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Relationship of shoulder position sense with trunk control, balance, and walking speed in patients with multiple sclerosis

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ABSTRACT

Aims: This study examined the relationship between altered shoulder joint position sense (JPS) and trunk control, balance, and walking speed in patients with multiple sclerosis (MS).

Methods: This case-control study included patients with MS and healthy controls. A digital inclinometer was used to determine shoulder JPS. Balance was measured using the Berg Balance Scale (BBS) and single-leg stance (SLS) test, trunk control using the Trunk Impairment Scale (TIS), and walking speed using the 10 meter walk test (10 mWT).

Results: The study included 40 MS patients (mean age: 44.68±8.71 years, 75% were females) and 40 healthy control subjects (mean age: 43.56±9.91 years, 65% were females). The BBS and SLS scores were significantly lower and the 10 mWT time was longer in the patients compared with the controls ($p<0.001$). The planar and total JPS scores (error rates) for both sides were higher in the MS group ($p<0.001$). Negative correlations were observed in the MS group between the total JPS score and the BBS, SLS, and total TIS score ($r=-0.770$, $r=-0.619$, $r=-0.665$; respectively) ($p<0.001$), and a positive correlation was observed between the total JPS score and the 10 mWT ($r=0.456$, $p=0.003$) at the dominant side. Total JPS score correlated with BBS, SLS and 10 mWT ($r=-0.658$, $r=-0.522$, $r=0.531$, respectively) ($p<0.001$) at the non-dominant side.

Conclusions: This study showed that decreased shoulder JPS relates to impaired trunk control, balance, and walking speed in MS patients.

Introduction

Multiple sclerosis (MS) is a chronic inflammatory disease characterized by progressive neuronal loss and demyelination in the central nervous system (1). Together with sensorial impairments such as pain, fatigue, visual deficits, and impaired somatosensory system, various physical functions, such as trunk control, gait, and balance, are affected in MS (2-4). Approximately 85% of MS patients describe gait abnormalities as their primary symptom, which causes a fear of falling and kinesiophobia, which restricts social participation and ultimately puts patients on a path to depression (5,6). Therefore, investigation of the causes of these impaired physical functions is crucial for a proper management.

The upper extremities function in reaching, holding, releasing, throwing, and writing, but more complicated processes such as postural control, trunk stability, and gait are also closely related to the upper extremities. The shoulder joint is of particular significance because it serves as a bridge between the upper extremities and the axial skeleton and being able to adjust the position of the hand in space is important to perform different upper extremity functions. The position of the upper extremity segments in the trunk is directly related to the position of the shoulder joint, for which there must be a strong proprioceptive capability to enable these actions (7,8).

Upper extremity reactions are a part of the whole-body response to keep the center of mass within the base of support against sudden balance changes (9). For example, falls are frequent in some neurological conditions such as hemiplegia, Parkinson's disease, and MS, in which upper extremity functions are impaired; therefore, the required upper extremity positioning cannot be made against the disruptive effect (2,10,11). Individuals with shoulder pain may experience balance problems, which can be explained by the lateral inhibition of pain in the sensory feedback that forms the afferent part of the balance function (12). In addition, torsional forces created by reciprocal lower extremity movements during walking are neutralized by rhythmic arm swings, which is the basis for the walking economy. In some specific diseases known to have proprioceptive disorders, the effects of impaired rhythmic arm swings on gait function have been reported (13).

The shoulder joint functions as a bridge between the upper extremity distally and the trunk proximally. Any deterioration in the shoulder joint may have a two-way effect in both the distal and proximal directions. Upper extremity dysfunctions may occur in at least two-thirds of MS patients (14). To date, only the distal reflection of the effects of decreased shoulder joint position sense (JPS) has been reported in MS (15). To the best of our knowledge, there has been no previous investigation of the effects of decreased shoulder JPS on trunk performance and lower extremities, which are the basis for gait and balance. Therefore, this study examined the effects of decreased shoulder JPS on trunk control, balance, gait, and functional mobility in MS patients.

