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ARAŞTIRMA / RESEARCH

Determination of lower extremity anthropometric measurements in adult healthy women wearing and non-wearing narrow toed high heeled shoes

Dar burunlu yüksek topuklu ayakkabı giyen ve giymeyen yetişkin sağlıklı kadınlarda alt ekstremite antropometrik ölçümlerin belirlenmesi

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Abstract

Purpose: The present study was aimed to analyze morphometric measurements of lower extremity dimensions in healthy females wearing and non-wearing high heeled shoes with narrow toe box.

Materials and Methods: Lower extremity length measurements were taken from 121 healthy adult females (64 females non-wearing high heel shoes with narrow toe box, 57 females wearing high heeled shoes with narrow toe box) aged 20 to 40 years using an anthropometer and caliper. Additionally, demographic data (age, height, weight and body mass index-BMI) were taken and tibia-femur ratio (the ratio between tibia length and femur length-T/F) were calculated.

Results: The mean values of Tibia - femur length ratio were found as 0.9087±0.038 (right) and 0.9088±0.036 (left) in females wearing high heeled shoes with narrow toe box, whereas the same values were established as 0.9128±0.035 (right) and 0.9157±0.032 (left) in females non-wearing high heeled shoes with narrow toe box. Furthermore, 53.12% of females non-wearing high heeled shoes with narrow toe box suffer from foot, knee and back pain, whereas 78.94% of females wearing shoes with narrow toe box suffer from foot, knee and back pain.

Conclusion: The observations presented in this report have defined anatomic parameters and morphometric changes that need to be taken into consideration when wearing narrow high heeled shoes and shoes having wide toe box in females.

Key words: Femur, morphometry, the ratio of tibia to femur, lower extremity anthropometry.

Öz

Amaç: Bu çalışma dar burunlu yüksek topuklu ayakkabı giyen ve giymeyen yetişkin sağlıklı kadınlarda alt ekstremite ile ilgili morfometrik ölçümleri analiz etmek için yapılmıştır.

Gereç ve Yöntem: Alt ekstremite uzunluk ölçümleri yaşları 20 ile 40 arası 121 yetişkin sağlıklı (geniş burunlu ayakkabı giyen 64 kadın; dar yüksek topuklu ayakkabı giyen 57 kadın) kadından antropometre ve kaliper kullanılarak yapıldı. Ayrıca, demografik veriler (yaş, vücut ağırlığı, boy uzunluğu, vücut kitle indeksi-BKI) alındı ve tibia-femur oranı hesaplandı.

Bulgular: Dar burunlu yüksek topuklu ayakkabı giyen kadınlarda tibia'nın femur uzunluğuna oranı 0.9087±0.038 (sağ) ve 0.9088±0.036 (sol) iken, dar burunlu yüksek topuklu ayakkabı giymeyen kadınlarda aynı ölçümler sırasıyla 0.9128±0.035 (sağ) ve 0.9157±0.032 (sol) olarak hesaplandı. Son olarak, dar burunlu yüksek topuklu ayakkabı giymeyen kadınların %53.12'i ayak, diz ve bel ağrısı çekerken, dar burunlu yüksek topuklu ayakkabı giyen kadınların %78.94'si ayak, diz ve bel ağrısı problemi yaşamaktadır.

Sonuç: Çalışmada elde edilen değerler, kadın populasyonunda dar burunlu yüksek topuklu ayakkabı ve geniş burunlu ayakkabı giyildiğinde dikkat edilmesi gereken anatomik parametreleri ve morfometrik değişimleri içermektedir.

Anahtar kelimeler: Femur, morfometrisi, Tibia uzunluğunun femur uzunluğuna oranı, Alt ekstremite antropometrisi.

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INTRODUCTION

The design and popularity of high heeled shoes (HHS) have always been a topic of interest to Today's fashion trends[1]. HHS are not only foot accessories but also an important part of female fashion[2]. Females wear high-heeled shoes due to some reasons[3]. Especially, these shoes are preferred by all females due to enhancing beauty and providing authority source[4,5]. Millions of females use high heeled shoes[3]. Moreover, walking with HHS shifts body weight toward medial with respect to the foot and alters the normal function of the ankle. Compensations occur at the knee and hip to maintain stability and progression during walking[3]. Furthermore, studies in literature have shown that wearing HHS leads to smaller and unstable supporting surface and alters lower extremity structure, reduces the shock absorbing ability and weight bearing functions[6,7].

