekmans T, Gijbels D, Eijnde BO, et al. The relationship between upper leg muscle strength and walking capacity in persons with multiple sclerosis. Mult Scler. 2013 Jan;19(1):112-9. doi: 10.1177/1352458512444497

[15] Callesen J, Dalgas U, Brincks J, et al. How much does balance and muscle strength impact walking in persons with multiple sclerosis? - A cross-sectional study. Mult Scler Relat Disord. 2019 Apr;29:137-144. doi: 10.1016/j.msard.2019.01.034.

[16] Brincks J, Andersen ED, Sørensen H, et al. Impaired postural balance correlates with complex walking performance in mildly disabled persons with multiple sclerosis. NeuroRehabilitation. 2017;41(1):227-235. doi: 10.3233/NRE-171475.

[17] Kalron A, Givon U, Frid L, et al. Static Posturography and Falls According to Pyramidal, Sensory and Cerebellar Functional Systems in People with Multiple Sclerosis. PLoS One. 2016 Oct 14;11(10):e0164467. doi: 10.1371/journal.pone.0164467.

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[18] Prosperini L, Kouleridou A, Petsas N, et al. The relationship between infratentorial lesions, balance deficit and accidental falls in multiple sclerosis. J Neurol Sci. 2011 May 15;304(1-2):55-60. doi: 10.1016/j.jns.2011.02.014

[19] Thompson AJ, Banwell BL, Barkhof F, et al. Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. Lancet Neurol. 2018 Feb;17(2):162-173. doi: 10.1016/S1474-4422(17)30470-2.

[20] Kurtzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). Neurology. 1983;33(11): 1444-1444

[21] Morales Rde R, Morales Nde M, Rocha FC, et al. Qualidade de vida em portadores de esclerose múltipla [Health-related quality of life in multiple sclerosis]. Arq Neuropsiquiatr. 2007 Jun;65(2B):454-60. Portuguese. doi: 10.1590/s0004-282x2007000300018.

[22] Soysal Tomruk M, Uz MZ, Kara B, et al. Effects of Pilates exercises on sensory interaction, postural control and fatigue in patients with multiple sclerosis. Mult Scler Relat Disord. 2016 May;7:70-3. doi: 10.1016/j.msard.2016.03.008

[23] Jørgensen M, Dalgas U, Wens I, et al. Muscle strength and power in persons with multiple sclerosis - A systematic review and meta-analysis. J Neurol Sci. 2017 May 15;376:225-241. doi: 10.1016/j.jns.2017.03.022.

[24] Matsuda PN, Shumway-Cook A, Ciol MA, et al. Understanding Falls in Multiple Sclerosis: Association of Mobility Status, Concerns About Falling, and Accumulated Impairments. Phys Ther. 2012;92(3):407–415. doi: 10.2522/ptj.20100380

[25] Cattaneo D, Jonsdottir J. Sensory impairments in quiet standing in subjects with multiple sclerosis. Mult Scler. 2009 Jan;15(1):59-67. doi: 10.1177/1352458508096874

[26] Horák J, Lord GJ, Peletier MA. Numerical Mountain Pass and its Applications In: PAMM: Proceedings in Applied Mathematics and Mechanics. Berlin: WILEY-VCH Verlag. 2006;6(1): 7–10. doi: 10.1002/pamm.200610003.

[27] Inojosa H, Schriefer D, Klöditz A, et al. Balance Testing in Multiple Sclerosis-Improving Neurological Assessment With Static Posturography? Front Neurol. 2020 Feb 26;11:135. doi: 10.3389/fneur.2020.00135

[28] Melillo F, Di Sapio A, Martire S, et al. Computerized posturography is more sensitive than clinical Romberg Test in detecting postural control impairment in minimally impaired Multiple Sclerosis patients. Mult Scler Relat Disord. 2017 May;14:51-55. doi: 10.1016/j.msard.2017.03.008.

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[29] Karst GM, Venema DM, Roehrs TG, et al. Center of pressure measures during standing tasks in minimally impaired persons with multiple sclerosis. J Neurol Phys Ther. 2005 Dec;29(4):170-80. doi: 10.1097/01.npt.0000282314.40230.40

[30] Remelius JG, Hamill J, Kent-Braun J, et al. Gait initiation in multiple sclerosis. Motor Control. 2008 Apr;12(2):93-108. doi: 10.1123/mcj.12.2.93

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