Methods

Study design and participants

Patients diagnosed with MS and age-matched healthy control subjects who volunteered to participate were included in this case-control study. The inclusion criteria were (a) diagnosis of MS verified by a neurologist according to the 2017 revisions of the McDonald criteria (1), (b) age between 18 and 60 years, (c) no MS attacks in the past three months, and (d) ability to walk independently. The inclusion criteria for healthy control subjects were (a) aged between 18 and 60 years and (b) absence of any disease that can affect physical function. Patients and controls were excluded if they (a) had any disease other than MS that would affect physical functioning, (b) had Meniere's syndrome or any other disease of the inner ear, (c) were pregnant, and (d) had a score of <24 points in the Mini-Mental State Examination. The study was approved by the Gülhane Scientific Research Ethics Committee (decision no: 2022-305, date: 17/10/2022). All the procedures were in accordance with the Declaration of Helsinki. All participants provided written informed consent.

Demographic characteristics were recorded on a standard form. The disability status was determined by a neurologist using the Expanded Disability Status Scale (EDSS) (16). Measurements were performed in the same order in a well-lit, quiet environment by the same physiotherapist with 10 years of experience in the field. Fatigue was consistently followed throughout the measurements and appropriate breaks were allowed.

The same procedures were followed in the control group. Demographic characteristics were recorded on a standard form, and measurements were performed in the same order by the same physiotherapist. Appropriate rest intervals were provided if needed.

Outcome measures

Shoulder position sense: A digital inclinometer (Dualer IQ Pro™ Digital Inclinometer, JTECH Medical; USA) was used to assess shoulder JPS as measured by repositioning errors. Both shoulders were assessed, and arm dominance was determined by asking the patient. Shoulder JPS was tested in four positions: 30°-60°flexion and 30°-60°abduction (17). Only the primary part of the inclinometer was used. It was secured with a Velcro strap to the lateral side of the subject's wrist, just proximal to the ulnar styloid process for the abduction measurement, and the anterior side of the humerus, on the biceps brachii belly for the flexion measurement. The participants were guided to move their arms to the target angle and were then instructed to hold the position for 3 seconds. The movement was demonstrated twice to ensure that the participants understood and remembered the target angle. Then, they were asked to repeat the previously achieved position five times consecutively. The absolute difference between the target position degree and the other five attempts was recorded. The lowest and highest results were discarded, and the average of the remaining 3 results was recorded as the angular JPS score.

A total JPS score was calculated for each shoulder joint for correlation analysis. First, the average of the angular scores at 30° and 60° was used to determine the planar proprioception score (flexion and extension), and the average of the planar proprioception scores was then used to calculate the total JPS score.

Trunk control: The Trunk Impairment Scale (TIS), a valid tool for measuring trunk performance in MS, was used to evaluate motor impairment of the trunk (18). This scale consists of 17 items under 3 sub-sections: static sitting balance, dynamic sitting balance, and coordination of trunk movement. Each item is scored according to the patient's ability to perform the assigned task. From a maximum of 23, higher scores indicate better trunk performance.

Balance: Dynamic and static aspects of balance were measured separately.

Dynamic balance*:* Dynamic balance was evaluated using the Berg Balance Scale (BBS), which is a 14-item, 56-point scale designed to measure balance through the assessment of functional tasks (19). This scale measures balance abilities during tasks involving sitting and standing, in addition to anticipatory balance during activities commonly performed in daily functions, including transfers, turning, and retrieving objects from the floor. A 5-point scale from 0 (unable to perform) to 4 points (normal performance) is used to score the patient's ability to perform the task assigned safely and independently. The total score is calculated as the total of the scores of each item, with higher scores from a maximum of 56, indicating better functional balance.

Static balance: Static balance was evaluated using the single-leg stance (SLS) test (20). In the SLS test, each subject was instructed to stand on one leg with the arms resting on the hips. Once the participant is in the test position, the test is timed (in seconds) until the other foot contacts the ground or until the arms are separated from the hips. The test was repeated in the same manner for both legs. If the participant failed to concentrate on the test, the session was invalidated and postponed. The maximum time allowed for the test was 60 seconds.

