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ORIGINAL ARTICLE

Postural stability, gait, and plantar pressure alterations in schizophrenia patients

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Purpose: Functional and biomechanical alterations have not been clarified yet although motor retardation, coordination and balance impairment are prevalent in schizophrenia patients. The aim of this study was to investigate the differences of postural stability, temporal-spatial gait parameters, dynamic plantar load distribution and functional performance, between schizophrenia patients and healthy controls.

Methods: Twenty-four schizophrenia patients and twenty-three healthy controls participated in this study. Functional performance was assessed by measuring 6-min walking distance. Functional performance was assessed by measuring 6-min walk distance. Biodex Balance System was used to postural stability and dynamic pedobarographic analysis was conducted using a pressure platform.

Results: Six minute walking distance was significantly lower in schizophrenia group than control group ($p<0.001$). Overall, anteroposterior and mediolateral stability score in static, dynamic and single leg on right and left foot conditions were higher in schizophrenia group ($p<0.001$). Time spent in quadrant IV (right anterior quadrant) in static condition and time spent in quadrant I (right posterior quadrant) in dynamic condition were less in schizophrenia group ($p<0.05$). Maximum plantar pressure in forefoot of both feet and in heel of non-dominant foot were less in schizophrenia group ($p<0.05$).

Conclusion: Our results revealed that functional performance was reduced, postural stability was impaired, and dynamic plantar pressure was altered in schizophrenia patients however temporal-spatial gait parameters were similar with healthy adults. These results may help to understand the underlying mechanisms of motor deteriorations, coordination and balance problems in schizophrenia patients.

Keywords: Gait, Functional performance, Postural stability, Schizophrenia.

Şizofreni hastalarında postural stabilite, yürüyüş ve plantar basınç değişiklikleri

Amaç: Şizofreni hastalarında motor gerilik, koordinasyon ve denge bozukluğu yaygın olmasına rağmen, fonksiyonel ve biyomekanik değişiklikler henüz açıklığa kavuşturulmamıştır. Bu çalışmanın amacı, şizofreni hastaları ile sağlıklı kontroller arasındaki postural stabilite, yürüyüşün zaman-mesafe parametreleri ve dinamik plantar yük dağılımı ve fonksiyonel performans farklılıklarını araştırmaktı.

Yöntem: Çalışmaya 24 şizofreni hastası ve 23 sağlıklı kontrol katıldı. Fonksiyonel performans 6 dakika yürüme mesafesi ölçülerek değerlendirildi. Postural stabiliteyi değerlendirmek için Biodex Denge Sistemi kullanıldı ve dinamik pedobarografik analiz basınç platformu kullanılarak yapıldı.

Bulgular: Şizofreni grubunda 6 dakika yürüme mesafesi kontrol grubuna göre anlamlı olarak daha düşüktü ($p<0.001$). Statik, dinamik, sağ ve sol tek ayak üzerindeki durumlarda genel, anteroposterior ve mediolateral stabilite skoru şizofreni grubunda daha yüksekti ($p<0.001$). Statik durumda IV. oktantta (sağ ön oktant) harcanan süre ve dinamik durumda I. oktantta (sağ arka oktant) harcanan süre şizofreni grubunda daha azdı ($p<0.05$). Her iki ön ayak ve dominant topuktaki maksimum plantar basınç şizofreni grubunda daha düşüktü ($p<0.05$).

Sonuç: Bulgularımız, şizofreni hastalarında, fonksiyonel performansın azaldığını, postural stabilitenin bozulduğunu ve dinamik plantar basınçlarda değişimler olduğunu, ancak yürüyüşün zaman-mesafe parametrelerinin sağlıklı yetişkinlerle benzer olduğunu ortaya koydu. Bu sonuçlar, şizofreni hastalarındaki motor bozuklukların, koordinasyon ve denge problemlerinin altında yatan mekanizmaların anlaşılmasına yardımcı olabilir.

Anahtar Kelimeler: Yürüyüş, Fonksiyonel performans, Postural stabilite, Şizofreni.

