Examination of the effects of coordination and balance problems on gait in ataxic multiple sclerosis patients

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ABSTRACT

الأهداف: التحقيق في تأثيرات مشاكل التناسق والتوازن علي المتغيرات الزمكانية للمشية وتوزيع على اخمص القدم في مرضى التصلب المتعدد

المنهجية: شملت الدراسة ما مجموعه ٦٠ شخصا لديهم مرض التصلب التعددي، (وكان ٢٤ شخصا منهم يعانون من مشاكل في التناسق و 36 الافراد الذين يعانون من مشاكل في التوازن) و 32 (64 قدم) من الافراد الأصحاء تم تظمينهم في الدراسة. تم تنفيذ اختبار المقياس الموسع لحالة العجز (EDSS) واختبار الوصول الوظيفي ، ومؤشر المشية الديناميكي ، وقياس الضغط على القدم (ثابت وديناميكي) ، وتقييمات قياس الاستقرار.

النتائج: كان هناك اختلاف كبير بين المجموعات (التسارع p=0.000، الإيقاع p=0.000، عرض الخطوة p=0.018، طول الخطوة p=0.000، زاوية القدم p=0.000). وقد أظهرت مقارنات متعددة ان تسارع وايقاعات مجموعة التناسق وجدت انها اقل في حين ان عرض الخطوة 3 وجد انه اعلي بالمقارنة مع مجموعه التوازن (p=0.012, p=0.004, p=0.017) ، في توزيع الضغط على أخمص القدم في حالة السكون ، الضغط على مقدمة القدم من الجهة الوحشية ، والضغط على مؤخرة القدم في الجهة الوحشية، والضغط على مؤخرة القدم من الجهة الانسية كانت مختلفه بشكل كبير بين المجموعات (p=0.000، p=0.002 علي التوالي). وأظهرت مقارنات متعددة ان الضغط علي الجزء الوحشي من مؤخرة القدم لمجموعة التناسق قد تبين انه اعلي بكثير مقارنه بمجموعه التوازن (p=0.002). ووفقا لتوزيع ضغط الأخمص الديناميكي ، فان الضغوط على مقدمة القدم الوحشية ، ومقدمة القدم الانسية ، ومؤخرة القدم الوحشية ، ومؤخرة القدم الانسية كانت مختلفه اختلافا كبيرا بين المجموعات (p<0.05). لكن مع ذلك، لم تكن هناك اختلافات في توزيع الضغط الديناميكي على اخمص القدم بين مجموعات التوازن والتناسق.

الخلاصة: تؤثر مشاكل التناسق والتوازن علي المشية وعلى توزيع الضغط في أخمص القدم. سيساعد التعرف على هذه التغييرات اخصائيي العلاج الفيزيائي علي تحديد أهداف علاجيه محدده.

Objectives: To investigate the effects of coordination and balance problems on gait and plantar pressure distribution in multiple sclerosis patients.

Methods: This was an observational, cross-sectional study. It was conducted at Necmettin Erbakan University between March and December 2017. Twenty-four individuals with coordination problems, 36 individuals with balance problems and 32 healthy individuals were included in the study. The EDSS, Functional Reach Test, Dynamic Gait Index, baropodometry and stabilometry evaluations were performed.

Results: There were significant differences between the groups (velocity p=0.000, cadence p=0.000, step width p=0.018, step length p=0.000, foot angle p=0.000). Multiple comparisons demonstrated that the velocities and cadences of the coordination group were lower, while their step widths were found to be higher, compared to the balance group (p=0.012, p=0.004, p=0.017, respectively). In static plantar pressure distribution, lateral forefoot pressure, lateral hindfoot pressure and medial hindfoot pressure were significantly different between the groups (p=0.002, p=0.000, respectively) Multiple comparisons showed that the pressure on the lateral part of the hindfoot in the coordination group was found to be significantly higher compared to the balance group (p=0.002). According to the dynamic plantar pressure distribution, lateral forefoot, medial forefoot, lateral hindfoot and medial hindfoot pressures were significantly different between the groups (p<0.05).

