Original Article

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Investigation of Plantar Pressure Distribution in Overweight and Obese Individuals

Aşırı Kilolu ve Obez Bireylerde Plantar Basınç Dağılımının İncelenmesi

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ABSTRACT

Objective: The increase in the incidence and prevalence of orthopaedic foot diseases may be related to changes in the plantar pressure distribution in overweight/obese individuals. Therefore, the purpose of the present study was to investigate the plantar pressure distribution in overweight/obese individuals.

Methods: The study included a total of 94 individuals between the ages of 19 and 62 years. Individuals were divided to two groups according to body mass index (BMI) as normal weight (BMI<25 kg/m^2) and overweight/obese (BMI≥25 kg/m^2). Static plantar pressure distribution and force measurement were assessed using MatScan System (Tekscan, Inc., South Boston, Massachusetts, USA).

Results: The total contact area (p<0.001) and midfoot maximum force (p<0.001) increased in overweight/obese individuals compared to normal weight individuals. Weight of individuals had a low correlation with peak pressure (r=0.23, p=0.026), mean pressure (r=0.24, p=0.018), midfoot maximum force (r=0.35, p=0.001) and metatars maximum force (r=0.36, p<0.001), and a moderate correlation with heel maximum force (r=0.47, p<0.001), and a strong correlation with contact area (r=0.79, p<0.001).

Conclusion: Obtained results show that total contact area and midfoot maximum force in overweight/obese individuals increased compared to normal weight individuals.

Keywords: Foot, pressure, obesity, body mass index

ÖZ

Amaç: Aşırı kilolu/obez bireylerde ortopedik ayak hastalıkları insidansı ve prevelansındaki artış, bu bireylerin plantar basınç dağılımındaki değişiklikler ile ilişkili olabilir. Bu nedenle, bu çalışmanın amacı, aşırı kilolu/obez bireylerde plantar basınç dağılımının araştırılmasıdır.

Yöntemler: Bu çalışma 19-62 yaş aralığında 94 sağlıklı bireyin katılımı ile gerçekleşti. Bireyler vücut kütle indekslerine (VKİ) göre normal kilolu (18,5 kg/m^2 <VKİ <25 kg/m^2) ve aşırı kilolu/obez (VKİ≥25 kg/m^2) olmak üzere iki gruba ayrıldı. Değerlendirilen bireylere ait statik ayak plantar basınç dağılımı ve kuvvet ölçümleri MatScan Sistemleri kullanılarak değerlendirildi (Tekscan, Inc., South Boston, Massachusetts, USA).

Bulgular: Aşırı kilolu/obez grubun total temas alanı (p<0,001) ve orta ayak tepe kuvvet değerinin (p<0,001) normal kilolu gruba göre yüksek olduğu bulundu. Kilo ile tepe basınç (r=0,23, p=0,026), ortalama basınç (r=0,24, p=0,018) ve orta ayak tepe kuvvet (r=0,35, p=0,001) arasında düşük düzeyde ilişki; kilo ile topuk tepe kuvvet (r=0,47, p<0,001) arasında orta düzeyde ilişki; kilo ile total temas alanı (r=0,79, p<0,001) arasında ise kuvvetli ilişki olduğu tespit edildi.

Sonuç: Elde edilen sonuçlar, aşırı kilolu/obez bireylerin total temas alanı ve orta ayak tepe kuvvetinde normal kilolu bireylere göre artış olduğunu göstermektedir.

Anahtar Sözcükler: Ayak, basınç, obezite, vücut kütle indeksi

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Introduction

The incidence of foot pain is reported as 14% in the adolescent population and 42% in geriatric individuals over 65 years of age (1,2). Foot pathologies and foot pain are associated with many factors, one of which is excessive weight and obesity (3,4). The increase in incidence and prevalence of foot diseases or pain in overweight/obese individuals may be associated with changes in plantar pressure distribution in these individuals. Plantar pressure distribution can significantly affect foot and ankle function. Changes in plantar pressure distribution may cause loss of support and flexibility of the foot during functional activities such as walking, running or standing (5-7). In addition, lower extremity posture is associated with plantar pressure distribution (8) Therefore, changes in plantar pressure distribution may cause changes in lower extremity posture, abnormal loading on the foot and foot-related structures, causing orthopedic diseases such as plantar fasciitis and anterior knee pain (5-9).

