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ARAŞTIRMA / RESEARCH

Os calcaneus angles in dry bones of Turkish population

Türk toplumuna ait kuru kemiklerde Os calcaneus açıları

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Abstract

Purpose: The aim of this study was to evaluate calcaneus angles in dry bones belonging to Turkish population.
Materials and Methods: Dry calcaneal bones which age and sex were unknown belonging to Cukurova University Faculty of Medicine were used in this study. The photographs of the bones were taken under fixed light and distance, positioned like lateral direct graph, the Böhler (BA) and Gissane (GA) angles were measured according to the reference points using the digital design program (SketchUp 2016). Calculation sensitivity was 1/10°. Angle value distrubitons and left right relations were examined. After the measurements minimum-maximum, median and standart deviation values were obtained.
Results: Total of 67 dry bones were clasified as left and right. The average BA was measured as (minimum-maximum); 29.68°±4.71° (20.00°-39.80°) on the right side and 31.54°±4.88° (20.20°-41.20°) on the left side. GA average was measured as (minimum-maximum); 102.96°±5.25° (93.70°-114.5°) on the right side, 103.89°±7.14° (93.10°-120.4°) on the left side. For both angles no significant difference was found between left and right calcaneus.
Conclusions: Calcaneus angles may differ between races and populations. These angular values are important in determining calcaneus fractures. Base values of these angles are especially important in determining the baseline values which will be useful in practice. In literature the risk of fractures (especially displaced fractures) increases as the Böhler Angle and Gissane Angle approach the lower limits. Therefore, values obtained in this study will contribute establishing reference values in Turkish population.
Keywords:. Böhler Angle, Gissane Angle, Os Calcaneus

Öz

Amaç: Türk toplumuna ait kuru kemiklerden os calcaneus açılarının değerlendirilmesi amaçlanmıştır.
Gereç ve Yöntem: Çukurova Üniversitesi Tıp Fakültesi Anatomi Anabilim Dalı'na ait yaşı ve cinsiyeti belli olmayan 67 adet os calcaneus kullanıldı. Sabit ışık altında ve sabit mesafeden lateral direkt grafideki pozisyonuna uygun şekilde konumlandırılan kemiklerin fotoğrafları çekildi, referans noktaları deforme olan kemikler ölçümden çıkartıldı, referans çizgiler aracılığı ile Böhler (BA) ve Gissane (GA) açıları dijital tasarım programı (SketchUp 2016) kullanılarak ölçüldü. Ölçümler 1/100 mm duyarlıkta yapıldı. Açıların dağılım özellikleri ve sağ-sol taraf ilişkisi incelendi. Bu ölçümlerden sonra minimum-maksimum, ortalama ve standart sapma değerleri elde edildi.
Bulgular: Toplam 67 kuru kemikten sağ ve sol olmak üzere iki grup oluşturuldu. Böhler açısı ortalama (minimum-maksimum) değeri sağ tarafta; 29,68°±4,71° (20,00°-39,80°), sol tarafta; 31,54°±4,88° (20,20°-41,20°), Gissane açısının ortalama (minimum-maksimum) değeri sağ tarafta; 102,96°±5,25° (93,70°-114,5°), sol tarafta; 103,89°±7,14° (93,10°-120,40°) olarak bulundu. Her iki açı için sağ ve sol taraf arasında anlamlı fark bulunmadı.
Sonuç: Os calcaneus açıları farklı ırk ve toplumlarda farklı dağılım gösterebilir. Bu açıların değerleri os calcaneus kırıklarının belirlenmesinde önem arz etmaktedir. Özellikle taban değerlerinin belirlenmesi uygulamalarda yarar sağlayacaktır. Literatüre bakıldığında, Böhler ve Gissane açı değerleri alt sınırlara yaklaştıkça kırık (özellikle deplase kırıklar) riskinin arttığı görülmektedir. Çalışmamızda saptadığımız değerler Türk toplumuna ait referans değerlerin belirlenmesine katkı sağlayacaktır.

