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EFFECTS OF ANTHROPOMETRIC FACTORS, AGE, GENDER, AND FOOT POSTURE ON SINGLE LEG BALANCE PERFORMANCE IN ASYMPTOMATIC SUBJECTS

ORIGINAL ARTICLE

ABSTRACT

Purpose: The aim of the present study was to investigate the effects of age, gender, height, weight, body mass index (BMI), and foot posture on single leg standing balance performance.

Methods: A total of 76 healthy young asymptomatic adults were enrolled (52 females and 24 males) with an age range of 19-49 years. Age, gender, height, weight, and BMI, foot posture (Foot Posture Index), and balance (Biodex Balance Systems) were assessed. Balance assessments were performed on the dominant leg.

Results: A regression analysis showed that 43.2% of the anterior- posterior (AP) stability index score explained the total variance, and the effects of height (p=0.006, B=-4.387, β=-1.974, SD=1.554), weight (p=0.001, B=0.068, β=4.550, SD=0.020), and BMI (p=0.003, B=-0.171, β=-2.833, SD=0.056) found statistically significant. The regression analysis also revealed that 66.5% of the variance in the medial-lateral (ML) stability index score and age (p=0.026, B=0.003, β=0.173, SD=0.001) and weight (p=0.048, B=0.022, β=2.031, SD=0.011). Foot posture and gender were not statistically significant in both AP stability index and ML stability index (p>0.05).

Conclusion: The findings of the study showed that age, and anthropometric factors (height, weight, and BMI) are potential markers for balance assessments. These results suggest that age and anthropometric factors play an important role in balance performance in asymptomatic subjects

Key Words: Aging; Anthropometry; Foot; Healthy Subjects; Postural Balance.

ASEMPTOMATİK BİREYLERİN TEK AYAK ÜZERİ DENGE PERFORMANSINDA ANTROPOMETRİK FAKTÖRLER, YAŞ, CİNSİYET VE AYAK POSTÜRÜNÜN ETKİLERİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Çalışmamızın amacı yaş, cinsiyet, boy, vücut ağırlığı, vücut kütle indeksi (VKİ) ve ayak postürünün tek ayak denge performansı üzerine etkilerini araştırmaktı.

Yöntem: Yaşları 19 ve 49 arasında değişen (52 kadın ve 24 erkek) 76 sağlıklı genç asemptomatik birey gönüllü olarak çalışmaya katıldı. Yaş, cinsiyet, boy, vücut ağırlığı ve VKİ, Ayak Postür İndeksi ve denge testleri (Biodex Denge Sistemleri) değerlendirildi. Denge değerlendirmesi dominant ayak üzerinde yapıldı.

Sonuçlar: Yapılan regresyon analizi sonuçları anterior-posterior (AP) stabilite indeks skorlarında total varyansın % 43,2'sini açıkladığı bulundu ve boy (p=0,006, B=-4,387, β=-1,974, SD=1,554), vücut ağırlığı (p=0,001, B=0,068, β=4,550, SD=0,020) ve VKİ'nin (p=0,003, B=-,171, β=-2,833, SD=0,056) etkisi istatistiksel olarak anlamlı bulundu. Regresyon analizi sonucunda medial-lateral (ML) stabilite indeks skorundaki toplam varyansın % 66,5'ini yaş (p=0,026, B=0,003, β=0,173, SD=0,001) ve vücut ağırlığı (p=0,048, B=0,022, β=2,031, SD=0,011) açıkladığı bulundu. Ayak postürü ve cinsiyet hem AP hem de ML stabilite indeksinde istatistiksel olarak anlamlı değildi (p>0,05).

Tartışma: Bu çalışma yaş ve boy, vücut ağırlığı, VKİ gibi antropometrik faktörlerin denge değerlendirmesinde potansiyel belirteçler olarak bilgi verdiğini göstermektedir. Bu sonuçlar, asemptomatik bireylerde yaş ve antropometrik faktörlerin, denge performansında önemli bir rol oynadığını göstermektedir.

