Comparative Evaluation of the Foot Measurements of Women Who Presented to the Obesity Outpatient Clinic in Eskişehir Osmangazi University

Eskişehir Osmangazi Üniversitesinde Obezite Polikliniğine Başvuran Kadınların Ayak Ölçümlerinin Karşılaştırmalı Olarak Değerlendirilmesi

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ABSTRACT Objective: Obesity, which shows ethnic differences, is a risk factor for many diseases. Of those, foot problems are salient. This study aims to examine the effects of obesity on foot structure in obese Turkish women and compares them with the measurements in controls. **Material and Methods:** This study included 100 obese and 84 non-obese women. Body mass index (BMI), percent body fat content (BF) and waist to hip circumference ratio (W/H) were measured to detect body fat mass and body fat distribution. Static weight-bearing ink footprints were taken from the right foot of each woman. Forefoot width and Footprint Angle were measured, and Chippaux-Smirak Index was calculated to evaluate foot structure. **Results:** Medians in controls were 22.91 (21.45-24.47) kg/m^2 for BMI; 34.30% (31.10%-36.57%) for BF; and 0.77 (0.74-0.79) for W/H and corresponding values for obese women were 35.32 (32.55-40.52) kg/m^2, 41.90% (39.60%-44.30%), and 0.82 (0.78-0.86), respectively. Non-obese women had higher BF than other populations. All parameters except age were different in obese women compared to controls. BMI increased with ageing in controls although it did not change in the obese group. However, median footprint angle showed normal arch foot type and median foot index displayed intermediary arch foot in both groups. In regression analysis, foot index and foot angle were related to only BMI in the obese group. There was no such correlation with foot parameters in the control group. **Conclusion:** Although excess body mass does not cause serious foot discomfort in obese women it may limit physical exercise. In addition, obesity can influence examination of foot impressions for example in a crime scene investigation.

Key Words: Obesity, foot, woman

ÖZET Amaç: Etnik farklılıklar gösteren obezite birçok hastalık için bir risk faktörüdür. Bunlardan ayak problemleri dikkat çekicidir. Bu araştırmada, obez Türk kadınında obezitenin ayak yapısına etkileri ele alınmış ve kontrollerle karşılaştırılmıştır. **Gereç ve Yöntemler:** Bu çalışmada, 100 obez ve 84 obez olmayan kadın incelemeye alındı. Vücut yağ içeriği ve vücut yağ dağılımı hakkında daha doğru bilgi sahibi olmak üzere, beden kitle indeksi (BKİ), beden yağ kitlesi (BYK) ve bel-kalça oranı (BKO) belirlendi. Ayakta duran kadınların sağ ayaklarından mürekkeple ayak izi alındı. Ayak genişliği ve ayak izi açısı ölçüldü. Ayak yapısını değerlendirmek üzere Chippaux-Smirak İndeksi (CSI) hesaplandı. **Bulgular:** Kontrol grubundaki ortanca değerler, BKİ için 22.91 (21.45-24.47) kg/m^2, BYK için %34.30 (%31.10-%36.57), BKO için 0,77 (0.74-0.79) idi. Obez kadınlar içinse ortanca değerler sırasıyla 35.32 (32.55-40.52) kg/m^2, %41.90 (%39.60-%44.30), 0.82 (0.78-0.86) olarak bulundu. Obez olmayan kadınlarda BYK, diğer popülasyonlarda olduğundan daha yüksekti. Yaş dışında bütün parametreler obezitede değişiklik sergiledi. BKİ yaşlanma ile artış göstersede, obez grupta herhangi bir değişiklik olmadı. Bununla birlikte, her iki grupta, ayak izi açısı normal, ayak indeksi ise ara form ayak tipi sergiledi. Regresyon analizinde, obez grupta ayak indeksi ve ayak açısı sadece BKİ ile bağıntılıydı. Kontrol grubu ayak ölçümleri herhangi bir bağıntıya sahip değildi. **Sonuç:** Aşırı kilo, obez kadınlarda ciddi bir ayak rahatsızlığına neden olmasa da fiziksel egzersizi kısıtlayabilir. İlaveten obezite, örneğin; bir suç alanı incelemesinde ayak izlerinin değerlendirilmesini etkileyebilir.