In overweight/obese individuals, plantar pressure distribution in static posture in standing is the subject of very limited research (10-13). Besides, the results of these studies are quite different. To give an example, some of these studies reported increased plantar pressure in overweight and/or obese individuals (12,13), while other studies reported similar plantar pressure distribution in obese individuals and individuals with normal weight (10,11). Exhibiting the changes in plantar pressure distribution in overweight/obese individuals can help developing new preventive and therapeutic approaches by providing better understanding of the increased foot and lower extremity orthopedic injuries in these individuals. Therefore, the aim of this study was to evaluate plantar pressure distribution in overweight/obese individuals and compare it with individuals with normal weight. The hypothesis of the study is that peak pressure, mean pressure and maximum force values in overweight/obese individuals will be higher than individuals with normal weight.

Methods

Power Analysis

Power analysis was conducted to determine the number of cases in this study. In order to perform this study with 80% power and 5% error margin, it was found that a minimum of 39 individuals in each group are needed to notice 10 cm^2 deviation in the contact area in case the average contact area of the control group is 81.8 cm^2 and the standard deviation (SD) is 16.7 cm^2 (13).

Participants

This study was conducted with the participation of 94 asymptomatic individuals in the 19-62 age range (35.2±11.5 years), including 68 females and 26 males. In the study, individuals with lower extremity injuries such as achilles tendinitis, plantar fasciitis and meniscopathy; with a history of major trauma or surgery of lower extremity; with a diagnosis of a rheumatic disease such as osteoarthritis or gout; with marked postural disorder such as hallux valgus and hammer toe; and with neurological diseases which may affect lower extremity were not included. This research was conducted after it was approved by the Toros University Clinical Research Ethics Committee (decision no: 2018-02/08). The research was conducted on individuals who read and signed the consent form which was approved by the ethics committee.

Body Composition Analysis

Measuring the height of the individuals was done using a standard stadiometer, in a standing upright position. Individuals' weight and body mass index (BMI) were measured using a standard scale (Tanita BC-418 MA, Tanita Corporation, Tokyo, Japan). Individuals were grouped according to their BMI as normal weight (18.5 kg/m^2<BMI<25 kg/m^2) and overweight/obese (BMI≥25 kg/m^2) (14).

Plantar Pressure Analysis

Plantar pressure distribution measurements of individuals in static posture in standing were evaluated using the MatScan system, which was reported to be reliable and valid (Tekscan, Inc., South Boston, Massachusetts, USA) (15). The device has a measuring area of 17.16x14.52" (435.9x368.8 mm). It also allows pressure measurement up to 862 kPa. After the calibration of the device, the measurements were performed at 50 Hz in bare feet and standing upright position for 30 seconds, as the manufacturer suggested. The peak pressure (kPa), mean pressure (kPa), heel maximum force (Ibs), metatars maximum force (Ibs), forefoot maximum force (Ibs) and total contact area (cm^2) values of each individual were calculated and recorded. Analysis of the data was done using FootMat™ software (Tekscan, Inc., FootMat™ for Clinicians software, South Boston, Massachusetts, USA) (Figure 1).

Statistical Analysis

Statistical analyses were done using special software (SPSS for Windows-version 18, IBM, USA). The parameters evaluated were given as mean ± SD. The Mann-Whitney U test was used to compare parameters without normal distribution between groups. The relationship level between parameters was evaluated

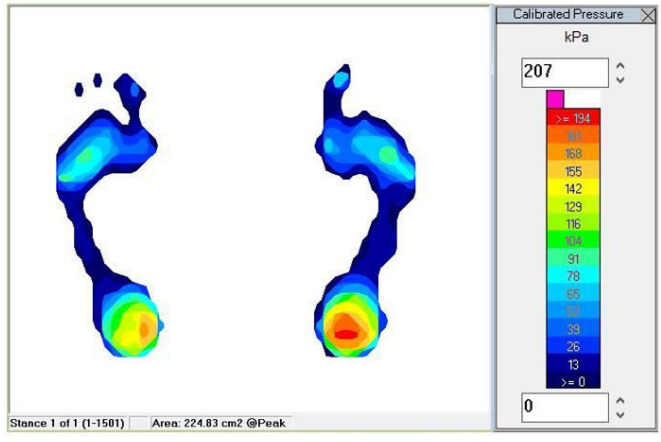

Figure 1. Plantar pressure distribution map obtained from pedographic analysis

by the Spearman test. Type 1 error level below 5% was interpreted as statistically significant. In correlation analyses, the relationship level was rated as 0-0.20 (weak correlation), 0.21-0.40 (low correlation), 0.41-0.60 (moderate correlation), 0.61-0.80 (strong correlation), and 0.81-1.00 (very strong correlation).