Anahtar Kelimeler: Yaş; Antropometri; Ayak; Sağlıklı Bireyler; Postural Denge.

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INTRODUCTION

Postural stability, also known as balance, is defined as the ability to keep the center of gravity of the body within the borders of the support surface. Postural control is essential for stability and balance during standing (1). Balance disorders are found to be associated with various orthopedic problems such as back pain, neck pain or ankle injuries (2,3). It has been also reported that the incidence of many orthopedic injuries is higher in middle-aged people, women, and obese individuals (4). The incidence of orthopedic disorders in these individuals may be associated with deteriorated postural control and balance performance. Determining the effects of age, gender, obesity, and foot posture on balance would help to understand the increase in the incidence of orthopedic injuries in these individuals, and maybe a guide regarding the treatment modalities administered in these individuals.

The effects of gender, age, obesity, and foot posture on balance have been previously studied. It has been reported that variables such as age, gender, anthropometric factors (height, weight, and body mass index (BMI)) and foot structure are effective on balance performance (5,6), and in addition, these variables are found to have no effect on balance performance (7,8). Since the studies on this subject have been carried out in different age groups using different evaluation methods, there is no consensus (5-8). Therefore, the present study aimed to investigate the effects of age, gender, height, weight, BMI, and foot posture on single leg standing balance performance. We hypothesized that all the assessed parameters would affect the balance performance in asymptomatic subjects.

METHODS

Design and Participants

Seventy-six healthy young asymptomatic adults (52 females and 24 males) aged between 19 and 49 years were evaluated. Those (1) who had spinal, hip, knee, ankle, or foot orthopedic injuries, such as back pain, plantar fasciitis, ligament injuries, tendinopathy, bursitis, or ligament injuries, (2) who had a history of lower extremities or spine surgery or a significant trauma, (3) who had neurological, cardiovascular, metabolic, or rheumatic diseases, and (4) who had a vestibular disease were excluded from the study. This study was approved by the Ethics Committee of Ankara Yıldırım Beyazıt University (No: 23.03.2018/06). Written informed consent was obtained from all participants, and the study was conducted following the rules of the Declaration of Helsinki.

The same investigator evaluated all the anthropometric measurements (height, weight, and BMI), Foot Posture Index (FPI), and balance test.

Body Composition Analysis

Body compassion analysis was performed in the morning. Height was measured using a portable stadiometer (Charder HM200P, Washington, USA) as the subject standing in barefoot. The weight was measured using the Bioelectrical Impedance Method (Tanita Corporation, Tokyo, Japan). Measurements were performed at the participant in light indoor clothing and barefoot. Participants were subsequently categorized as normal-weight (18.5 kg/m^2<BMI<25 kg/m^2) or obese (BMI ≥25 kg/m^2).

Foot Posture

The participants' foot posture was assessed using the FPI, which was reported to be reliable and valid for the detection of foot posture types (9). FPI was evaluated with each participant standing and using the six-item foot posture assessment tool, where each item is scored between -2 and +2 to give a total between -12 (highly supinated) and +12 (highly pronated), indicative of the position of each foot along the supinated to pronated continuum of foot posture. Items include talus head palpation, curves above and below the lateral malleoli, calcaneal angle, talonavicular bulge, medial longitudinal arch, and forefoot-to-rear foot alignment (9). The permission for FPI was taken via e-mail.

Postural Stability

Balance assessments as part of single-leg standing were carried out using the Biodex Balance Systems (Biodex Medical Systems, Shirley, New York, USA), which was reported as a reliable device for the detection of changes in postural control (10). The mobile platform of the device provides surface tilts of up to 20° and allows a 360° range of motion, allowing individuals to move forward, backward, and both ways. The balance test is most difficult when the platform has the least resistance to tilting. The mobility level of the platform varies between 0 (minimum stability) and 12 (maximum stability). Balance assessments were performed on the dominant leg similar to the literature (11,12). The dominant leg was determined by having the participant kick a ball.