Conclusion: Coordination and balance problems affect gait and plantar pressure distribution. The identification of these changes will help physiotherapists determine specific therapeutic targets.

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Multiple sclerosis (MS) is an infectious disease of the central nervous system of unknown etiology. Typically, patients initially experience a relapse and remission course (RRMS). In many cases, secondary progressive MS (SPMS) is observed, causing the slow and insidious development of disability.[1] One of the common symptoms of MS is ataxia. Ataxia, which is characterised by postural control, balance and coordination impairment that causes limitation in MS, is one of the most important causes of disability. Coordination problems are common due to problems in the cerebellum and its connections. Cerebellar pathology causes nystagmus, dysarthria and tremor with limb, trunk and gait ataxia depending on the lesion area. In about 80% of MS patients, different types of ataxia emerge as significant symptoms.[2]

Ataxia is one of the most critical factors affecting gait. Gait ataxia emerges with balance and coordination problems or a combination of these. While previous studies have clearly displayed the effect of balance on gait, the effects of coordination problems on gait are not apparent.[3-5] In a limited number of studies, the effect of coordination on gait was investigated, and conflicting results were found. Limb coordination,[3] standing and balance control[4,5] and locomotion[6–8] were the subjects that the researchers emphasised frequently. Morton and Bastian reported that balance in patients with cerebellar ataxia caused an impairment in the spatiotemporal parameters of gait, but coordination did not affect the spatiotemporal parameters of gait.[9,10] Winfried et al[11] reported that coordination problems affect gait. This study aimed to investigate the effect of balance and coordination problems on gait and plantar pressure in MS patients and to compare its effects with balance problems.

Methods.

Study design. An observational, cross-sectional study design was applied. This study, which was planned in order to investigate the effect of balance and coordination problems on gait in ataxic MS patients, was conducted in Turkey at Necmettin Erbakan University between March 2017 and December 2017.

Participants. A total of 60 MS patients and 32 healthy volunteers were included in the study.

Inclusion criteria. Being older than 18 years, having an EDSS score between 3 and 5, not taking corticosteroids within the 3 months before the study, having an EDSS pyramidal system score < 3 and being diagnosed with definite MS by a neurologist were the inclusion criteria.

Exclusion criteria. Patients who had a history of MS attacks in the last 3 months, who had orthopaedic or systemic problems that prevented their participation in the evaluations, who had peripheral vestibular problems and who were using gait orthosis/aids were excluded from the study.

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

Ethics committee approval. Permission for the study was received from Necmettin Erbakan University's Non-Interventional Clinical Research Ethics Committee (ON: 2017/850). The MS patients were divided into 2 groups: those with marked balance problems (balance group) and those with marked coordination problems (coordination group).

Balance group (BG). According to the cerebellar evaluation of the EDSS, patients with trunk ataxia signs only and more patients whose Romberg tests were mild and more and patients whose functional reach tests were less than 25 cm were included in this group.

Coordination group (CG). According to the cerebellar evaluation of the EDSS, patients whose lower limb ataxia was sign only and more and patients whose functional reach tests were less than 25 cm were included in this group.

If the functional reach test was lower than 25 cm, the patient was included in the BG even if he/she had mild coordination problems. Patients with functional reach tests higher than 25 cm and mild coordination problems were included in the CG even if they had mild trunk ataxia.

Healthy group (HG). The inclusion criteria for healthy individuals were determined as not being diagnosed with any neurological disease, not having vertigo or loss of sensation in the foot and not having any wound or foot or ankle problems that would affect plantar sensation.

Individuals were informed about the purpose and methods of the study. Their written consent for participation in the study was obtained. The patients' ages, heights, weights, disease durations, dates of last attack, drugs used, dates of last corticosteroid use, number of attacks experienced, physiotherapy and rehabilitation programs previously participated in and presence of systemic and orthopaedic diseases were recorded in detail.

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

Evaluation procedure. Before the gait evaluation, clinical evaluations of the patients were made.