Walking speed: The 10 mWT was used to determine the ability to increase walking speed (21). Paying attention to the acceleration and deceleration phases of walking the participants were instructed to walk 14 m along a straight corridor, in which the middle 10 m were marked with tape. The subjects were asked to walk as fast as possible without running, but safely, and the time taken to cover the middle 10 m was recorded in seconds. The physiotherapist walked with the subject during the test to guard against the risk of falling.

Statistical Analyses

Data were analyzed using IBM Statistical Package for the Social Sciences statistics version 21.0 software (IBM Corp. released in 2012., Armonk, NY, USA). Normal distribution was tested using the Shapiro-Wilk test. Values are expressed as mean±standard deviation for normally distributed variables or median (minimum-maximum) values for non-normally distributed variables. Categorical data are stated as number (n) and percentage (%). Comparisons between the two groups of continuous data were tested using the independent samples t-test and the Mann-Whitney U test. The chi-square test was used to compare categorical variables. Correlations between shoulder JPS and other measurements were calculated using Spearman's correlation coefficients. A value of $p<0.05$ was considered statistically significant.

Results

Demographic and clinical characteristics

The study included 40 MS patients (44.68±8.71 years old, 75% female) and 40 age-matched healthy control subjects (43.56±9.91 years old, 65% female). The mean age, gender, body mass index, and dominant extremity were similar in the two groups. Disease duration ranged between 1 and 18 years, and the mean EDSS score of the patients was 2.5 (range, 1-4). The demographic and clinical characteristics of the groups are given in Tables 1 and 2.

Table 1. Demographic characteristics

Characteristic		MS (n=40)		Control (n=40)		t, Z	p
Age, years, mean±SD		44.68±8.71		43.56±9.91		0.537	0.592[a]
BMI, kg/m², median (min-max)		24.24 (19.33-31.25)		24.92 (18.65-31.22)		-0.933[b]	0.353[b]
Gender		n	%	n	%	χ^2	
Female		30	75	26	65	0.536	0.464[c]
Male		10	25	14	35		
Dominant hand	**Right**	34	85	37	92.5	-	0.481[d]
	Left	6	15	3	7.5		
Dominant foot	**Right**	34	85	36	90	0.114	0.735[c]
	Left	6	15	4	10		

[a]Independent samples t-test, [b]Mann Whitney U-test, [c]Continuity correction, [d]Fisher's exact test.
BMI: Body mass index, min-max: Minimum-maximum, MS: Multiple sclerosis

Table 2. Clinical characteristics of multiple sclerosis patients

Expanded Disability Status Scale, median (min-max)	2.5 (1-4)
Duration of diagnosis, years, median (min-max)	8 (1-18)
Number of attacks, median (min-max)	3 (0-20)
Number of falls in the last year, median (min-max)	0.5 (0-8)

min-max: Minimum-maximum

Comparison of the groups

Significant differences between the groups were apparent across all measurements. BBS score, SLS for both sides, and TIS scores were significantly lower, and the 10 mWT time was significantly longer in MS patients than in controls (p<0.001). The planar and total JPS scores (error rates) for both sides were significantly higher in the MS group (p<0.001). The differences between the groups in all measurements are shown in Table 3.

Correlation analyses

Moderate to strong correlations were observed between the total JPS scores and BBS, SLS, and 10 mWT (p<0.05). Negative correlations were found between the total JPS score and BBS, and SLS, showing that balance and trunk control deteriorated as shoulder JPS decreased (p<0.001). A positive correlation was observed between the total shoulder JPS score and the 10 mWT time, indicating that as shoulder JPS decreased, walking speed also decreased (p<0.05). The results of the correlation analyses are presented in Table 4.