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Schizophrenia is a serious psychiatric disorder that causes motor dysfunction, postural control impairments and gait abnormalities due to the nature of the disease, intensive antipsychotic drug and/or alcohol use.[1] These problems adversely affect the quality of life of the patients, yet causing serious injuries, increasing fall risk, aggravating cognitive symptoms and further extending the duration of hospitalization.[2] Assessment of balance and gait disturbances in psychiatric patients, may provide significant information about the prognosis of the disease and the follow-up processes of the paients.[1]

Literature reports motor symptoms such as inadequate movements, Parkinsonism alike neurological symptoms, or psychomotor retardation as characteristics of the schizophrenia.[3] Reduced motor activity is associated with abnormal local resting brain perfusion, decreased cingulate changes in gray matter, and alterations in white matter integrity in schizophrenia patients.[3] Decrease in performance has been found to be related with negative, positive and depressive symptoms and further with clinical, and functional outcomes of the patients.[4]

Dysfunction of motor, cerebellar, and sensory integration leads to the impairment in postural stability and increased risk of falls.[2,5] Some previous studies reported that postural sway was related with increased symptom severity while others stated this condition was independent of clinical characteristics in patients with schizophrenia.[5-7] But it is expected that postural instability which is common in patients with schizophrenia adversely affect their physical function. Therefore, it is clinically important to demonstrate the worsening of postural control and balance mechanisms in this population.[1]

As a reflection of psychomotor changes, the step width of schizophrenia patients is increased, and the tandem gait is slightly deteriorated. Also the gait slows down along with the decreasing step length.[8,9] Although poly-pharmacy is known as an important risk factor for falls, some previous studies showed that gait parameters even alter independently of drug use in schizophrenia patients.[1,9] Besides, patients with severe mental illnesses have been reported to have higher rates of podiatric problems compared to the healthy individuals. The most common podiatric problems of the patients with severe mental illnesses were foot pain, nail problems, corns and calluses, flatfoot and foot deformities. These complaints were reported to cause the patients to fail performing even their basic daily activities including ambulation.[10] Podiatric problems are also known to be associated with impairments in plantar loading.[11-13]

Previous studies showed alterations in plantar loading, which are associated with balance impairments, and gait alterations in populations with motor dysfunction such as geriatrics and patients with neurological problems.[14-16] However, dynamic plantar loading of the patients with schizophrenia has not been investigated although motor dysfunction is permanent among these patients. The aim of this study was to investigate the differences of postural stability, temporal-spatial gait parameters, dynamic plantar load distribution and functional performance between schizophrenia patients and healthy controls. Our hypothesis was that schizophrenia patients have biomechanical alterations in terms of postural stability, gait, plantar pressure and functional performance alterations compared to healthy controls.

METHODS

This is a cross sectional study conducted by Zonguldak Bulent Ecevit University, Faculty of Health Sciences Department of Physiotherapy and Rehabilitation. Twenty-four schizophrenia patients age between 18-65 years, being diagnosed with schizophrenia according to The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), having symptoms of schizophrenia for at least six months, and no change of the medication type (patients were using atypical antipsychotic drugs) prescribed in last six weeks (although dosage may change) recruited for the study. Exclusion criteria were any additional neurological or medical diseases, or any other condition that impairs gait and balance for schizophrenia patients. 23 healthy controls age between 18-65 years having no psychiatric, neurological, or orthopedic disorders, visual or vestibular disturbances or any other condition that may affect gait and balance participated in

the study. In order to minimize the age and gender-related outcomes between the groups and to ensure homogeneity among the groups, the controls matched to the schizophrenic patients in terms of age and gender.

Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Zonguldak Bulent Ecevit University (Protocol no: 2015-84-21/10). All participants understood and signed written informed consent. The study conforms to The Code of Ethics of the World Medical Association (Declaration of Helsinki), printed in the British Medical Journal (18 July 1964).

Demographic data of the participants were recorded. Dynamic plantar pressures, balance and functional performance were evaluated by the same physical therapist at the research laboratory of the Zonguldak Bulent Ecevit University, Faculty of Health Sciences.