Anahtar kelimeler: Böhler açısı, Gissane açısı, os calcaneus

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INTRODUCTION

The calcaneus located at the back of the foot is the longest, thickest and largest of the tarsal bones. It plays an important role in force transfer by forming the heel protrusion. It also serves as a fulcrum for the superficial flexor muscles located in the hind limb [1]. The calcaneus has four joint surfaces supported by corticocancellous bone. In the anterior part, the anterior part of the subtalar joint forms a sellar type joint with the cuboid bone. The posterior side of the subtalar joint and the sustentaculum tali are separated from the anterior part of the talus by the tarsal canal and sinus tarsi. Bottom face of the bone is absent of joint surface. Calcaneal fractures occur as a result of high-energy trauma, the mechanism of occurrence is a traffic accident or fall from a height where the heel is overloaded. The position of the foot at the time of injury, the bone quality and the intensity of the force applied determine the anatomy of the fracture. Compression angulation and shear forces play a role in the formation of these fractures. Depending on the direction and impact of these forces, different fracture geometries from simple non-displaced fractures to complicated fractures involving joint surfaces and extending to adjacent joints are encountered. Calcaneal fractures constitute 2% of all fractures and are the most common fractures of tarsal bone fractures, 65% of all tarsal bone fractures are calcaneus fractures, intraarticular calcaneal fractures constitute 75% of calcaneus fractures. Intra-articular fractures of the calcaneus cause significant morbidity and loss of labor if not properly diagnosed and treated [2-6].

One of the most important factors in prognosis in calcaneus fractures is the Böhler Angle (BA) value at the time of initial evaluation [7-9]. The fact that this angle proposed by Lorenz Böhler in 1931 as tuber-joint angle is reduced or negatively measured in the calcaneus fractures indicates posterior facet depression [10]. Böhler et al declared the the normal valued of the BA angle as 30°-35°. Lower angles than 30-35° are accepted as a marker of fracture. In the literature in various studies results such as 25°-40°, 14°-50°, 28°-38°,20°-50°, 16°-47° and 20º-40º for normal values of BA were also reported (Table 2) [11-16]. Gissane Angle (GA) is another angle used to evaluate calcaneus fractures. Several studies report the normal value for GA between 96°-152°, 100°-130°, 120°-145° and 95º-105º [5,14-16]. GA below the specified limits indicates calcaneus fracture; however, there is no definite lower limit reported in the literature. Knowing the normal limits of calcaneal angles is important for determining the degree of deformity in calcaneus fractures and expecting morbidity after reduction [17].

In the studies conducted in America, Africa, Saudi Arabia and Turkish populations, the variations between the normal values of calcaneus angles are observed among the societies [12-14]. In the literature review it is seen that studies assessed the normal values for calcaneus by using radiological imaging methods. Different from the literature, this study was conducted for the first time by using Sketchup design program in dry bones. In this study we aimed to investigate the calcaneus angles and their consistency with measurements on radiographs by examining the calcaneus angles in undeformed dry bones without calcaneal fractures and to contribute to the literature on the determination of normal limits.

MATERIALS AND METHOD

In the literature, direct radiography (X-ray) images are used to measure GA and BA. In this study, we planned to measure angles in dry bones using photographic method for the first time. Positioning was performed with the face with three joints facing up, the sustentaculum tali inward and the end with one joint face facing forward. Calcaneus bones which were obtained from local turkish cemeteries absent of information about age and gender which are kept in the Department of Anatomy were used in this study.

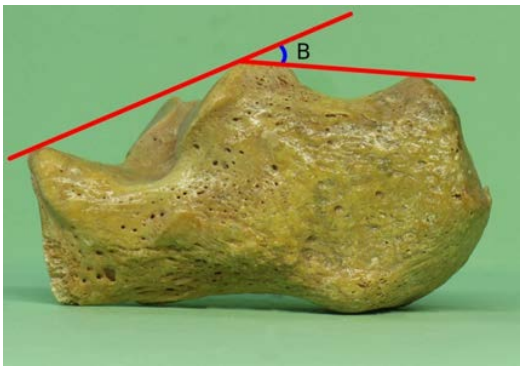

Figure 1. Böhler angle.

All the test procedures were performed according to the Helsinki Declaration of Principles and measures were done in Department of Anatomy. Bones without deformation were identified at the points to

be used as reference in the measurement. 36 right and 31 left bones were included in the study.

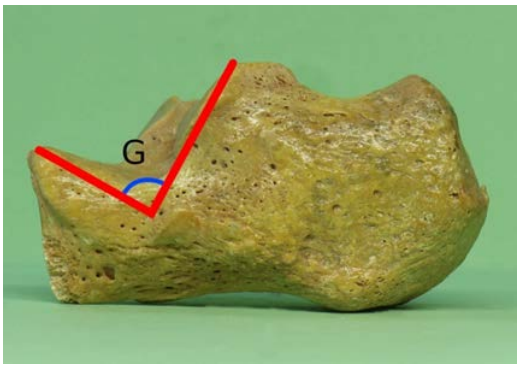

Figure 2. Gissane angle.