The weight bearing bone of lower limb is the femur. It is the longest and strongest bone of the body. While the proximal part of femur constitutes the hip joint with the pelvis and femur distal part constitutes knee joint with tibia[8]. Tibia is the second longest bone and the proximal part joins in knee joint structure while the distal part constitutes ankle joint[8]. The fibula is usually used for bone grafts. Also, fractional surgical resection of this bone is performed in limb lengthening[9]. The fibula plays a role in stabilization of the talocrural joint in spite of deficiency of weight-bearing function and it is not directly a part of the knee joint[10].

Lower extremity that have been studied in various scientific fields including anatomy, anthropology, forensic medicine, ergonomics and orthopedics is well-adjusted bipedal locomotion and weight bearing as both structurally and functionally. This adaptation affects bone features such as length or strength[11]. Moreover, in forensic investigations long bones like tibia and fibula play a critical function for stature estimation. These present more reliable estimates of stature than the upper extremity bones[12]. Femoral anthropometric measurements show differences due to racial variations in nutrition, heredity, climate and geographical factors[13]. In a surgical correction of lower extremity limb deficiency, the surgeon must decide whether the tibia or femur should lengthen or shorthen in orthopaedic clinics[14].

In the literature, little is known about the ideal T/F ratio. The study declares the mean ideal T/F ratio to be between 0.78 and 0.85 and it is stated that increase in the ratio of T/F leads to hip and knee arthritis. Moreover, the shorter femur requires increased motion at the hip and knee joints. Furthermore, it is stated that this condition leads to develop speedy of degenerative joint disease. Briefly, longer femur and shorter tibia or decrease in the ratio of tibia to femur can prevent development of osteoarthritis (OA)[14]. OA of the hip and knee is an important public health subject[15]. The prevelance studies both in Turkey and in international literature show that women are more inclined to OA according to men[15-17]. Additionally, it is declared the ratio of body measurements to each other is affected from demographic data, geographical condition, genetic and enviromental factors and these features can change according to race and country. In anatomical studies made in the human body especially it is aimed to find the ideal beauty from the artistic point[18,19].

Footwear is more important for prevent foot from some problems. The main task of footwear began to change due to fashion from 15th.century on and fashion caused the changes of footwear features such as high heel or extended forward toe box[20]. Especially, it is declared that forefoot pain is often related to wear inappropriate shoes and wearing shoe with diminished toe box induces the health problems about foot[21]. High heeled shoes is commonly contain narrow toe box, rigit heel cap and curves plantar region. So, high heeled shoes vary from normal footwear[22].

As a result, we believe that the data obtained in this study can provide principal information for lower extremity morphometry and may help the orthopaedic surgeons and rheumatologists design for having a succesful surgery and minimize the related problems. Additionally, we think that our study will make a significant contribution to the literature about the ratio of tibia/femur studies in females wearing two type shoes what these length must be aesthetically.

MATERIALS AND METHODS

The study was approved by our institutional review board and ethics committee approval also was obtained. Bilateral lower extremity length measurements were obtained from 121 adult

females (64 females non-wearing high heeled shoes wide narrow toe box, 57 females wearing high heeled shoes with narrow toe box) between 20 and 40 years of age with no history of trauma or congenital anomalies. Each subject was asked to gently place her/his body in suitable position to each measure over a platform. In this study, 57 healthy females wearing high heel shoes with narrow toe box at least 5 cm height, at least one year and three days in a week were recruited, whereas 64 females non-wearing high heeled shoes with narrow toe box, less than 5 cm height and shoes having wide toe box were included.

Measurements and reference points

The distance between umblicus and malleolus medialis (MM), The distance between spina iliaca anterior superior (SIAS) and malleolus medialis (MM), the distance between trochanter major and malleolus medialis (MM) were measured. The femur length is the distance from the greater trochanter to the lateral condyle[8]. The tibia length measurement was taken from the medial condyle of the tibia to the medial malleolus (spherion)[12]. The fibula length was performed from the head of fibula to the lateral malleolus[12]. Tibia/femur ratio was calculated[14]. After these measurements, the body mass index (BMI) was calculated with kg/m^2 formula. All these measurements were done with antropometer (Anthropometry 01290 Lafayette Instrument) and caliper [Mitutoyo Vernier Kaliper (0-150 mm)] measurement tools.