Dynamic pedobarographic analysis was conducted using a pressure platform (Zebris® FDM 2, 212.2x60.5x2.5 cm, Zebris Medical GmbH, Germany) located middle of an 8 m walk path. Participants walked through the path at a self-selected pace in the barefoot condition for the measurement. Three valid trials were recorded. Temporal-spatial gait parameters (foot rotation, step length, stride length, step width, percentage of stance, load response, mid stance, pre swing, swing, and double stance phases, step time, stride time, cadence, velocity, and time change heel to forefoot), and maximum force, maximum pressure, and time maximum force percentage of forefoot, midfoot and heel were obtained from Zebris® FDM 2 software package.

Postural stability was assessed by Biodex Balance System (Biodex® Medical Systems, Shirley, NY, USA) which has a circular movable platform allows up to 20° of surface tilt in all directions (Figure 1). Participants were evaluated in static (on stable platform), dynamic (on moving platform) and single leg (on each left and right legs) conditions. Overall (OA), anterior/ posterior (AP), and medial/ lateral (ML) stability scores were obtained from Biodex software (Version 3.1, Biodex Medical Systems). Higher stability scores indicate poor balance. Time in Quadrant percentages, which indicate the time, spent in any given quadrant in static and dynamic protocol was also obtained from the assessment. Four quadrants are set on the

Figure 1. Postural stability assessment.

platform (Quadrant I: right anterior, Quadrant II: left anterior, Quadrant III: left posterior and Quadrant IV: right posterior). Biodex Balance System was indicated as a reliable balance device.[17]

Functional performance was evaluated with the 6-min walk test (6MWT). Patients were instructed to walk in a 30 m corridor, and to cover as much distance as possible in the allotted period of 6 min. Two tests were monitored. The second test began 60 min after the first one, in order to reach similar heart rate. The maximum 6-min walk distance (6MWD) achieved (better of the two tests) was recorded in meters.[18] It has been reported that the 6MWD ranges from 400 to 700 m in healthy subjects.[19-21]

Statistical analysis

Data was evaluated using the Statistical Package for Social Science 18 (SPSS Inc., Chicago, IL, USA) program for Windows. The significance level was set to $p<0.05$. Normality tests (visual and analytical) were conducted. Mann Whitney U test was used to compare age, height, weight, BMI (Body Mass Index), pedobarographic analysis, and postural stability

data, which were not normally distributed between schizophrenia and control groups. Independent Sample t test was used to compare normally distributed 6MWD scores and Chi-square test was used to compare sex ratio between two groups. Post-hoc power analysis was performed using G* Power (Version 3.0.10 University of Dusseldorf, Germany). Static overall index score was taken as the primary variable and the power of the study was found to be 99% for 23 individuals in each group with α= 0.05 Type I error.

RESULTS

This study included 24 schizophrenia patients and 23 healthy controls. The mean age was 40.87±7.45 years in schizophrenia group and 37.21±7.83 years in control group. There was no significant difference between two groups in demographic features and leg dominancy (Table 1).

Pedobarographic assessment was indicated that maximum plantar pressure in forefoot of both feet and in heel of dominant foot were less in schizophrenia group compared to control group (Table 2). There was no significant difference between two groups in terms of the other pedobarographic data (Table 3).

According to the postural stability assessment; overall index, anteroposterior index and mediolateral index in static, dynamic and single leg on right and left foot conditions were higher in schizophrenia group compared to control group. Time in quadrant IV percent in static condition and in quadrant I percent in dynamic condition were less in schizophrenia group compared to control group. Percent of time in quadrant I, II and III in static condition and percent of time in quadrant II, III and IV in dynamic condition were similar in two groups (Table 4).

6MWD was significantly reduced in schizophrenia group (372.33±63.88 m) compared to control group (509.61±77.21) ($p<0.05$).

DISCUSSION

This study was conducted to determine the differences of postural stability, temporal-spatial gait parameters and dynamic plantar loading between schizophrenia patients and healthy adults. According to our results, schizophrenia patients had reduced functional performance while temporal-spatial gait parameters were similar with healthy population. Additionally, schizophrenia patients had reduced maximum plantar pressure in the forefoot and heel, deteriorated postural stability in static, dynamic, and single leg conditions and less time spent in the right side of sagittal plane.

The 6MWD, which provides information about functional exercise performance, was found to be reduced in schizophrenia patients. There are recent studies reporting that schizophrenia patients had shorter 6MWD

Table 1. Demographic features of the participants.