Anahtar Kelimeler: Obezite, ayak, kadın

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Obesity is a significant health problem in most parts of the world and its frequency has been increasing gradually. This fact proves that the methods used for the prevention and treatment of obesity is inadequate.[1-4]

Various methods are used for the evaluation of obesity. The BMI which has been traditionally used does not provide the exact information about body fat mass and body fat distribution. Anthropometry is a simple and practical method which can be used among large populations.[1,5] Circumference measurements and skinfold thickness measurements provide the opportunity for the evaluation of fat mass content as well as fat localization.[2] Waist circumference and waist-to-hip ratio were important in assessing obesity in addition to BMI.[6] Considering the body fat distribution, obesity types show variations in their threatening effects on health. The increase in the abdominal fat tissue aggravates the risk derived from obesity.[2]

Currently, early diagnosis and evaluation of obesity is of great importance since obesity is a risk factor for various disorders such as cardiovascular diseases, type II diabetes, osteoarthritis and various musculoskeletal disorders. Diet and physical exercise are important factors for the treatment of obesity. Decline in physical activity increases obesity.[1-4] In addition, obesity was shown to have different ethnic characteristics and thus, related population-based researches are needed.[7]

The problems about lower extremity and foot are significant when musculoskeletal disorders are concerned. However, there have been limited researches so far about the effect of obesity on foot structure among adults.[8-11] Various methods were used in these studies. In addition, some researches have revealed that obesity can be a risk factor for osteoarthritis because of increased mechanical effects. The findings show that the metabolic consequences of obesity may be effective on small joints, which are not subject to overweight.[12]

In addition, footprint analysis is used for careful examination of foot impressions in forensic science to determine the identity of a victim or suspect. A number of methods have been suggested to estimate the height and sex of a person, using foot measurements.[13]

The objective of this study was to identify the body fat content of normal-weight and obese Turkish women, considering the values obtained through anthropometric measurements, to contribute to the knowledge on ethnic differences and to examine the effects of obesity on foot structure, which is important for physical activity.

MATERIAL AND METHODS

This research included 100 Turkish women with a BMI 30 or over and 84 control subjects whose BMI was lower than 25. In this study, the subjects were selected among women who had undergone medical examinations at the Eskişehir Osmangazi University Training, Practice and Research Hospital from 2005-2006 and who had consented to the anthropometric measurements. Informed consents were taken from all subjects. This study was planned based on Helsinki Declaration principles and was approved by the local ethics committee.

The following anthropometric measurements were done on the participants by an anthropometrist successively:

1. BMI: The weight (kg) and height (m) of the body were measured. BMI was obtained when the weight was divided into the square of the height.

2. Circumference measurements (cm): When the individual was standing straight with arms at her sides, waist and hip circumferences were measured with a flexible plastic measuring tape starting from certain standard points.[14] The ratio of waist to hip circumference (W/H) was identified.

3. Skinfold thickness measurements with skinfold caliper (mm): Subscapular, suprailiac, triceps and biceps skinfold thickness were measured with a millimeter-sensitive Holtain Tanner/Whitehouse (T/W) Skinfold Caliper, using standard techniques.[14] The sum of the values obtained from the four folds of the body was used to identify the percent body fat mass (BF), using the formula developed by Durnin and Womersley.[14,15]