Results

There was no difference between groups in terms of age (p=0.402) and height (p=0.550) (Table 1). Total contact area (p<0.001) and metatars maximum force values (p<0.001) of the overweight/obese group were found to be higher compared to the normal weight group. The peak pressure (p=0.239), mean pressure (p=0.190), heel maximum force (p=0.164), forefoot maximum force (p=0.215) and change in center of force (p=0.558) values of both groups were found to be similar (Table 2).

When we examined the results of correlation analysis between the parameters evaluated, there were low correlation between weight and peak pressure (r=0.23, p=0.026), mean pressure (r=0.24, p=0.018), metatars maximum force (r=0.35, p=0.001) and forefoot maximum force (r=0.36, p<0.001); moderate correlation between weight and heel maximum force (r=0.47, p<0.001); strong correlation between total contact area and weight (r=0.79, p<0.001). There were low correlation between BMI and heel maximum force (r=0.25, p=0.015) and forefoot maximum force (r=0.21, p=0.048); moderate correlation between BMI and metatars maximum force (r=0.48, p<0.001); and strong correlation between BMI and total contact area (r=0.62, p<0.001) (Table 3).

Discussion

This study was planned to investigate possible changes in plantar pressure distribution in overweight/obese individuals. The hypothesis of this study was that peak pressure, mean pressure and

Table 1. Demographic data of the patients.

Parameters	Control group (n=54) Mean ± SD (min-max)	Obese group (n=40) Mean ± SD (min-max)	p
Age (years)	34.5±11.6 (19-62)	36.3±11.5 (19-58)	0.402
Gender (female/male)	41/13	27/13	
Height (m)	1.66±0.09 (1.51-1.87)	1.67±0.09 (1.48-1.86)	0.550
Weight (kg)	60.6±10.4 (43.3-85.4)	77.3±12.0 (54.8-107.0)	<0.001
BMI (kg/m²)	21.9±2.2 (16.7-24.8)	27.8 (25.0-42.1)	<0.001

m: Meter, kg: Kilogram, SD: Standart deviation, Min: Minimum, Max: Maximum, BMI: Body mass index

Table 2. Plantar pressure analysis results of the groups

Parameters	Control group (n=54) Mean ± SD (min-max)	Obese group (n=40) Mean ± SD (min-max)	p
Peak pressure (kPa)	136.5±44.1 (80.0-253)	143.2±38.5 (81-223)	0.239
Mean pressure (kPa)	111.2±39.4 (55-234)	116.9±33.3 (51-196)	0.190
Heel maximum force (Ibs)	36.5±17.6 (14.7-126.4)	40.5±16.8 (16.8-88.0)	0.164
Metatars maximum force (Ibs)	19.7±9.9 (4.0-60.5)	29.8±14.5 (11.2-93.0)	<0.001
Forefoot maximum force (Ibs)	35.2±12.3 (10.5-78.3)	37.5±12.4 (12.1-62.8)	0.215
Contact area (cm²)	90.0±16.9 (71.0-168.3)	101.5±11.8 (75.9-126.1)	<0.001
Change in the center of force (cm)	7.2±2.5 (1.6-13.2)	7.0±2.6 (1.4-12.5)	0.548

kPa: Kilopascal, Ibs: Pound, SD: Standart deviation, Min: Minimum, Max: Maximum

Table 3. Results of analyses of correlation between parameters

	Age	Height	Weight	BMI
Peak pressure	-0.18	0.15	0.23*	0.17
Mean pressure	-0.19	0.16	0.24*	0.19
Heel maximum force	-0.06	0.52**	0.47**	0.25*
Metatars maximum force	-0.02	-0,03	0.35*	0.48**
Forefoot maximum force	0.05	0.31*	0.36**	0.21*
Contact area	-0.01	0.58**	0.79**	0.62**
Change in the center of force	-0.02	-0.14	0.09	0.04