	Control Group (N=23) X±SD	Schizophrenia Group (N=24) X±SD	p
Age (year)	37.21±7.83	40.87±7.45	0.120
Height (cm)	170.86±8.71	166.04±7.98	0.077
Body weight (kg)	76.95±15.33	79.66±14.31	0.462
Body mass index (kg/m^2)	26.29±4.54	28.47±4.31	0.090
	n	n	
Gender (Female/Male)	8/15	10/14	0.627
Leg dominance (Left/Right)	7/16	2/22	0.075

* $p<0.05$.

Table 2. Comparison of plantar pressures between schizophrenia patients and healthy controls.

	Dominant	Control Group X±SD	Schizophrenia Group X±SD	p
Maximum force, forefoot (N)	ND	657.26±111.72	589.72±104.18	0.073
	D	643.82±113.34	569.05±119.06	0.064
Maximum force, midfoot (N)	ND	214.08±117.45	224.02±66.16	0.525
	D	220.08±115.74	229.37±68.59	0.454
Maximum force, heel (N) X±SD	ND	479.85±101.97	442.22±74.71	0.173
	D	465.98±79.22	446.02±77.39	0.296
Maximum pressure, forefoot (N/m^2)	ND	34.35±8.24	28.30±7.09	0.004*
	D	34.41±8.033	27.18±5.28	0.001*
Maximum pressure, midfoot (N/m^2)	ND	14.80±5.84	13.73±3.75	0.496
	D	14.79±4.19	14.30±4.11	0.307
Maximum pressure, heel (N/m^2)	ND	24.76±5.15	23.07±3.74	0.261
	D	24.65±4.03	22.21±3.63	0.041*
Time maximum forefoot force, % of stance time	ND	77.01±2.82	75.77±3.70	0.407
	D	76.71±2.58	77.38±2.78	0.334
Time maximum midfoot force, % of stance time	ND	51.23±9.00	51.75±11.05	0.759
	D	52.13±7.42	55.33±10.36	0.242
Time maximum heel force, % of stance time	ND	24.03±4.00	23.91±4.94	0.812
	D	23.70±3.39	25.07±4.00	0.156

N: Newton; ND: Non-Dominant; D: Dominant. * $p<0.05$.

Table 3. Comparison of temporal-spatial gait parameters between schizophrenia patients and healthy controls.

	Dominant	Control Group X±SD	Schizophrenia Group X±SD	p
Foot rotation (°)	ND	11.27±6.19	11.19±7.05	0.919
	D	14.68±7.23	16.64±5.20	0.166
Step length (cm)	ND	51.00±12.28	51.50±11.66	0.658
	D	53.73±10.16	48.04±10.37	0.082
Stride length (cm)		104.85±13.38	99.45±17.98	0.117
Step width (cm)		15.08±4.29	15.18±2.92	0.918
Stance phase (%)	ND	65.34±2.44	67.05±3.53	0.097
	D	66.23±2.34	65.09±3.70	0.104
Load response (%)	ND	16.16±2.34	15.22±3.64	0.078
	D	15.16±2.44	16.77±3.55	0.120
Mid stance (%)	ND	34.03±2.51	34.69±3.53	0.247
	D	34.51±2.33	32.90±3.48	0.114
Pre swing (%)	ND	15.26±2.53	17.01±3.68	0.107
	D	16.25±2.45	15.27±3.63	0.100
Swing phase (%)	ND	34.65±2.43	32.94±3.53	0.097
	D	34.15±2.44	34.89±3.71	0.216
Double stance phase (%)		43.41±57.62	32.12±6.42	0.759
Step time (sec)	ND	0.62±0.09	0.64±0.07	0.381
	D	0.63±0.09	0.64±0.09	0.578
Stride time (sec)		1.26±0.18	1.28±0.16	0.427
Cadence (steps/min)		97.39±13.72	94.72±12.20	0.340
Velocity (km/h)		3.03±0.58	2.84±0.64	0.186
Time change heel to forefoot (sec)	ND	0.36±0.13	0.40±0.12	0.292
	D	0.36±0.11	0.41±0.13	0.171
Time change heel to forefoot (%)	ND	42.50±10.70	44.61±8.17	0.883
	D	43.21±8.11	47.15±8.42	0.100

ND: Non-Dominant; D: Dominant.