4. The evaluation of the foot structure: This evaluation was carried out on footprints, which

were obtained through static weight effect.[16] A footprint system was designed as shown in Figure 1. Sirchie fingerprint ink was spread on a smooth thick glass surface by a special roller. The subjects were asked to step their right foot first on the glass surface and then on a piece of paper. Here, equal weight distribution was taken into consideration. Some ink was added on the glass surface after every 4-5 cases. The individual was asked to remove her foot from the paper after standing straight on it for 2-3 seconds. The Footprint Angle (FA) and Chippaux-Smirak Index (CSI) were calculated for each footprint, following the protocol of Forriol and Pascual, as representative measures of plantar contact area with the ground, which was an indirect method to measure the foot arch height.[16,17] Figure 2 illustrated the points taken into account for calculating the angle and the index: **aâ**: The line which combines the medial points on the heel and on the forefoot. **ad**: The line which combines point **a** and the apex of the medial arch concavity. The angle between these two lines at point **a** is FA (α).

b: The line extending from point **a** to the lateral, the largest point of the forefoot. It was measured and determined as forefootprint width. **c**: The line which is parallel to **b** and which is between the narrowest points of the medial arch. CSI = c/b; % (in percentage)

Foot angle values were classified as flat arch, (0-29.9°), low arch (30-34.9°), intermediary arch (35-41.9°) and normal arch (42° +) foot types. CSI values were categorized as high arch (%0), normal arch (%0.1-29.9), intermediary arch (30-39.9), lowered arch (40-44.9) and flat arch (%45 +) foot types.[16,17]

FIGURE 1: The footprint system composed of Sirchie fingerprint ink, special roller, smooth thick glass and a piece of paper.

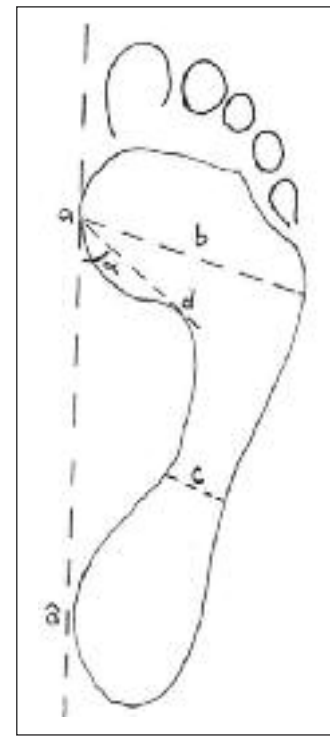

FIGURE 2: The points used in Footprint Angle (FA) and Chippaux-Smirak Index (CSI). FA (α), CSI (c/b;%).

STATISTICAL ANALYSIS

The SPSS 10.0 and SAS 9.1 for Windows program were used for the analysis of the data. Tests of normality for all variables were performed using Kolmogorov-Smirnov with Lilliefors Significance Correction. The results of the normality test showed that all variables were not distributed normally. Spearman correlation analysis was used to determine the relationship between parameters. Regression analysis was used to describe the relations of foot measurements with all other parameters. Comparison of the two groups was made with Mann-Whitney test. Data were expressed as medians and 25th-75th percentiles.

RESULTS

Age had a positive correlation with body fat mass in control ($r= 0.56$, $p< 0.01$) and in obese subjects ($r= 0.77$, $p< 0.01$). BMI increased with age in con-

trols, but did not show any correlation with age in the obese group. There was a significant correlation between BMI and BF in the control (r= 0.66, p< 0.01) and obese groups (r= 0.37, p< 0.01). However, waist/hip ratio had no correlation with BMI and BF in both groups. On the other hand, W/H was correlated with age (r= 0.22, p< 0.05) in obesity although it did not show a significant correlation in the control group.

Percentiles of control and obese subjects for each variable were given in Table 1. All parameters (p< 0.001) except age (p> 0.05) in obese women had significant differences compared to controls, although the BF rate was higher than 30% in Turkish women.