Measurements

Each bone was photographed under artificial light at a distance of 100 cm. The photography system was set up by fixing the camera with an adjustable tripod at a distance of 100 cm. The tripod height was also adjusted so that the camera was at same level as the dry bones. The photographs were taken with a Digital SLR camera with constant photographing settings (Canon EOS 80D; ISO 100 f / 4.5). It was aimed to simulate the image obtained on lateral direct radiography in vivo with respect to the positioning of the bones and the angle of photo shoot.

The photographs taken were transferred to the computer and loaded to Sketchup design program. The reference points of the angles to be measured were determined and the lines were drawn in the photographs. The angles of the intersecting lines were measured with 0.1° accuracy using the angle meter tool included in the program. BA was measured as the angle between the line drawn from the highest point of the calcaneus posterior facet and the line drawn from the highest point of the posterior facet to the highest point of the anterior process (Figure 1). GA was measured as the angle between the line drawn parallel to the edge of the posterior facet and the line drawn parallel to the edge of the anterior facet (Figure 2).

Statistical analysis

Descriptive statistics for continuous variables were summarized as mean ± standard deviation. and categorical variables were given with n (%). The normal distribution of the data was tested and parametric or non-parametric methods were selected as appropriate. In independent group comparisons "Independent-Samples t test" was taken as $p < 0.05$. IBM SPSS version 19 software was used for statistical analysis of the data obtained in the study.

RESULTS

A total of 67 dry bones were consisted of 36 right and 31 left groups. In the right side, the average and range of the Böhler Angle was 29.68°±4.71° and 20.00°-39.80°, respectively. In the left side, the average and range of the Böhler Angle was 31.54°±4.88° and 20.20°- 41.20°, respectively. In the right side, the average and range of the Gissane Angle was 102.96°±5.25° and 93.70°-114.5°, respectively. In the left side, the average value of the Gissane angle was 103.89°±7.14°, however the range of the same angle was measured as 93.10°-120.40° (Table 1). There was no significant difference between right and left sides for both angles ($p = 0.118$ for BA; $p = 0.545$ for GA).

Table 1. Mean and standard deviation values of the measurements performed in the study

Calcaneus Angles	N (%)	Mean ± SD	Side	Mean ± SD	95% Confidence Range	P
GA	36 (53.73)	133.43°±6.20°	Right	102.96°±5.25°	93.70°-114.5°	0.545
	31(46.27)		Left	103.89°±7.14°	93.10°-120.4°	
BA	36(53.73)	30.61°±4.80°	Right	29.68°±4.71°	20°-39.8°	0.118
	31(46.27)		Left	31.54°±4.88°	20.20°-41.20°	

N; Number of people of study, GA; Gissane Angle, BA; Böhler Angle, SD; Standard Deviation.

DISCUSSION

Calcaneus, the largest and first to ossifying of the ankle bones is the only short bone ossified from a secondary ossification center. Calcaneus the only bone in contact with the ground from the tarsal bones makes joints with the talus and cuboid bone. The retinaculum in the ankle is important for the attachment of plantar aponeurosis ligaments and some sole muscles. People who jump or fall from a height may develop fractures in the calcaneus. Since

most of the patients with calcaneus fracture are middle-aged working men, the morbidity and labor loss caused by the fracture is great [18-26]. There fore diagnosis and treatment of patients with calcaneal fractures and re-employment is important. Schepers et al. found that an average of 920 intraarticular calcaneal fractures occurred in one year in the Netherlands. 21% of these patients underwent secondary arthrodesis and the cost of this to the national economy was significant [23]. The determination of the treatment process is linked to the diagnosis and severity of the fracture. In recent years computed tomography (CT) has been used instead of radiographic methods [27-31]. In calcaneal fractures detailed evaluation of pathoanatomy with CT demonstrating the integrity of the joint surfaces and better understanding of the mechanisms of fracture formation have led to progress in classification and treatment. Since the angle calculations of the dry bone calcaneus were made by photographing, the super-position with other anatomical structures encountered during direct X-ray measurements were prevented problems such as over or under dosing were taken out of the picture thus making the measurements easier and clearer.