Expanded disability status scale (EDSS). This test was developed to follow up the disease stage in MS patients by evaluating pyramidal, cerebellar, brainstem, sensory, bowel and bladder, visual, cerebral and other systems. The scores obtained from all these functional systems evaluations are converted into a single score, and the disease is graded between 0 and 10. As the score increases, the severity of the disability increases.[12] The EDSS assessment was performed by a certified physiotherapist.

International Cooperative Ataxia Rating Scale (ICARS). This scale was developed for ataxic patients and is also valid and reliable for MS patients.[13] In this test, in which postural and gait disorders, kinetic functions, speech disorders and oculomotor disorders are evaluated under four headings, the score distributions of the sections are 34, 52, 6 and 8, respectively. Of the 34 points that represent the sum of posture and gait disorders, 12 points are used for gait evaluation and 22 points are used for posture evaluation. The scale is scored on a total of 100 points, and the score increases as the severity of the ataxia increases.[14]

Stabilometric test. In the stabilometric evaluation, a STABYLO platform, which is produced by Diagnostic Support, is used. A 40x80 cm sensing surface with 12,800 active sensors is used for the examination of body oscillations in the upright position (the foot at 30°) and for the evaluation of body strategies in a specific time frame (maximum 51.2 sec) by maintaining the eyes in the open and closed positions. In the present study, the body oscillations with open and closed eyes were calculated as an area in cm^2.[15]

Functional Reach Test (FRT). The patients, who were positioned in the upright position without touching the wall, were asked to lift their hands at 90 degrees by keeping the elbow of the dominant arms straight, to make fists and to reach forward without any loss of balance. The third metacarpophalangeal joint's projection on the wall was marked before and after the measurement, and the distance between these measurements was recorded in cm.[16]

Evaluation of Gait Problems in MS. Evaluation of the spatiotemporal parameters of gait: The spatiotemporal parameters of gait were evaluated using the Diagnostic Support Baropodometer Footscan® 3D system. The system consists of a pressure-sensing platform, power unit, cameras (high-speed and video), printer, monitor and connections between the printer and the platform and between the monitor and the platform. A dynamic analysis was performed with the gaits of patients at normal gait speeds on the platform, which perceives pressure and is 4 m in length and 40 cm in width. First, the patients were made to walk in order to ensure their adaptation to the base of the platform. In order to be reliable, the gait cycle was completed with 3 trials of going and returning. Specific parameters of gait, such as cadence, acceleration, step width and step length, were obtained. Static analysis was carried out in a stationary standing position on the work platform, which is 45 cm x 45 cm and which has 4,024 sensors and a frequency of 300 MHz. The spatial parameters of gait, step length (cm), step width (cm) and foot angle (degrees) and the temporal parameters of gait, speed (m/min), cadence (step/min) and stance time (sec) were recorded.[15,17]

Evaluation of the plantar pressure distribution: By using the Diagnostic Support Baropodometer Footscan® 3D system, besides the dynamic evaluation and recording of the spatiotemporal parameters, the data on the total load on the forefoot, midfoot and hindfoot; the average pressure; and the distribution of load in the forefoot, midfoot and hindfoot were also obtained. Moreover, with static evaluation, on the work platform, data such as the total load on the forefoot

Table 1 - Distribution of descriptive characteristics by groups.

Characteristics	CG n=24	BG n=36	HG n=32	*P*-value
		Mean±SD		
Age (years)	41.54±10.23	40.64±8.63	42.25±10.81	0.644
Height (m)	1.66±0.09	1.65±0.10	1.67±0.07	0.196
Weight (kg)	64.79±10.82	66.25±11.75	69.50±8.72	0.206
BMI (kg/m^2)	23.63±4.63	24.37±4.07	24.95±3.40	0.483
Gender n(%)				
Male	8 (33.3)	9 (25.0)	13 (40.6)	0.389
Female	16 (66.7)	27 (75.0)	19 (59.4)	

SD - standard deviation, BMI - Body Mass Index, CG - coordination group, BG - balance group, HG - healthy group,$*p<0.005$

Table 2 - Comparison of descriptive measurements results between groups.