Statistical analysis

After these calculations statistical analysis was performed with SPSS 21.0. From these measurements, minimum (min.), maximum (max.), means and standard deviations (SD) values were evaluated. Moreover, the correlation analysis between parts of the lower limb were performed. Furthermore, females were asked whether they suffer from pain or not. After, the pain ratio calculated in two groups.

RESULTS

The records of 121 adult females wearing and non-wearing high heeled shoes with narrow toe box were assessed. The mean and standard deviation values of age, weight, height and BMI measurements were found to be 33.07±5.77 years, 58.75±6.93 kg, 163.19±6.47 and 22.27±2.88 kg/m^2 in females wearing high heeled shoes with narrow toe box respectively, whereas the same values were 29.66±5.76 years, 58.24±6.52 kg, 163.61±5.79 cm and 21.79±2.27 kg/m^2 in females non-wearing high heeled shoes with narrow toe box (Table 1). Moreover, the mean and standard deviation values of heel height, footwear length and footwear width were measured as 2.78±0.76 cm; 24.73±1.47 mm (right) and 24.75±1.47 mm (left); 8.68±0.40 cm (right) and 8.71±0.43 (left) in non-wearing high heeled shoes with narrow toe box, whereas, corresponding values were determined as 9.01±1.80 cm; 7.81±0.35 cm (right) and 7.83±0.36 (left); and 22.85±2.04 mm (right) and 22.86±2.02 mm (left) in wearing high heeled shoes with narrow toe box (Table 1). There were found a significiant difference in heel height, footwear length and foot wear width measurements ($p<0.05$).

Statistical analysis of lower extremity length measurements of females wearing shoes having two type were shown in Table 2. There are no statistically differences in measurements including distance between umbilicus and malleolus medialis, spina iliaca anterior superior (SIAS) and malleolus medialis and trochanter major and malleolus medialis in females wearing and nonwearing high heeled shoes with narrow toe box. Moreover, in comparing the mean values of the right extremity with that of the left extremity, there was no difference between them for two groups. Furthermore, the correlation analysis of lower extremity measurements were shown in Table 3. The tibia/femur length ratio (T/F) were found as 0.9087±0.038 (right), 0.9088±0.036 (left) in females wearing high heeled shoes with narrow toe box, whereas the same values were established as 0.9128±0.035 (right) and 0.9157±0.032 (left) in females wearing shoes with wide toe box (Table 4). In addition, 53.125% (34) of females non-wearing high heeled shoes with narrow toe box suffer from foot, knee and back pain, whereas 78.947% (45) of females wearing high heeled shoes with narrow toe box have foot, knee and back pain.

DISCUSSION

Anthropometry is a reliable technique to evaluate various body parts. Body proportions show change between population[11]. Lower extremity is well-adjusted bipedal locomotion and weight bearing as both structurally and functionally[11]. This adaptation

affects musculoskeletal system including the length and strength of the bone, muscle origin, insertion and mass[11]. The measurements of body are affected from gender, age, socio-economic condition, nutrition and geographic factors[18-20]. Moreover, the long bones play an important role in forensic studies[12]. Furthermore, the information about the tibia dimensions is critical in forensic, anatomic, orthopaedic clinic and archeological studies to determine unknown bodies and stature[21].

Table 1. Demographic data in females wearing and non-wearing high heeled shoes with narrow toe box

Variable	Females wearing high heeled shoes with narrow toe box (n=57)	Females non-wearing high heeled shoes with narrow toe box (n=64)	p
Age (year)	33.07±5.77	29.66±5.76	p=0.001
Weight (kg)	58.75±6.93	58.24±6.52	p=0.676
Height (cm)	163.19±6.47	163.61±5.79	p=0.711
Body Mass Index-BMI (kg/m^2)	22.27±2.88	21.79±2.27	p=0.310
Heel height (right)	9.01±1.80	2.78±0.76	p<0.001
Footwear width (right)	7.81±0.35	8.68±0.40	p<0.001
Footwear width (left)	7.83±0.36	8.71±0.43	p<0.001
Footwear length (right)	22.85±2.04	24.73±1.47	p<0.001
Footwear length (left)	22.86±2.02	24.75±1.47	p<0.001

p=significant value

Table 2. Statistical analysis of lower extremity length measurements in females wearing and non-wearing high heeled shoes with narrow toe box