Table 4. Comparison of postural stability scores between schizophrenia patients and healthy controls.

	Control Group X±SD	Schizophrenia Group X±SD	p
Static	0.44±0.18	1.71±1.43	<0.001*
Overall index	0.32±0.12	1.10±1.21	<0.001*
Anterior/posterior index	0.22±0.13	0.97±1.04	<0.001*
Medial/lateral index	18.56±12.26	15.04±12.79	0.291
Time in quadrant I (%)	7.30±6.10	17.31±17.89	0.190
Time in quadrant II (%)	22.17±18.01	30.95±26.62	0.407
Time in quadrant III (%)	51.95±16.49	36.68±27.95	0.032*
Time in quadrant IV (%)	66.23±2.34	65.09±3.70	0.104
Dynamic			
Overall index	1.06±0.35	2.63±1.47	<0.001*
Anterior/posterior index	0.73±0.21	1.67±0.93	<0.001*
Medial/lateral index	0.59±0.27	1.62±1.10	<0.001*
Time in quadrant I (%)	30.69±18.96	19.33±17.48	0.040*
Time in quadrant II (%)	21.34±16.18	18.28±22.04	0.269
Time in quadrant III (%)	19.47±13.99	27.90±23.25	0.353
Time in quadrant IV (%)	28.47±15.45	34.47±23.15	0.510
Single leg (left)			
Overall index	1.00±0.35	3.27±2.08	<0.001*
Anterior/posterior index	0.64±0.27	2.35±1.87	<0.001*
Medial/lateral index	0.59±0.21	1.80±1.23	<0.001*
Single leg (right)			
Overall index	1.02±0.29	2.82±1.32	<0.001*
Anterior/posterior index	0.63±0.18	1.75±1.38	<0.001*
Medial/lateral index	0.63±0.23	1.70±0.96	<0.001*

* p<0.05.

compared to healthy adults.[22-24] High BMI, smoking behavior, antipsychotic drugs, low physical self-perception, low physical activity level, and having metabolic syndrome are known to be related with 6MWD in patients with schizophrenia.[25] Vancampfort et al. found a mean 6MWD of 573.1±115.5 m in schizophrenia patients.[23] However, mean 6MWD of the schizophrenia patients was 372.33±63.88 m in the current study. This difference may be important because the range of 6MWD was reported to be 400 to 700 m in healthy subjects, so schizophrenia patients seem to have reduced functional performance according to our results.[20] This study included schizophrenic patients without metabolic syndrome, and the BMI value of our patients was between normal limits. So, it is not possible to associate the reduced 6MWD with these factors. Since the level of physical activity of the patients was not evaluated in the current study because it is not related with our hypothesis, it is not possible to comment on the known effects of low physical activity level on functional performance of schizophrenic patients. Thus, considering remaining potential risk factors of our patients, we think the antipsychotic drugs which may alter dopamine levels in the brain, might affect motivation and drive in the patients during 6MWT.[26]

Dynamic pedobarographic analyses revealed that when compared to healthy adults, schizophrenia patients had less maximum plantar pressure in the forefoot and heel. In the literature, we could not meet any other study investigating the plantar pressures of schizophrenic patients. So it is not possible to discuss the reduction of foot pressure on the plantar aspect of the forefoot and heel considering previous studies. However, since the motor slowing seen in schizophrenia patients are similar to the motor problems seen in older adults and patients with Parkinson's disease we can comment on the similarity of our results with the previous studies on these populations.[27-29] Previous studies showed that