*p<0.05, **p<0.001, BMI: Body mass index

maximum force values in overweight/obese individuals would be higher compared to individuals with normal weight. Unlike the hypothesis of the study, the results showed that peak pressure, mean pressure, heel maximum force and forefoot maximum force values for overweight/obese and normal weight groups were similar. However, similar to the study's hypothesis, it was found that the total contact area and metatars maximum force of overweight/obese individuals were higher than individuals with normal weight. It was also found that there were varying correlations between the increase in total contact area and force parameters and the increase in weight and BMI, ranging from low to strong. Similar to our results, Yoon et al. (10) found that there was no change in forefoot and hind-foot pressure in obese individuals. Birtane and Tuna (13) reported that total contact area and forefoot pressure values increased in obese individuals, but heel pressure was similar in obese individuals and individuals with normal weight. Unlike our results, Hills et al. (12) reported that heel, middle foot and forefoot plantar pressure values were higher in obese individuals compared to individuals with normal weight. Cimolin et al. (11) reported that in obese adolescents, the contact area of the forefoot and metatars increased, but the peak pressure value did not change. There appear to be significant differences between studies in the literature. Differences between the study results may be related to differences in the populations of the studies (adolescents (11), adults (12) and geriatric individuals (13) and differences in the obese individuals included in the studies (obese individuals (13) and individuals with morbid obesity (11,12).

Obese individuals may be expected to have an increase in peak and mean pressure values due to an increase in body mass. The increase in metatars maximum force values in overweight/obese individuals indicates an increased load on the foot of these individuals, but this increased load caused an increase in total contact area and did not cause a change in mean and peak pressure values. In addition, the increase in metatars maximum values of overweight/obese individuals suggests that the increase in total contact area of these individuals was more associated with a decrease in medial longitudial arch height. Similarly, many studies in the literature report a decrease in medial longitudial arch height in overweight/obese individuals (16,17).

Our results show changes in the total contact area and force distribution of overweight/obese individuals. Changes in foot pressure distribution are known to be associated with orthopedic foot diseases such as foot pain, plantar fasciitis and achilles tendinitis (18-20). The increase in incidence of foot diseases in overweight and obese individuals may be associated with changes in plantar pressure distribution in these individuals. In addition to the increased loading of feet due to increased body weight in obese individuals, changes in plantar pressure distribution in these individuals are likely to cause abnormal loading on some parts of the foot, causing different orthopedic foot injuries (18,19). For this reason, foot posture should be evaluated in obese individuals and orthotic approaches such as medial longitudinal arch reinforcement should be applied to correct pressure distribution where appropriate. It is also thought that directing overweight and obese individuals to physical activities and diet programs to lose weight could reduce the risk of possible foot injury.

Study Limitations

This study has some limitations. First of all, foot pressure distribution was evaluated only in static standing posture in this study. If plantar pressure distribution could be measured during different activities such as walking and standing on one foot, the effects of excess weight and obesity on plantar pressure distribution could be explained in more detail. Only adult young and/or middle-aged individuals were evaluated in the study. In different populations, such as geriatric, adolescent, recreational athletes or professional athletes, the effects of excess weight and obesity on plantar pressure distribution could have been more different.

Conclusion

As a result, mid-foot peak force and total contact area were found to increase in overweight/obese individuals. In addition, peak pressure, mean pressure, heel maximum force, forefoot maximum force and change in center of force were found to be similar in both groups. When the results of the correlation analysis were examined, it was determined that the increase in weight and BMI was related to the increase in maximum force and total contact area.

Ethics

Ethics Committee Approval: This research was conducted after it was approved by the Toros University Clinical Research Ethics Committee (decision no: 2018-02/08).

Informed Consent: A consent form was completed by all participants.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: S.T., Y.S., Design: S.T., Y.S., Data Collection or Processing: S.T., Y.S., Analysis or Interpretation: S.T., Y.S., Literature Search: S.T., Y.S., Writing: S.T., Y.S.

Conflict of Interest: No conflict of interest was declared by the authors.

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