Length Measurements (cm)	Females wearing high heeled shoes with narrow toe box (n=57)	Females non-wearing high heeled shoes with narrow toe box (n=64)	P
Femur length (right)	38.32±2.43	37.94±1.99	p=0.352
Femur length (left)	38.28±2.45	37.98±2.02	p=0.464
Tibia length (right)	34.79±2.17	34.62±2.00	p=0.647
Tibia length (left)	34.76±2.09	34.76±1.83	p=0.995
Fibula length (right)	37.79±2.27	36.96±1.92	p=0.031
Fibula length (left)	37.71±2.27	36.98±1.95	p=0.060
Umbilicus- Malleolus medialis (right)	89.36±4.91	88.73±4.17	p=0.447
Umbilicus – Malleolus medialis (left)	89.42±4.94	88.95±4.28	p=0.583
Spina Iliaca anterior superior- malleolus medialis (SIAS-right)	82.76±4.60	82.09±4.35	p=0.410
Spina Iliaca anterior superior- malleolus medialis (left)	82.89±4.48	82.32±4.35	p=0.478
Trochanter major - malleolus medialis (right)	74.01±4.09	74.41±4.19	p=0.590
Trochanter major - malleolus medialis (left)	73.96±4.03	74.45±4.29	p=0.523

p=significant value

Table 3. Correlation analysis of lower extremity measurements according to height and weight measurements

Measurements	Height	Weight
Femur length (right)	0.671 p<0.001	0.682 p<0.001
Femur length (left)	0.376 p<0.001	0.388 p<0.001
Tibia length (right)	0.680 p<0.001	0.326 p<0.001
Tibia length (left)	0.694 p<0.001	0.323 p<0.001
Fibula length (right)	0.707 p<0.001	0.322 p<0.001
Fibula length (left)	0.713 p<0.001	0.339 p<0.001
SIAS-MM distance (right)	0.746 p<0.001	0.300 p<0.001
SIAS-MM distance (left)	0.741 p<0.001	0.303 p<0.001
Umblicus-MM (right)	0.801 p<0.001	0.339 p<0.001
Umblicus-MM (left)	0.800 p<0.001	0.338 p<0.001

p: significant value; r:correlation coefficient

Table 4. Ratio of tibia to femur length (T/F) and correlation analysis between right and left ratio in two groups.

Groups	Parameters	Mean±Standard deviation	T/F ratio correlation (right)	T/F ratio correlation (left)
Females wearing high heeled shoes with narrow toe box	T/F ratio (right)	0.9087±0.037	0.910*	-
	T/F ratio (left)	0.9088±0.036		
Females wearing shoes with wide toe box	T/F ratio (right)	0.9128±0.035	-	0.910*
	T/F ratio (left)	0.9157±0.032		
Comparison of groups (p)	T/F ratio (right)	0.267		
	T/F ratio (left)	0.545		

r≥0.900*: Very highly correlated

The femur is the weight bearing lower extremity bone[8] and is one of the most crucial bones in identifying gender, race, sport-culture habits[23]. The anatomical knowledge of different dimensions of femur can provide very important data for radiologist, rheumatologists and orthopaedic surgeons for treatment planning and diagnosis[8]. In Indians, the mean value of femur length was found as 43.98±2.15 cm (right) and 44.15±2.15 cm (left)[8]. Whereas, in Iran the mean value of the femur length were declared as 40.81±2.18 cm[24]. In this paper, the mean value of femur length was established as 38.32±2.43 cm (right) and 38.28±2.45 cm (left) in wearing high heeled shoes with narrow toe box. The same measurements were found as 37.94±1.99 cm (right) and 37.98±2.02 cm (left) in females non-wearing high heeled shoes with narrow toe box.

There was no significant differences in the mean values of the femur lengths for our two groups. Moreover, the differences in literature can result from racial variations, genetic, climate and geographical conditions[14]. In Thai Cadaveric study performed by Pureepatpong et al, it was declared that the longest bones were femur, fibula and tibia respectively[25].