Age had a positive correlation with foot index only in controls (r= 0.23, p< 0.05). In the obese group, a negative correlation was detected between foot angle and BF (r= -0.22, p< 0.05). However, when foot measurements were classified according to the protocol of Forriol and Pascual, median footprint angle showed normal arch foot type and median foot index (CSI) displayed intermediary arch foot in both groups. In regression analysis, CSI and foot angle were related only to BMI in the obese group whereas foot parameters did not show any correlation in the control group (Table 2). The finding that forefootprint width did not have any correlation with BMI, BF or W/H was noticeable. Similarly, age and BF did not correlate with each other.

TABLE 1: Median, and 25 and 75 percentile values concerning all parameters in control and obese women.

Parameter	Group	Percentiles			Significance (p)
		25	50	75	
Age	Control	31.00	38.00	43.00	=0.060
	Obese	31.00	40.50	50.00	
BMI	Control	21.45	22.91	24.47	<0.001
	Obese	32.55	35.32	40.52	
W/H	Control	0.74	0.77	0.79	<0.001
	Obese	0.78	0.81	0.86	
BF	Control	31.10	34.30	36.57	<0.001
	Obese	39.60	41.90	44.30	
CSI	Control	25.05	32.20	37.75	<0.001
	Obese	33.04	37.86	44.12	
FA	Control	40.00	43.50	48.00	0.047
	Obese	36.00	42.00	48.00	
b	Control	8.20	8.50	8.90	<0.001
	Obese	8.60	9.00	9.20	

Body mass index (BMI), ratio of waist to hip circumference (W/H), percent body fat mass (BF), Chippaux-Smirak Index (CSI), Footprint Angle (FA), forefootprint width (b).

TABLE 2: Regression analyses of foot measurements with other parameters in both groups (Parameters with p> 0.05 were excluded).

Dependent variable	Constant	Nonstandardized Regression Coefficients	
		Independent variable	
		BMI	Age
FA (obese group)	56.782 (p< 0.001)	-0.414 (p= 0.016)	-0.131 (p= 0.122)
CSI (obese group)	24.994 (p< 0.001)	0.376 (p= 0.017)	0.144 (p= 0.062)
CSI (control group)	22.032 (p< 0.001)	0.901 (p= 0.112)	0.258 (p= 0.027)

Body mass index (BMI), Footprint Angle (FA) Chippaux-Smirak Index (CSI).

DISCUSSION

Recently, there has been an increase in obesity among children, and 30% of obese children grow into obese adults.[14,18]

The frequency of obesity varies from one society to another.[7,14] Furthermore, body composition displays ethnic differences.[19] Some studies reported that the age was correlated with only body fat mass.[1,2] BMI, waist circumference and waist-to-hip ratio, as indicators of obesity, were strongly associated with the risk of death.[6] Our study revealed that BF, BMI values of control subjects and BF, W/H values of obese women increased with age. In a previous study, waist/hip ratio had no correlation with BMI and body fat mass,[2] similar to the results of our study where W/H had no correlation with BMI and BF in both groups.

Foot structure varies among populations as well.[20] Various techniques have been reported to be used for the evaluation of medial longitudinal arch in foot. Footprint analysis was one of the most common methods to asses plantar contact area.[21] A research among prepubertal children displayed that excessive weight had an effect on foot structure and that there was a significant decrease in FA and a significant increase in CSI ($p< 0.001$) among obese children as compared to non-obese children.[16] Wearing et al found differences in arch index values in overweight and obese subjects.[22] Our results revealed a significant increase in CSI ($p< 0.001$) and a significant decrease in FA ($p< 0.05$) in obese women compared to controls. Excessive weight had an adverse impact on medial longitudinal arch structure of the foot.

A decreased FA indicated lower medial longitudinal arch of the foot and an increased CSI indicated a broader width in the arch area of the footprint.[17] Given the evaluations concerning footprint in our study, CSI values corresponded to intermediary arch foot index in both groups according to the classification of Forriol and Pascual.[17] However, FA values in both groups corresponded to normal arch foot type.