Descriptive measurements	CG N=24	BG N=36	HG N=32	*P*-value
	Mean±SD			
EDSS	3.92±0.69	3.89±0.76	----	0.804
Functional Reach(cm)	27.38±3.55	19.80±3.99	5.908	0.000*
ICARS Total	26.42±8.38	24.86±5.94	----	0.540
Oscillation Length: Eyes open (mm)	303.53±189.99	431.58±220.00	196.63±144.77	0.000*
Oscillation Length: Eyes closed (mm)	359.77±204.92	609.28±352.61	218.45±158.27	0.000*
Romberg	105.98±81.64	299.74±228.14	154.02±206.09	0.000*
DGI	16,25±5,64	13,14±5,46	------	0,037*

SD - standard deviation, EDSS - Expanded Disability Status Scale, DYI -Dinamik Gait jndex, CG - coordination group, BG - balance group, HG - healthy group,**p*<0.005

Table 3 - Comparison of the spatiotemporal parameters of Gait.

Parameters	CG N=40 feet	BG N=72 feet	HG N=64 feet	**P*-value
	Mean±SD			
Velocity(m/s)	0.44±0.28	0.59±0.26	0.71±.13	0.000*
Foot angle (°)	10.63±4.68	12.31±4.63	14.13±3.80	0.000*
Step width (cm)	13.50±5.64	11.27±6.34	10.46±2.86	0.018*
Step length (cm)	29.92±18.42	32.89±15.56	44.46±8.10	0.000*
Cadence (step/per min)	31.87±17.66	40.33±17.76	52.06±16.94	0.000*
Stance time (s)	0.74±0.52	0.74±0.28	0.77±0.12	0.529

SD - standard deviation, **p*<0.005, CG - coordination group, BG - balance group, HG - healthy group

and midfoot, hindfoot, right and left foot weight ratios, average pressure on the feet, and maximum pressure were obtained as percentages. Static pressure and dynamic pressure were evaluated over the percentages.[17]

Dynamic gait index. The DGI, which is a valid and reliable scale in the evaluation of gait in MS patients, consists of 8 items.[18,19] The highest score that can be obtained from the test is 24. The highest score demonstrates the best physical condition.

Statistical analyses. Statistical analyses were performed using the SPSS 20 (IBM Corp., Armonk, NY, USA) analysis program. For descriptive statistics, number, percentage, mean and standard deviation were presented, and the homogeneity of the descriptive characteristics of the groups was evaluated with Pearson's chi-square test in categorical variables and with a one-way analysis of variance in independent groups in numerical variables. The aim was to determine the sample size required for the study, and the G*Power (G*Power Ver. 3.0.10, Franz Faul, Kiel University, Germany) software package was used.[20] In the power analysis carried out before the study in order to determine the number of patients in the groups, the study by Morton and Bastian was taken as a reference.[9] It was calculated that a sample size of 90 patients (30 patients in each group) would achieve 80% power (d=0.50 effect width, α=0.05 type I error, β=0.20 type II error).

In the comparison of the mean scores of the dependent variables (dynamic foot analyses and gait analyses) of the 3 study groups, in the independent groups, the one-way analysis of variance (Tukey's honestly significant difference (HSD) for post hoc analysis) was used for normally distributed variables, and the Kruskal-Wallis test (the Bonferroni-corrected Mann-Whitney U test for post hoc analysis) was used for non-normally distributed variables. The comparison of the dependent variables was performed according to the type of ataxia (balance or coordination). The t-test was used in the independent groups. The relationship between the dependent variables was evaluated by the Pearson correlation analysis.[21] The normal distribution of the data was examined with Skewness-Kurtosis values and the Kolmogorov-Smirnov test. The statistical significance level was accepted as $p<0.05$.[22]

The average of the plantar pressure distribution was evaluated by comparing it with the one-way analysis of

Table 4 - Pairwise comparison of the spatiotemporal parameters of Gait in healthy individuals and ataxia types.