older people had reduced maximum dynamic plantar pressures in the heel and forefoot.[15,30] Reduced maximum plantar pressure of heel was reported to be related with reduced force production to stabilize the ankle in heel strike. Reduced maximum pressures in the forefoot was explained with decreased flexibility of the metatarsal, midfoot, and ankle along with reduced muscle strength and muscle recruitment in propulsion phase of gait.[15] These changes were also explained by reduced step length and foot structure differences in older adults.[30] Kimmeskamp et al. revealed that patients with Parkinson's disease had reduced peak pressures in the heel indicating a less pronounced heel strike, and relatively higher forefoot loading to use a strategy of forefoot balance control to compensate gait instability.[16] Dynamic plantar pressure patterns of the schizophrenia patients were found to be similar with older adults. Reduced forefoot pressure in schizophrenia patients differs from patients with Parkinson's disease although heel pressure patterns seem to be similar in both groups. Balance deficiency in schizophrenia patients might cause a more conservative gait, and further leads to less pronounced heel strike and propulsion to compensate gait instability. Otherwise, effect dynamic plantar pressures know gait alterations. However, the results of the current study exhibited no differences in temporal spatial gait parameters between schizophrenia patients and healthy controls. On the other hand, it was not possible to evaluate the risk factors such as reduced muscle strength, joint stiffness and foot deformities, which might affect the altered dynamic plantar pressure pattern in schizophrenia patients in our study. Further studies should investigate the factors associated with altered plantar pressure patterns of schizophrenia patients.

Temporal-spatial gait parameters were similar in both schizophrenia and healthy groups in this study. Putzhammer et al. indicated that schizophrenia patients had shorter stride length leading decreased gait velocity, while their cadence did not change compared to healthy controls.[9] Gait disturbances of schizophrenia patients are thought to be related to hypokinesia due to changes in sensorimotor cortex and reduction of supplementary motor area activation.[9] However, results of the present study conflict with that previous study in regards of the stride length and gait velocity. The study of Putzhammer et al. also exhibited that decreased velocity and stride length was more significant in patients under conventional antipsychotic treatment than in patients treated with atypical antipsychotic or untreated.[9] All of the patients were treated with atypical antipsychotic drugs in the current study. So, our results present that gait velocity and stride length of schizophrenia patients under atypical antipsychotic treatment do not differ from healthy adults.

The results of the postural stability analysis indicated that OA, AP, and ML stability scores of schizophrenia patients were increased in static, dynamic, and single leg conditions. These results are consistent with the studies demonstrating increased postural sway in schizophrenia patients, and this impairment is thought to be depending on cerebellar abnormalities.[5,31,32] As another possible reason, balance deficiency might arise as a side effect of the atypical antipsychotics used.[5] The current study exhibited that schizophrenia patients spent less time in right posterior on stable platform, and in right anterior on moving platform. Besides, although not statistically significant, schizophrenia patients spent less time in right anterior on stable platform, and less time in left anterior on moving platform compared to healthy adults. These results mean schizophrenia patients spent more time on left foot on stable platform and more time on backwards on moving platform. These findings showed the reactions of schizophrenia patients to restore their impaired dynamic balance. In this study, the number of left-dominant individuals in the patient group was higher than that of the control group. More use of the dominant side in stabilization while standing is an expected and plausible attitude. According to the healthy group of patients with schizophrenia, more time on the left side may be due to this reason. We could not reach any previous study investigating the time spent in quadrants during the postural control trial in schizophrenia patients. However, increased time spent of schizophrenia patients on backwards on moving platform is consistent with the results of a previous study which showed that patients with Parkinson's disease inclined backwards during the postural stability test.[33]

This study was conducted to identify the differences between schizophrenia patients and healthy controls in terms of functional performance, dynamic plantar pressures, temporal-spatial gait parameters and postural stability. Our results revealed that schizophrenia patients had lower functional exercise performance, less dynamic plantar pressure in the forefoot and heel and impaired postural stability while they had similar temporal-spatial gait parameters with healthy adults.

Limitations

However, underlying mechanisms that can influence the evaluated parameters and the associations among these parameters were not investigated in the current study. Lack of knowledge about the participant's activity levels, and other factors made interpretation of the data in this study difficult. Also, our trial had a relatively small sample size to achieve more accurate results.

Conclusion

The findings obtained from this study show that schizophrenia patients had some functional and biomechanical alterations. Assessment of the patients with a more comprehensive approach may help to decide most appropriate treatment and rehabilitation protocols. In order to clarify the causes of motor deteriorations in schizophrenia patients', further studies investigating the relationship between postural stability, functional performance and alterations in dynamic plantar pressures should be conducted.

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