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Morphometric Measurements of Calcaneus; Boehler's angle and Bone Length Estimation

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Abstract: Measurements of bones give us information about the individual and the population it belongs to. In these studies, in addition to head and pelvis skeleton, calcaneus bone is also one of the other studied body bones as it can be preserved well. In the present study, 65 (35 right-30 left) well-preserved calcaneus bones were evaluated in Anatomy Laboratories of Cumhuriyet University and Muğla Sıtkı Koçman University. With these bones, 10 linear measurements were made and Boehler's angle was measured. In calcaneus measurements, right-left side difference was determined in body height (BH) of the bone ($P<0.05$). Boehler's angle was found 20-40°, and a significant correlation was found between Boehler's angle and minimum width (MINW) of the bone ($P<0.01$). A significant correlation was detected between all other linear bone measurements except for anteroposterior maximum length (MAXL) of calcaneus and width of calcaneal sulcus (WSC) ($P<0.01$). By regression of calcaneus measurements, anteroposterior length of the bone can be calculated up to 1mm. Calcaneus is one of the bones commonly used by anthropologists and forensic scientists as it is preserved well. Morphometric values of calcaneus and the analyses made shall contribute to anatomy science, orthopedic surgery, kinesiology and forensic sciences.

Keywords: Calcaneus, measurement, Boehler's angle, osteology

Kalcaneus'un Morfometrik Ölçümleri; Boehler Açısı ve Kemik Boyunun Hesaplanması

Özet: Kemiklerden elde edilen ölçümler bize birey ve ait olduğu popülasyona ait bilgiler verir. Bu çalışmalarda özellikle tercih edilen kafa ve pelvis iskeleti yanında calcaneus kemiği de iyi korunabilmesi nedeni ile çalışılan vücudun diğer kemiklerinden biridir. Çalışmamızda Cumhuriyet Üniversitesi ve Muğla Sıtkı Koçman Üniversitesi, Anatomi Laboratuvarlarında bulunan iyi korunmuş 65 (35 sağ-30 sol) calcaneus değerlendirildi. Kemiklerden 10 linear ölçüm ve Boehler's açısı ölçüldü. Calcaneus ölçümlerinde kemiğin vücut yüksekliğinde (BH) sağ-sol taraf farklılığı belirlendi ($P<0.05$). Boehler's açısı 20-40° arasında bulundu ve Boehler's açısı ile kemiğin minimum genişliği (MINW) arasında anlamlı bir korelasyon olduğu bulundu ($P<0.01$). Calcaneusun anteroposterior maksimum uzunluğu (MAXL) ile calcaneal sulcus genişliği (WSC) haricinde diğer tüm linear kemik ölçümleri arasında anlamlı bir korelasyon belirlendi ($P<0.01$). Calcaneus ölçümlerinin regresyonu ile kemiğin anteroposterior uzunluğu 1mm yakınlığa kadar hesaplanabilir. Calcaneus iyi korunduğu antropologlar ve adli bilimciler tarafından sıklıkla kullanılan kemiklerdendir. Calcaneus morfometrik değerleri ve yapılan analizler anatomi bilimi, ortopedik cerrahi, kinesyoloji, antropoloji ve adli bilimlere katkı sağlayacaktır.

Anahtar Kelimeler: Kalkaneus, ölçüm, Boehler açısı, osteoloji

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1. INTRODUCTION

The standardized measurements from bones enable us to obtain information such as population affinity, gender, age, history of the individual before death and time of death [1].

Use of cranio-facial morphology is still the most determinant in evaluation of population affinity. However, complexity of this method is a disadvantage and requires the researchers to be experienced for several years [2]. Pelvis measurements are the other skeletal parts used by the researchers to determine differences [2,3]. When the head and pelvis skeleton is ill-preserved, it may be possible that these bones have been broken or even lost, or they may not show all of the analyses for the purpose of research. In such cases, use of other bones is required to evaluate the research. The researchers made gender, age, stature and measurement analyses from the bones other than the head and pelvis skeleton. They determined length of humerus in association with depth and width of intertubercular sulcus[4]. They studied gender differences on femur [5]. They calculated length of talus with other measurements of the bone [6].