As previously described in the literature (13), the tests were performed in bare feet, as the knee of the tested side is at about 10° flexion, the contralateral knee is at 90° flexion, and the hands are crossed over the chest. The tests were performed at platform level 6. During the test, the participants were asked to keep their balance centers at the target center of the display screen for 20 s with visual feedback. The tests were performed three times with 30-s intervals of resting. In this study, the individuals' balance performance was assessed using the center of balance (COB) parameters, which were the standard deviation of the COB amplitude in the anterior-posterior (AP_SD) and medial-lateral (ML_SD) directions.

Statistical Analysis

Power analysis was carried out in the present study to determine the number of cases. The minimum number of cases to be included in the study was found as 75 to obtain an effect size of 0.20, the desired statistical power level of 0.08, the probability level of 0.05, and the number of predictors of 6 (14). Statistical analyses were performed using SPSS version 22 (IBM SPSS Statistics 22, New York, USA). The variables were investigated using histograms, probability plots, and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk Test) to determine whether or not they were normally distributed. The parameters affecting the single leg balance performance were investigated using the Spearman Correlation Test for non-normally distributed variables. A multiple linear regression model was used to identify the independent predictors of the single leg balance tests results. The model fit was assessed using appropriate residual and goodness-of-fit statistics. A 5% type-I error level was used to infer statistical significance.

RESULTS

The median and interquartile range of the variables (demographic and clinical characteristics of the participants) subsequently included in the regression analyses are presented in Table 1. Based on the BMI values, 54 subjects were normal weight, and 22 subjects were obese. Considering the FPI scores, 44 subjects were detected as having a normal foot posture, with an FPI score of 0 to +5, and 32 subjects as having an over-pronated foot posture, with a score larger than +6.

Regression analysis revealed that 43.2% of the total variance in the AP stability index score was predicted by age, gender, height, weight, BMI, and foot posture (R^2=0.432, $F_{(7,67)}$=7.274, $p<0.001$). It was found that height (p=0.006, B=-4.387, β=-1.974, SD=1.554), weight (p=0.001, B=0.068, β=4.550, SD=0.020), and BMI (p=0.003, B=-0.171, β=-2.833, SD=0.056) were significantly different ($p<0.05$). Age (p=0.323 B=0.002, β=0.098, SD=0.002), gender (p=0.351, B=0.062, β=0.150, SD=0.066), and FPI (p=0.601, B=-0.006, β=-0.105, SD=0.011) were not significantly different ($p>0.05$) (Table 2).

Table 1: Demographic and Clinical Characteristics of the Participants.

Variables	Median (Interquartile Range)
Age (years)	23 (21-33)
Height (m)	1.67 (1.59-1.72)
Weight (kg)	60.75 (53.4-73.55)
Body Mass Index (kg/m²)	22.74 (20.57-25.22)
Foot Posture Index (-12, +12 score)	3 (1-8)
Anterior-Posterior Sway (score)	0.47 (0.37-0.56)
Medial-Lateral Sway (score)	0.40 (0.34-0.50)

Table 2: Regression Analysis Results Between Balance and the Parameters Investigated.

Variables	Anterior-posterior Sway				Medial-lateral Sway			
	p	B	β	SD	p	B	β	SD
Age (years)	0.323	0.062	0.150	0.011	**0.026***	0.003	0.173	0.001
Gender (Male: 1/Female: 2)	0.351	0.062	0.150	0.066	0.607	0.019	0.063	0.036
Height (m)	**0.006***	-4.387	-1974	1.154	0.351	-0.800	-0.504	0.851
Weight (kg)	**0.001***	0.068	4.550	0.020	**0.048***	0.022	2.031	0.011
Body Mass Index (kg/m²)	**0.003***	-0.171	-2.833	0.056	0.160	-0.041	-1.007	0.031
Foot Posture Index (score)	0.601	-0.006	-0.105	0.011	0.731	0.002	0.053	0.006