Table 3. Comparison analyses

		MS (n=40)	Control (n=40)	t, Z	p
Berg Balance Scale, median (min-max)		50 (33-56)	56 (54-56)	-7.353[b]	**<0.001***
Single-leg stance (D), median (min-max)		4.23 (0-60)	60 (28.35-60)	-7.582[b]	**<0.001***
Single-leg stance (ND), median (min-max)		6.76 (0-60)	60 (18.50-60)	-7.583[b]	**<0.001***
10-meter walk test, median (min-max)		9.10 (4.67-28.75)	5.81 (4.17-8.22)	-6.967[b]	**<0.001***
Trunk Impairment Scale	Static sitting, median (min-max)	7 (5-7)	7 (6-7)	-2.715[b]	**0.007***
	Dynamic sitting, median (min-max)	6 (0-10)	10 (8-10)	-5.566[b]	**<0.001***
	Coordination, median (min-max)	6 (2-6)	6 (6-6)	-4.925[b]	**<0.001***
	Total score, median (min-max)	18.50 (11-23)	23 (20-23)	-6.044[b]	**<0.001***
Shoulder JPS	Sagittal JPS Score (D), mean±SD	3.25±1.19	0.87±0.45	2.380[a]	**<0.001***
	Sagittal JPS Score (ND), median (min-max)	3.32 (1-8.45)	1.47 (0.45-2.95)	-6.502[b]	**<0.001***
	Frontal JPS Score (D), median (min-max)	3.32 (1.60-8)	1.12 (0.30-2.15)	-7.589[b]	**<0.001***
	Frontal JPS Score (ND), mean±SD	3.40±1.42	1.58±0.45	1.821[a]	**<0.001***
	Total JPS Score (D), median (min-max)	3.16 (1.70-7.25)	0.97 (0.30-1.63)	-7.700[b]	**<0.001***
	Total JPS Score (ND), median (min-max)	3.23 (1.23-7.95)	1.55 (0.80-2.38)	-6.675[b]	**<0.001***

[a]Independent samples t-test, [b]Mann-Whitney U test, *p<0.05, min-max: Minimum-maximum, JPS: Joint position sense, D: Dominant, ND: Non-dominant, MS: Multiple sclerosis

Table 4. Correlation analyses

			Total JPS score (D)	Total JPS score (ND)
Berg Balance Scale		rho	-0.770	-0.658
		p	**<0.001***	**<0.001***
Single-leg stance (D)		rho	-0.619	-0.500
		p	**<0.001***	**0.001***
Single-leg stance (ND)		rho	-0.653	-0.522
		p	**<0.001***	**0.001***
10-meter walk test		rho	0.456	0.531
		p	**0.003***	**<0.001***
Trunk Impairment Scale	**Static sitting**	rho	-0.374	-0.290
		p	**0.017***	0.070
	Dynamic sitting	rho	-0.587	-0.472
		p	**<0.001***	**0.002***
	Coordination	rho	-0.414	-0.382
		p	**0.008***	**0.015***
	Total score	rho	-0.665	-0.517
		p	**<0.001***	**0.001***

rho: Spearman's rank correlation coefficient, *p<0.05. JPS: Joint position sense, D: Dominant, ND: Non-dominant

Discussion

We observed that both sagittal and planar shoulder proprioception were significantly lower in MS patients compared with the controls. Decreased shoulder proprioception was also associated with trunk control, balance, and walking speed. To the best of our knowledge, this is the first study investigating the relationship between impaired shoulder JPS and proximal reflections in MS.

MS is a chronic and progressive neurodegenerative disease. During disease progression, many motor functions are affected due to axon loss and decreased nerve conduction velocity. Reduced trunk and lower extremity performance can lead to impairment in tasks such as balance and walking, ultimately restricting the independence of patients in daily life. However, the symptoms of MS extend beyond those related to motor issues. A range of deep and superficial sensation deficits are also evident in MS due to lesions on various ascending pathways in the spinal cord, thalamus, and sensory cortex (1). The effect of JPS on function may be dramatic and warrants further investigation. Accordingly, the impact of decreased shoulder JPS was investigated in this study because of the significance of the proprioceptive function of the shoulder joint, which connects two major body components with a structure rich in proprioceptors (8). Numerous previous investigations have been conducted to determine proprioceptive abnormalities in patients with MS and other neurological conditions (3,15,22,23). Consistent with the findings of those investigations, the current study also showed that shoulder position sense was reduced in MS patients compared with controls.