Calcaneus is the biggest tarsal bone among all other tarsal bones. It makes up talocalcaneal/subtalar joint with talus. This joint allows for eversion and inversion movements of the foot. Morphometric values of calcaneus are important for anatomy science, diagnosis procedure and treatment in orthopedic surgery, kinesiology, anthropology and forensic sciences. The differences in anatomical structure of calcaneus play an important role in dynamic, kinetic and static of the foot [7]. Calcaneus is one of the bones used in determination of gender and calculation of stature [8,9]. Furthermore, it is one of the bones used in forensic sciences as it is preserved well and abundant [7].

2. MATERIAL AND METHOD

In our study, totally 65 well-preserved calcaneus bones (35 right, 30 left) - 53 calcaneus in Laboratory of Anatomy Department of Cumhuriyet University and 12 calcaneus in Laboratory of Anatomy Department in Muğla Sıtkı Koçman University – were used. In calcaneus analyses, 10 distances were measured and 11 measurements were made including Boehler's angle (Figure 1). These measurements are Maximum anteroposterior length (MAXL), maximum height (MAXH), cuboidal facet height (CFH), body height (BH), loadarm length (LAL), minimum transverse width (MINW), maximum transverse width (MAXW), dorsal articular facet breadth (DAFB), dorsal articular facet length (DAFL), width of the sulcus calcanei (WSC) and Boehler's angle (BA): These lines are; 1-superior margin of posterior to facet superior margin on anterior process 2-superior margin of posterior facet to superior margin of tuberosity