Parameters (Dependent variables)	Group(I)	Group 2(J)	Mean Difference (group 1-2)	*P*-value
Velocity(m/s)	CG	BG	-0.15	0.012*
	CG	HG	-0.27	0.000*
	BG	HG	-0.12	0.011*
	CG	BG	-1,68	0.126
Foot angle(°)	CG	HG	-3,50*	0.000*
	BG	HG	-1,82*	0.043*
Step width(cm)	CG	BG	2.23	0.017*
	CG	HG	3.04	0.003*
	BG	HG	0.81	0.887
Step length(cm)	CG	BG	-2.98	0.614
	CG	HG	-14.55	0.000*
	BG	HG	-11.57	0.035*
Cadence (step/per min)	CG	BG	-8.46	0.004*
	CG	HG	-20.19	0.000*
	BG	HG	-11.73	0.000*
Stance time(s)	Post hoc analysis was not performed since a difference was not found in the primary analysis			

*p<0.005, CG - coordination group, BG - balance group, HG - healthy group

Table 5 - Comparison of dynamic and static plantar pressure of individuals with MS and healthy individuals.

Dynamic foot analysis	CG n=40 feet	BG n=72 feet	HG n=64 feet	*P*-value
		Mean±SD		
Forefoot pressure: Lateral (g/cm²)	40.80±2.32	40.42±2.73	43.56±5.05	0.002*
Forefoot pressure: Medial (g/cm²)	55.05±5.29	54.07±6.44	58.87±4.24	0.000*
Midfoot pressure: Lateral(g/cm²)	73.73±13.92	73.43±13.69	68.69±14.73	0.136
Midfoot pressure: Medial (g/cm²)	27.52±13.72	26.57±13.69	29.14±14.36	0.584
Hindfoot pressure: Lateral(g/cm²)	53.34±3.51	54.66±5.00	50.99±4.96	0.001*
Hindfoot pressure: Medial (g/cm²)	49.98±5.59	48.00±4.99	45.79±4.51	0.002*
Static foot analysis				
Forefoot pressure: Lateral (g/cm²)	44.40±7.69	43.36±12.33	52.64±13.97	0.002*
Forefoot pressure: Medial (g/cm²)	54.55±9.07	49.90±17.09	48.96±13.26	0.218
Midfoot pressure: Lateral (g/cm²)	50.53±46.66	54.53±46.36	61.60±41.62	0.584
Midfoot pressure: Medial (g/cm²)	6.45±14.76	6.06±12.93	10.15±16.03	0.359
Hindfoot pressure: Lateral(g/cm²)	52.78±7.35	44.15±15.57	44.09±12.17	0.000*
Hindfoot pressure: Medial (g/cm²)	47.17±9.93	49.43±12.97	55.83±10.61	0.000*

SD - standard deviation, *p<0.005, CG - coordination group, BG - balance group, HG - healthy group

variance (advanced analysis with Tukey's HSD) in the independent groups.

Results. For this study that included 24 individuals (8 males and 16 females) in the CG, 36 individuals (9 males and 27 females) in the BG and 32 individuals (13 males and 19 females) in the HG, the demographic characteristics of the groups and their characteristics related to the course of the disease are summarised in **Table 1 & 2.**

Spatiotemporal parameters of gait. All spatiotemporal parameters of gait, except for stance time, were significantly different between the groups ($p<0.05$). When multiple comparisons were performed, it was found that velocity$_1$ and cadence$_2$ were lower in the CG than in the BG (p_1=0.012, p_2=0.004). Step

Table 6 - Pairwise comparison of the dynamic footh analyses.