The changes in FA and footprint index were reported to be associated with the changes in plantar pressure.[23] BMI had a positive correlation with total plantar contact area and total plantar force.[11] Another study on plantar pressure changes revealed that the plantar pressure and forefoot width increased in obese individuals as compared to the non-obese. Besides, plantar pressure was higher among women than among men and this difference was attributed to the weakness of foot ligaments in women[8]. Kanatlo et al showed a positive correlation between BMI and plantar pressure although BMI was normal.[21] Our study also showed an increase in forefoot width in obesity ($p< 0.001$).

The feet were continually exposed to high ground reaction forces generated during activities of daily living. Excess body weight or excess adiposity was a major limiting factor in movement.[3,18] Excessive increases in weight-bearing forces caused by obesity may be detrimental to the lower limbs and feet. In addition, body composition changes as a function of ageing. Age-related changes are the increases in fat mass and reductions in the muscle mass and strength.[3] CSI increased with aging in our control subjects. Both groups had correlations between age and BF. Therefore, body fat content of non-obese Turkish women was higher than the standards according to Durnin and Womersley.[15]

Hills et al concluded that increased body weight would result in higher plantar foot pressures. Moreover, it was emphasized that this effect would apply merely to women during walking since their foot ligaments are weak. An increase in both foot width and foot pressure was observed in overweight individuals of both sexes during standing and walking.[3] There was evidence in our study that forefootprint width had no relations with BMI, BF and W/H in regression analysis. Foot and shoe dimensions were reported to be used to estimate the stature and sex of an individual.[13]

Obesity is an important health problem in the world. Obesity prevalence is higher in females than in men. It is a risk factor for numerous medical disorders, including cardiovascular diseases, diabetes, osteoarthritis and various musculoskeletal disorders, especially in the lower limb and feet.[3,24] However, improvements occurred in musculoskeletal findings after treatment of obesity.[24] Only limited

research has considered the effects of obesity on foot structure in obese people. Examination of footprint is frequently used to measure the dimensions of the foot indirectly. Foot type and the effects of some parameters can be investigated with this simple method.[3,25] Body fat content in the obese group had a correlation with FA in the correlation analysis. In addition, BMI had relations with FA and CSI in obese women in the regression analysis (Table 2). These parameters can be used to examine the structure of the foot in obesity. Few studies reported that foot length and especially foot width were increased in obesity. Hills et al showed increased foot width and higher plantar pressures in obese adults.[8]

In forensic sciences, significant correlations were found between foot length, width and stature in relation to ethnic group. Height estimation by foot length measurements were reported to give better results than width measurements.[13] Jasuja and Manjula used footprint measurements to estimate stature and they stated that it was better to prefer foot length rather than foot width.[26]

Özden et al saw the important relationship between height and foot width for males whereas they could not determine a relationship for females.[13] Our study revealed a significant increase in forefoot width in obese women. However, regression analysis did not show any relations with BMI, BF and W/H in both groups. Analysis of forefootprint width can be used to estimate bodyheight, and CSI and FA may be helpful to investigate BMI.

In conclusion, body fat mass and BMI are of great importance for the evaluation and follow-up of obesity if they are considered together. Furthermore, these anthropometric parameters have some different correlations compared to some studies based on other populations. It is noticeable that body fat content of non-obese women in our Turkish population was higher than in other populations. It may be useful to determine the body fat content of Turkish women whose BMI are within normal range, to prevent the effects of excess body fat content, which is a risk factor for various diseases.

On the other hand, excessive body weight and body fat content have different but not serious adverse impacts on foot structure in Turkish women although previous studies have shown more adverse effects on other populations. Women have weak foot ligaments and excess body mass may limit physical exercise in obese women; thus, it is necessary to investigate their foot structures. In addition, examination of foot impressions in females and some measurements of foot may cause mistakes in the estimation of the stature and in identifying possible individuals in a crime scene investigation.

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