Morphometric Measurements of Calcaneus

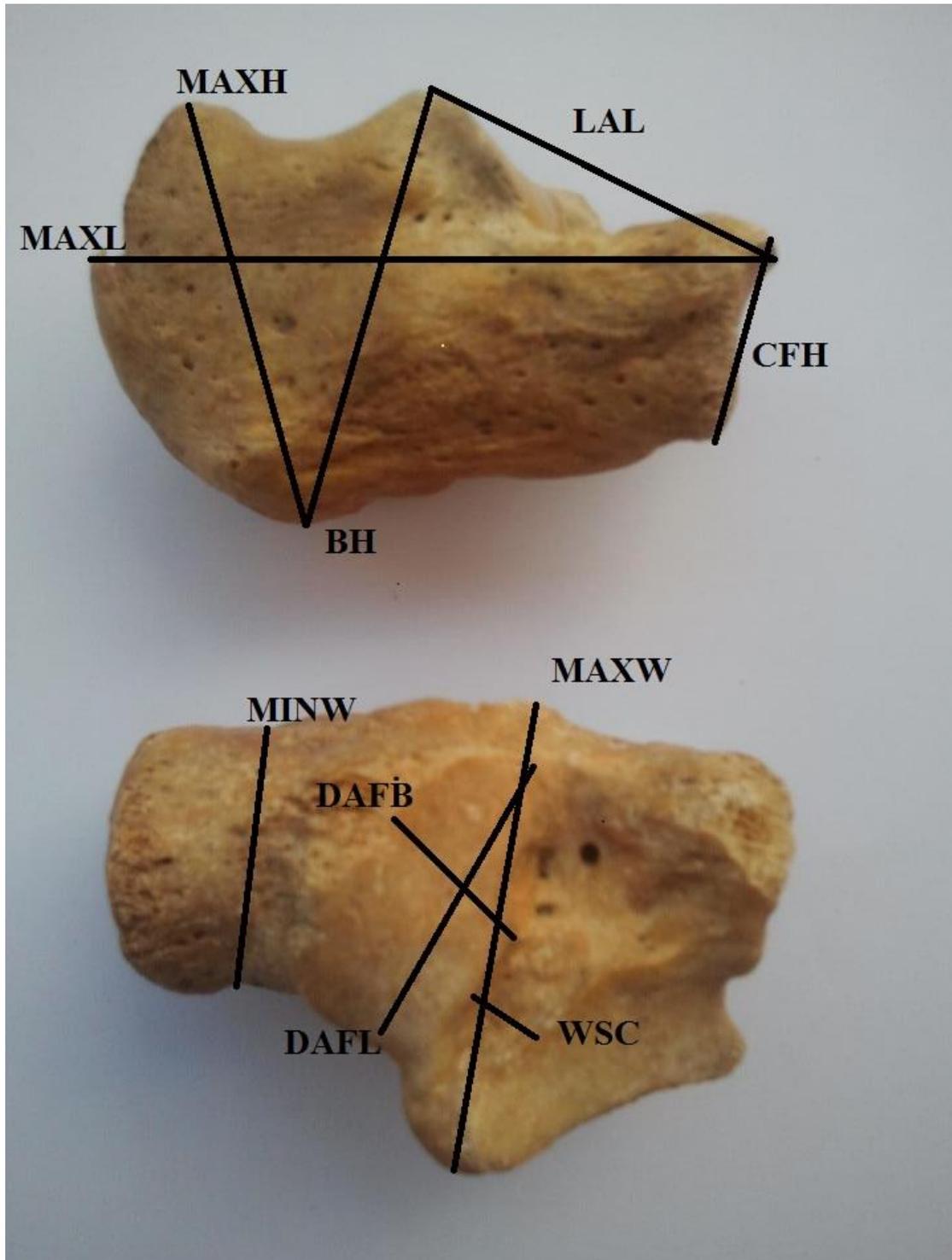


Figure 1. Measurement points used in calcaneus bone; MAXL;Maximum anteroposterior length MAXH; maximum height CFH; cuboidal facet height BH; body height LAL;loadarm length MINW;minimum transverse width MAXW;maximum transverse width DAFB;dorsal articular facet breadth DAFL;dorsal articular facet length WSC; width of the sulcus calcanei



Figure 2. Boehler's angle: These lines are; 1-superior margin of posterior facet to superior margin on anterior process 2-superior margin of posterior facet to superior margin of tuberosity

A sliding caliper with sensitivity of 0.1 mm was used in linear measurements and a goniometer was used in measurement of Boehler's angle. All calcaneus data was analyzed in order to determine right-left differences. Correlation of Boehler's angle and MAXL data with other measurements of the bone was examined. Regression of MAXL measurement of calcaneus with other bone measurements was evaluated. In statistical analyses, SPSS (version 14) was used.

3. RESULTS

When right-left difference was evaluated from calcaneus data, BH shows a statistically significant difference between right and left calcaneus ($P < 0.05$). There is no significant difference between right and left side in terms of other measurements of calcaneus except for BH ($P > 0.05$) (Table 1). Boehler's angle was found between 20 and 40 degrees in our study.

Morphometric Measurements of Calcaneus

Table 1. Measurement values of calcaneus.

Parameter	Side	N	Mean	SD	SEM
MAXL (mm)	R	35	76.21	5.68	0.96
	L	30	76.14	5.53	1.00
MAXH (mm)	R	35	44.05	4.73	0.80
	L	30	45.83	3.33	0.60
CFH (mm)	R	35	24.48	2.19	0.37
	L	30	24.94	3.10	0.56
BH*(mm)	R	35	49.00	3.70	0.62
	L	30	51.60	5.44	0.99
LAL (mm)	R	35	47.09	3.27	0.55
	L	30	47.63	3.58	0.65
MINW (mm)	R	35	25.19	3.08	0.52
	L	30	26.22	2.40	0.43
MAXW (mm)	R	35	42.97	3.75	0.63
	L	30	43.51	3.34	0.60
DAFB (mm)	R	35	21.19	2.47	0.41
	L	30	21.89	2.24	0.41
DAFL (mm)	R	35	29.52	2.64	0.44
	L	30	30.01	2.56	0.46
WSC (mm)	R	35	4.96	1.48	0.25
	L	30	5.28	1.16	0.21
BA (°)	R	35	29.97	5.22	0.88
	L	30	28.50	5.00	0.91
*P< 0.05					

When relationship of Boehler's angle with other measurements of calcaneus was examined, a significant correlation was found between Boehler's angle and MINW(P<0.01) (Table 2).

Table 2. Correlation of Boehler's angle with calcaneus measurements.