Dynamic foot analysis	Group 1	Group 2	Mean difference (group 1-2)	*p-value
Forefoot pressure: Lateral	CG	BG	.38	0.732
	CG	HG	-2.75	0.012*
	BG	HG	-3.14	0.001*
Forefoot pressure: Medial	CG	BG	.97	0.782
	CG	HG	-3.82	0.000*
	BG	HG	-4.79	0.000*
Hindfoot pressure: Lateral	CG	BG	-1.31	0.410
	CG	HG	2.35	0.005*
	BG	HG	3.66	0.000*
Hindfoot pressure:Medial	CG	BG	1.98	0.089
	CG	HG	4.19	0.001*
	BG	HG	2.20	0.016*
Static foot analysis				
Forefoot pressure: Lateral	CG	BG	1.04	0.995
	CG	HG	-8.24	0.005*
	BG	HG	-9.28	0.001*
Hindfoot pressure: Lateral	CG	BG	8.63	0.002*
	CG	HG	8.69	0.000*
	BG	HG	.06	0.403
Hindfoot pressure: Medial	CG	BG	-2.26	0.069
	CG	HG	-8.66	0.000*
	BG	HG	-6.40	0.018*

*p<0.005, CG - coordination group, BG - balance group, HG - healthy group

width was found to be higher in the CG than in the BG (p=0.017). Step length$_1$ and foot angle$_2$ were lower than in the HG (p<0.05) but were similar in the BG and CG (p_1=0.614, p_2=0.126) (**Tables 3-4**).

Plantar pressure distributions. In a static plantar pressure distribution, lateral forefoot pressure, lateral hindfoot pressure and medial hindfoot pressure were significantly different between groups (p=0.002, p= 0.000, p=0.000, respectively). Multiple comparisons showed that the pressure on the lateral part of the hindfoot of the CG was found to be significantly higher compared to the BG (p=0.002). According to the dynamic plantar pressure distribution, lateral forefoot, medial forefoot, lateral hindfoot and medial hindfoot pressures were significantly different between groups (p <0.005). Multiple comparisons showed that there were no differences between the BG and the CG (p>0.005) (**Tables 5-6**).

Dynamic gait index: The DGI average of the BG was significantly lower compared to the CG (p=0.037) (**Tables 2**).

Discussion. This study sought to investigate the effects of coordination and balance problems on gait and the plantar pressure distribution in ataxic MS patients and to determine the differences between them. This study is different from other studies in terms of gait and plantar pressure assessment in different ataxia types, such as trunk and extremity. The most important results of the present study are that the velocity and cadence of MS individuals with coordination problems are lower than those of individuals with balance problems, while the step width is higher. The foot angle, step length and stance time were found to be similar. The static pressure distribution in the lateral hindfoot for the CG was found to be significantly higher compared to the BG, while dynamic plantar distribution was similar between both ataxic groups. In other words, MS patients with coordination problems walk with more short steps and more slowly; at the same time, they cannot make normal plantigrade contact.

Many studies have demonstrated a slower gait,[23-25] short step-taking (decreased step length),[23, 26-28] slow step-taking (decreased cadence)[23,26-28] and less joint motion[28-29] in MS patients in comparison with control groups and variabilities in many gait parameters. However, it is not clear to what extent these balance and coordination problems affect the spatiotemporal parameters of gait in MS individuals. Morton and Bastian evaluated 20 patients with cerebellar damage in order to observe which one of the factors of balance and coordination affects gait, and they found that the step length was shorter, the gait speed was slower and the step width was higher in patients with balance problems in comparison to those with coordination problems.[9] In contrast to the study by Morton and Bastian,[10] in this study, the gait speed and cadence of the group with coordination problems were found to be significantly lower compared to the group with balance problems, while the step width was higher and the step length was similar. It is an expected result that both groups walk more slowly and with shorter steps than healthy individuals. However, the slower walking of individuals with coordination problems than those with balance problems can be explained as follows: individuals may be using the support period more effectively since their trunk and pelvic stabilisations are better. This may be advantageous in terms of single-leg stance. As a result, the joints are locked in the load-bearing leg, and dynamic activity may only be sustained relatively in the subtalar joint. This situation causes mediolateral mobility in the foot but at a position where the ataxic movements of the transferred leg are less observed. This stability may provide more appropriate control of the swing phase. However, there was rapid activity in the BG due to the reduction in trunk and pelvic stabilisation.