In Sudanese, the mean value of tibia length was found as 38.21±1.93 cm[11], whereas in Indians, the same values were 35.26±1.69 cm (right) and 35.43±1.71 cm (left)[12]. In our study, this measurement was 34.79±2.17 cm (right) and 34.76±2.09 cm (left) in wearing high heeled shoes with narrow toe box and the same values were 34.62±2.00 cm (right) and 34.76±1.83 cm in females non-wearing high heeled shoes with narrow toe box, respectively. Due to these reports, we found differences in mean values of Indian and Sudanese populations compared with our result: they have higher values than us. We think that these discrepancies can result from race variation, climate, geographical condition, genetic features.

Gaur et al reported the mean value of fibula were established as 36.39±1.95 cm (right) and 36.35±1.85 cm (left) in Indians[12]. In this study, the same value was declared as 37.79±2.27 cm (right) and 37.71±2.27 cm (left) in females wearing high heeled shoes with narrow toe box whereas, in females non-wearing high heeled shoes with narrow toe box, these were found as 36.96±1.92 cm (right) and 36.98±1.95 cm (left) respectively. Also, this study showed that the fibula is longer than tibia in a similarly to our study.

After these measurements, the tibia- femur ratio was estimated. The advantages of this ratio include that it is easy and it does not require the use of investigation such as magnetic resonance. In a surgical correction of lower extremity limb deficiency, the orthopedist must decide whether lengthening or shortening of the tibia or femur should occur, because of preventing osteoarthritis hip and knee and decreasing the tibia femur ratio which is reported the tibia femur ideal ratio as 0.78 and 0.85[14]. In this investigation, the tibia femur ratio value was found as 0.9087±0.038 (right), 0.9088±0.036 (left) in females wearing narrow high heeled shoes, whereas the same measurement was established as 0.9128±0.035 (right) and 0.9157±0.032 (left) in females non wearing high heeled shoes with narrow toe box. It was found no significant differences between our two groups. According to the literature data, our findings were higher than this study. However, we think that this situation results from especially climate and racial differences and this results from both narrow high heeled shoes and inappropriate wide shoes or unsuitable heel height which may predispose to OA in the joint. Kerrigan et al declared during walking in

high heeled shoes than barefoot, increased force across the patellofemoral joint and a greater compressive force on the medial compartment of the knee[3]. Moreover, this increase in compressive forces the tibiofemoral region for knee OA (26). It could be important because osteoarthtitic changes are more common in the medial than in the lateral aspect of the knee. Both prolonged strain and pressures may lead to degenerative joint changes[3]. Additionally, It was shown that wearing wide heeled shoes and narrow heeled shoes increased peak knee varus torque by 26% and 22%, respectively and wide heeled shoes have the same effect on knee torque as narrow heeled shoes[3]. Whereas, other study showed that mildly high-heels (1.5 inch=3.81) cause changes in knee joint torques that are similar to that caused by females' wear shoes with heel heights mean 2.5 (6.5 cm) and 2.8 inch (7.11 cm) [26]. We consider that these diversities may be a result of such factors like individual constitution, genetic variables, climate type and the using of high heeled shoe or unsuitable heel height as well. We can say both wearing narrow high heeled shoes and low heeled shoes may not cause the differences in right and left side about lower extremity lengths including Umblicus-medial malleolus (MM), Spina iliaca anterior superior (SIAS)-Medial malleolus (MM) and trochanter major-Medial malleolus (MM) distances.

As a result, we believe that the data obtained in this study can provide principal information for lower extremity morphometry and may help the orthopaedic surgeons, rheumatologists for minimize the problems connected with ill-fitting shoes. We think that the T/F ratio is as one of the important guide for determining knee osteoartrit. Moreover, normally the ratio of tibia length to femur length is known as between 0.78 and 0.85, whereas in knee dislocation and hip - knee osteoarthritis, this value shows deviation from ideal values. Additionally, we believe that our study values will contribute to the literature about lower limb anatomy and the ratio of tibia/femur studies regarding what these length must be aesthetically. But, further researches are needed to determine whether high heeled shoes affect the osteoarthritis or not and moreover, we think that shoes that are fit and suitable subjects'feet structure should be prefer. So, the foot injuries can be decreased.

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