Studies using radiographic methods are very common yet no studies have been performed with dry bones. There fore the findings in our study were compared with those performed by radiographic methods (Table 2). Age and sex information was not present about the bones in our study. No significant relationship was found between age and calcaneus angles in the literature therewith [18]. In our study the mean GA was 102.96°±5.25° on the right side and 103.89°±7.14° on the left side. When the relationship of this angular parameter with the side was examined, no significant difference was found (P=0.545). Khoshhal et al.[14], in their study of 229 foot radiography have not procured any significant difference between sides as well. The GA value that we obtained in our study was compared with the values in the literature (Table 2). The reason for this is the conduction method of measurements, we used photographic evaluation of dry bones whereas studies in the literature were conducted using radiological images.

In our study, BA was 29.68°±4.71° on the right side and 31.54°±4.88° on the left side. the literature Didia and Dimkpa[12] in their study with 302 cases in Nigeria in 1999, the average value was calculated as 32.8°±2.8°. In a study performed by Igbigbi and Mutesasira[13] by 206 Uganda subjects in 2003, the mean values were found to be 35.1°±7.5° and 37.6°±5.6° in males and females, respectively. The results of these studies in Africa were found to be higher than our results and it was stated that the angles may vary due to ethnic differences (Table 2).

Table 2. Comparison of the mean value of the calcaneus angle measurements with the literature results

Literature	N	Population	BA Mean±SD (°)	GA Mean±SD (°)
Chen et al.11	120	North Carolina	30°±6°	-
Didia and Dimkpa.12	302	Nigeria	32.8°±2.8°	-
Igbigbi and Mutesasira. 13(M)	114	Uganda	35.1°±7.5°	-
Igbigbi and Mutesasira 13(F)	92	Uganda	37.6°±5.6°	-
Khoshhal et al.14 (M)	71	Saudi Arabia	31.15°±6.64°	115.66°±7.26°
Khoshhal et al.14 (F)	158	Saudi Arabia	31.24±5.27	116.39°±9.03°
Seyahi et al.18	308	Turkey	33.8±4.8	115.0°±6.5°
Boyle et al.19	763	New Zeland	39.2	113.8°
Shoukry et al.20 (M)	103	Egypt	29.84±4.08	122.2°±7.00°
Shoukry et al.20 (F)	97	Egypt	30.44±4.30	123.64°±6.90°
Ramachandran and Shetty.21	92	South India	31.32±4.79	108.7°±11.33°
Anivanović-Mačužić et al.22	225	Serbia	34.1°±4.2°	-
Schepers et al.23	33	Netherlands	32°	113°
Sengodan et al. 24	324	India	30.14±4.18	126.80°
Willmott et al.32	128	England	36.4°±4.2°	-
This study	67	Turkey	30.61°±4.80°	133.43°±6.20°

N; Number of people of study, SD; Standard Deviation, M; Male, F; Female.

In a radiological study performed with Serbian population by Anivanović-Mačužić et al.22, Willmott et al.32 in the British population and obtained values were closer to the studies conducted in Africa. In addition Khoshhal et al.14 examined the relationship between the right and left sides and found no significant results 14. Morover, BA mean values performed by Schepers et al.23 in 2007, Khoshhal et al.14 in 2004, Boyle et al.19, Ramachandran and Shetty21 in South India compared with our study, it is observed to have higher values (Table 2). Calcaneus angles may vary between different races and societies. Since the values of these angles are important in the diagnosis of calcaneus fractures, the determination of the baseline values will be beneficial in clinical practice. In literature, the risk of fracture (especially displaced fractures) increases as the BA and GA values approach the lower limits. The studies performed average of BA and GA by Saudi population by Khoshhal et al.14, Shoukry et al.20 in Egyptian population are close to the values obtained in our study (Table 2). When the literature is examined, it is seen that our results are in parallel with the studies conducted in America, India and Egypt (Table 2). A review study conducted by Isaacs et al. 25 in 2013, in order to increase the accuracy of the diagnosis of calcaneus fractures, the mean value of BA was explained to be 29.4°±4.1°. In the study performed by Seyahi et al.18 in 2009 with 308 Turkish population, the average value of BA was measured as 33.8°±4.8° (Table 2). When this value was compared with our study, the difference in results showed that there might be different normal limits for individuals belonging to the same or different ethnic groups. As a result, calcaneus angles may show different distribution in different races and societies. The values determined in our study will contribute to the determination of reference values for Turkish society.

We think that it will be important in setting a guideline for determination of mean values of calcaneus, for detailed evaluation of fracture pathoanatomy, for better understanding of the mechanisms of fracture formation for diagnosis and treatment approaches for each population.

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