These patients may have difficulties in controlling the swing phase and may choose to quickly lift their legs and place them on the floor. The similarity of the stance time in both groups confirms this theory. Since there is no study to support this in the literature, interpretation of the results is limited in this context. However, the results are different from the study by Morton and Bastian[9] since the number of individuals involved in the latter was small, and the disease group was different.

The foot angle is the line that connects the calcaneus to the second metatarsal.[30] It is observed that this angle deteriorates in the elderly.[31] Parkinson's patients,[31] pregnant women[32] and children with Down syndrome.[33] In a study conducted on cerebellar patients, the foot angle was demonstrated to increase in order to ensure stability.[7] In the present study, the average of the foot angle of patients with coordination disorders was similar to those with balance problems, but it was lower in both groups compared to the HG. The ankle angle is affected by many factors, such as spasticity power loss.[34] Although pyramidal symptoms were kept minimal in our patients (only patients with EDSS pyramidal system scores below 3 were included), it is expected that it does not show similarities with the results found in isolated cerebellar patients.

Although there are many studies on plantar pressure in the literature,[35,36] the number of studies on plantar pressure in MS is limited. Abdurakhmanov demonstrated that the pressure under the first metatarsal and in the heel decreased in MS patients. It is stated that the pressure reduction under the first metatarsal provides trunk stability.[37] In the present study, static and dynamic analyses show that the load was distributed normally, as expected, in healthy individuals, whereas the static hindfoot medial load was distributed less in the other groups. This situation is more pro-nounced in individuals with coordination problems. The load transfer route is located laterally in the heel in patients with coordination problems. The increase in the lateral hindfoot load and the de-crease in the medial may be caused by the inadequacy of normal subtalar joint pronation that occurs during stance. Consequently, foot pronation is restrained due to the coordination difficulty of the distal extremity. Similar results have been reported by Keklicek et al.[8] Additionally, it was seen that the BG performed better foot accommodation to the ground. This may be the result of better extremity control in the BG.

In the dynamic analysis, it was observed that the pressure increases, especially in the heel medial and lateral regions, and decreases in the forefoot medial and lateral regions in individuals with coordination problems and balance problems, and it is higher compared to healthy individuals. However, there is no significant difference between the ataxia groups. This result suggests that there is a compensation mechanism developed to increase ankle joint motion width at the same time that patients with MS use the same compensation mechanisms to ensure balance, even if the ataxia is different. Another thought is that MS patients have a general neuromuscular response even if they are divided into groups.[38]

The DGI is a balance and gait evaluation developed by Shumway-Cook and Woollacott for the evaluation of individuals with ambulation and balance problems.[39] In the present study, when the DGI averages were examined according to ataxia type, the DGI averages of the patients with balance problems were significantly lower than for those with coordination problems. Since the DGI also evaluates balance together with gait, the score of the group with balance problems was lower, as expected.

This study has several limitations. In the present study, only the spatiotemporal parameters of gait were evaluated. In a study in which kinetic and kinematic analyses were performed, more data on limb and trunk ataxia could be attained. In MS patients, it is difficult to separate the symp-toms from each other with sharp limits. Just as it is difficult to find patients with only balance problems or only coordination problems, it is also impossible to exclude the pyramidal problem completely. Although in the present study the groups were not separated with sharp limits using clinical tests, we were able to group the patients according to low pyramidal scores, marked balance problems and marked coordination problems. Although this is a limitation, it is also related entirely to the complex nature of the disease.

In conclusion, spatiotemporal parameters of gait and static plantar pressure distribution were different between balance and coordination problems in MS patients. Patients with coordina-tion problems walked with more short steps and more slowly; in both dynamic and static processes, patients with coordination problems carried the load with the hindfoot. Knowing the differences in gait and plantar pressure in patients with balance and coordination problems will guide the devel-opment of treatment programs. We believe that performing rehabilitation and orthosis applications considering these differences will improve the quality of gait. Our study may be a guide for future studies for MS and ataxia patients.

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