*p<0.05

The regression analysis also revealed that age, gender, height, weight, BMI, and FPI values predicted 66.5% of the variance in the ML stability index (R^2=0.665, $F_{(7,67)}$=18.993, p<0.001). In the ML stability index, age (p=0.026, B=0.003, β=0.173, SD=0.001) and weight (p=0.048, B=0.022, β=2.031, SD=0.011) were significantly different (p<0.05). Gender (p=0.607, B=0.019, β=0.063, SD=0.036), height (p=0.351, B=-0.800, β=-0.504, SD=0.851), BMI (p=0.160, B=-0.043, β=-1.007, SD=0.031), and FPI (p=0.732, B=0.002, β=0.053, SD=0.006) were not significantly different (p>0.05, Table 2).

The correlation analysis revealed that there was a mild correlation of age with AP sway (r=0.311, p=0.006) and ML sway parameters (r=0.325, p=0.004). There was a moderate correlation of weight with AP sway (r=0.532, p<0.001) and ML sway parameters (r=0.721, p<0.001). There was also a moderate correlation between BMI and AP sway (r=0.505, p<0.001) and ML sway parameters (r=0.581, p<0.001). While there was a mild correlation between height and AP sway (r=0.381, p=0.001), the correlation was moderate between height and ML sway (r=0.589, p<0.001). There was a moderate correlation of BMI with AP sway (r=0.505, p<0.001) and ML sway parameters (r=0.581, p<0.001). However, no correlation of FPI with AP sway (r=-0.044, p=0.708) and ML sway parameters (r=-0.045, p=0.704) was found (Table 3).

DISCUSSION

The most important findings of the present study were the age affected the balance in terms of ML sway, and height and BMI affected the balance in terms of AP sway. Among the anthropometric factors, weight affected the balance in terms of both AP and ML sways, and gender and foot posture was not found to be associated with balance.

There are many studies in the literature investigating the effects of anthropometric factors, age, gender, and foot posture on balance (5,6,15). The results vary because those studies have usually examined the effects of different variables in different age groups. Age is an essential factor in evaluating postural balance. There are studies in the literature indicating that age is not effective on balance in young adults (3,5,10), while other studies are indicating that balance disorders increase with age; therefore, in the literature, age-related changes in postural sway are still controversial (16). Lizama et al. (17), investigated the effect of age on balance responsiveness, eyes open and eyes closed, in younger and older healthy subjects who had no balance impairments. They found no age effect but observed a trend only towards a lower

Table 3: Correlation Analysis Results between Balance and the Parameters Investigated.

Variables	Age	Weight	Height	BMI	Foot Posture
Anterior-Posterior Sway	**0.311***	**0.532 ****	**0.381***	**0.505****	-0.044
Medial-Lateral Sway	**0.325***	**0.721****	**0.589****	**0.581****	-0.045
Weight (kg)	**0.001***	0.068	4.550	0.020	**0.048***
Body Mass Index (kg/m²)	**0.003***	-0.171	-2.833	0.056	0.160
Foot Posture Index (score)	0.601	-0.006	-0.105	0.011	0.731

* p<0.05, **p<0.001. Spearman Test. BMI: Body Mass Index.

velocity Center of Pressure (CoP)-sway in the ML direction. However, Alonso et al. (18) reported that older age was correlated with greater AP sway among the women and it explained 5% of the eyes closed performance. Hageman et al. (8) demonstrated that age had a significant effect on the sway area with eyes open and closed and with visual feedback in younger and older healthy adults. According to the results of the regression analysis in the present study, only age was found to affect ML instability, which is consistent with the literature. This outcome could be explained by that the increase in the excitation threshold of the cutaneous plantar receptors and the decrease in the function of the vestibular system affect the ML balance as reported previously (19). In addition, in the musculoskeletal system, AP instability is mainly controlled by the muscular system on the ankle level (20), but it is known that the pelvic muscles, especially the gluteus medius muscle, are active on ML balance (21). This outcome suggests that there is a need to focus on the effect of age on postural control in the evaluation of ML balance.