Arm reactions are a strategy used to maintain postural control. Reactive arm movements against a destabilizing effect as a part of balance reactions may provide extra moments to keep the center of gravity within the support surface (positioning arms to absorb disruptive momentum) or stabilize the body (reach and grasp) (9). Compared with the general healthy population, people with MS have impaired reactive balance (24). Aruin et al. (25) compared the onset of muscle activation of the trunk and lower extremities against an external disruption and observed a delay in anticipatory postural adjustments in MS. Suhaimy et al. (26) also reported that subjects with MS had significantly delayed response initiation compared with healthy control subjects, suggesting an impairment in balance. These reports can clarify the connection between reduced shoulder proprioception sense and balance-related measurements (TIS, SLST and BBS) in MS patients in the current study. A slower spinal somatosensory conduction speed in MS may cause impairments in the reception and response processes (27). Consequently, the protective and corrective responses of MS patients to various disruptive forces and situations will be reduced and delayed.

Walking speed and economy are two significant characteristics of walking capacity, and walking capacity is compromised in various types of neurological diseases. There have been reports of abnormal physiological responses during walking performance in patients with MS. Goldman et al. (28) observed a significantly lower mean walking speed in the 6-min walk test that is closely correlated with the 10 mWT in MS patients (21). In addition, the results of a recent systematic review indicate that MS subjects walk more slowly and with higher energy expenditure than healthy subjects (29). A lower walking speed may indicate a more cautious walking strategy that requires more energy. These changes in walking capacity can be attributed to inadequacies such as disability level, balance confidence, motor planning, cardiopulmonary capacity, and muscle performance (28,30). Arm swings during human locomotion are known to reduce the energy cost of walking and facilitate leg movements (31). Previous studies have stated that arm movement during walking improves stability (32). Central pattern generators in the medulla spinalis control and regulate arm swing in human locomotion based on accurate and adequate proprioceptive perception (31). In addition to being one of the primary structures affected by MS itself, reduced shoulder joint proprioceptive feedback could compromise the control of arm swings (33). Although the current study did not include such a methodology, future studies investigating the association between decreased shoulder proprioception and arm movements in MS patients may provide additional insights on this topic.

Study Limitations

There are some limitations to this study that could present potential for additional research. One limitation of this study is that it was conducted in a single center. Multicenter studies allow for the expansion of the sample population and evaluation of the results with a larger sample size. In addition, the cross-sectional design of our study limited the results to patients who came to our clinic within a certain period. Further multicentral studies are warranted to determine how proprioceptive changes affect MS patients in various joints with larger sample sizes.

Conclusion

All functions in the human body coordinated by the nervous system operate with feedback control, which allows for fine adjustments, such as the amplitude and timing of the response. It is well known that decreased feedback flow in many neurological diseases affects the quality of the response. In this study, we focused on the proprioceptive feedback integrity of the junction between the trunk and upper extremity in MS patients with well-defined sensory symptoms. This study demonstrated that decreased positional feedback flow in the shoulder joint, which has some auxiliary roles in complex functions such as balance and walking, is associated with the worsening of these functions. Based on these results, new rehabilitation strategies can be developed to strengthen the positional relationship between the shoulder and trunk in MS patients.

Ethics

Ethics Committee Approval: Approval for this study was granted by the Gülhane Scientific Research Ethics Committee (decision no: 2022-305, dated: 17/10/2022).

Informed Consent: All participants provided written informed consent.

Authorship Contributions

Concept: M.E.Y., T.Ö., N.Ö.Ü., Design: M.E.Y., T.Ö., G.V., Data Collection or Processing: M.E.Y., T.Ö., B.K., G.V., Analysis or Interpretation: M.E.Y., T.Ö., B.K., Literature Search: M.E.Y., T.Ö., N.Ö.Ü., Writing: M.E.Y., N.Ö.Ü.

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