Gender is also not directly and solely effective on balance, but it is effective in conjunction with other parameters. Ku et al. (11) investigated the effect of BMI and gender on static postural control in healthy adults aged between 19 and 26 years. They reported a greater AP and ML postural sway in the female group in comparison with the male group. On the other hand, Alonso et al. (18) assessed the influence of anthropometric features and gender on postural balance in young adults (aged between 20 and 40 years) standing on two feet with eyes open and eyes closed. They indicated that postural balance was more influenced by anthropometric factors in males than females. However, no effect of gender on AP and ML balance was found, which is similar to the finding of Hageman et al. (8), who demonstrated that gender did not have a significant effect on balance in younger and older individuals. This outcome may be explained by the fact that the present study involved only younger individuals because gender-specific changes may not be effective in young individuals, and thus gender differences may not affect balance results.

An increase in weight and BMI, both of which are among the anthropometric factors, has been reported to affect postural balance directly, but most of these studies have been performed in individuals with high risk of falls, such as geriatric (22) or obese groups (23,24). The typical result in these studies is that balance diminishes with increasing weight (23-25), but there are not a sufficient number of studies in the literature evaluating the balance in healthy young people with normal weight (5,15). Hue et al. (15) analyzed the contribution of weight and balance stability in healthy male subjects aged between 24 and 61 years. The authors comprised a wide range of anthropometric features, particularly weight (59.2-209.5 kg) and their results showed that increasing weight correlates with a higher balance instability with and without visual feedback. Alonso et al. (18) reported that with higher weight, there was greater ML and AP sways and displacement in the whole group. In the present study, on the other hand, weight affected both AP and ML instability, which is in line with the literature. However, while weight was found to be effective in ML instability, the fact that both height and weight were found to be effective in AP instability may have resulted in the effectiveness of BMI in AP balance. In addition, the increasing BMI is considered to be a mechanical factor in providing balance against gravity. Moreover, the present results support the idea that AP instability in single leg balance is somewhat reflexive and an increase in BMI increases the balance instability more in this direction (11,18).

It has been reported in the literature that the increase in weight and height causes instability in the balance by affecting the support surface between the body and the center of gravity and creating a change in the musculoskeletal system (26,27). Therefore, it has been shown that increased height worsens balance (15,27). The present regression analysis results showed that height is also a factor for AP stability index, which is parallel with the literature (18,28).

There are studies in the literature indicating that postural stability decreases in individuals with abnormal foot postures and foot posture is a risk factor for some lower limb injuries (29,30). The present study showed that foot posture might not be necessary for assessing balance, which does not agree with the findings of Cobb et al. (12). On the other hand, our results agree with Büyükturan et al. (7) who showed that there was no relationship between balance and flat foot. In the present study, unlike other studies in the literature, the relationship between different foot postures and the balance was not investigated, and our participants have normal posture and horizontal posture so it may not affect the balance.

The factors affecting balance are considered to vary depending on the condition where eyes open or closed; however, one of the limitations of the present study is that there is no balance inquiry with eyes closed. Because when the vision is suppressed, the other systems of the body (sensory-motor, vestibular) get activated more. Therefore, eyes-closed evaluations in healthy individuals should have been performed. Finally, only the stability index in balance was examined in the present study, but in future studies, the evaluation of other parameters such as dynamic balance components and limits of stability in healthy young individuals may contribute to the literature.

In conclusion, our findings recommend the use of such indices as potential markers for balance assessments. An increase in weight appears to be a cause of AP and ML instability, which makes it a risk factor for maintaining balance. In addition, one of the findings of the present study is that age is an essential factor in ML stability, which reminds us of the musculoskeletal changes. For this reason, it is considered that, to inform healthy people, it is important to evaluate individual risk factors in preventive rehabilitation studies especially for healthy individuals.

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Conflict of Interest: None.

Ethical Approval: This study was approved by the Ethics Committee of Ankara Yıldırım Beyazıt University (No: 23.03.2018/06).

Informed Consent: Written informed consent was obtained from all participants.

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