Parametre			
BA	MAXL	0.34	
	MAXH	0.12	
	CFH	0.58	
	BH	0.78	
	LAL	0.53	
	MINW*	0.00	
	MAXW	0.58	
	DAFB	0.06	
	DAFL	0.40	
	WSC	0.51	
	*P< 0.01		

When correlation of MAXL measurement with other calcaneus measurements, a significant correlation was detected with MAXH, CFH, BH, LAL, MINW, MAXW, DAFB and DAFL (P<0.01). There was no statistically significant correlation between MAXL and WSC and BA (Table 3).

Table 3. Correlation of antero-posterior length of calcaneus with other bone measurements

Parametre		
MAXL	MAXH*	0.000
	CFH*	0.002
	BH*	0.000
	LAL*	0.000
	MINW*	0.000
	MAXW*	0.000
	DAFB*	0.000
	DAFL*	0.000
	WSC	0.440
	BA	0.344
*P<0.01		

In simple regression analysis, a significant regression of MAXL measurement was determined with MAXH, CFH, BH, LAL, MINW, MAXW, DAFB and DAFL measurements (Table 4).

Table 4. Simple regression of maximum antero-posterior length of calcaneus with other measurements

Parametre		Costant±SE	B±SE	R ²	SEE	P
MAXL	MAXH	37.6 ± 5.7	0.85 ± 0.12	0.42	4.2	0.000
	CFH	56.1 ± 6.0	0.81 ± 0.24	0.14	5.1	0.002
	BH	31.2 ± 4.8	0.89 ± 0.09	0.57	3.6	0.000
	LAL	20.7 ± 6.8	1.17 ± 0.14	0.51	3.9	0.000
	MINW	48.8 ± 5.4	1.06 ± 0.21	0.29	4.7	0.000
	MAXW	41.9 ± 7.3	0.79 ± 0.17	0.25	4.8	0.000
	DAFB	53.2 ± 5.6	1.06 ± 0.26	0.20	4.9	0.000
	DAFL	30.7 ± 5.6	1.52 ± 0.18	0.50	3.9	0.000
SE:StandardError, SEE: StandardError of theEstimate						

4. DISCUSSION

Osteotomy, anatomic reduction and soft tissue relaxation to determine normal dimensions are among treatment options for complex foot disabilities. During making some structural treatment plans, it is useful to know pathology and anatomy of the deformed foot. Many foot diseases such as talocalcanealarthritis and coalition, intra-articular breaks, flatfoot relate to talus or calcaneus and other bones of the foot [10]. Detailed knowledge about calcaneus anatomy can facilitate alternative treatment procedures. Furthermore, calcaneus measurements are necessary for osteotomy [11,12].

In the present study, we made morphometrical measurements on well-preserved calcaneus bones from skeleton remains. When we evaluated these measurements, we determined that right-left difference of calcaneus existed statistically significantly only in BH measurements (P<0.05). In their study, Arı and Kafa stated that right-left difference of calcaneus was significant in DAFB and DAFL measurements [13], Koshy et al stated that there was a significant difference in MAXW measurement [6] and Gualdi-Russo stated that there was no significant difference [14]. It is observed that right-left difference of calcaneus measurements is limited.

Morphometric Measurements of Calcaneus

A foot is divided into three parts: forefoot, midfoot and hindfoot. The joint between inferior surface of talus and superior surface of calcaneus is known as subtalar joint and inversion and eversion movements of hindfoot occur here. Calcaneus breaks are the most common tarsal breaks. Many breaks are obviously distinct. However, the breaks which are diagnosed hardly can only be diagnosed with low Boehler's angle [15]. Boehler's angle is composed of the line combining posterior tuberosity of calcaneus and peak of posterior surface and the line between the peak of posterior surface and anterior process of calcaneus [16]. Boehler's angle shows the strongest relationship for walking dynamic and produces clinical information for the researched issues. The main aim of treatment of calcaneal breaks reconstruction of Boehler's angle and restoration of calcaneus shape together with convenience of joint surface [17]. Especially for calcaneus breaks, Boehler's angle is used in diagnosis and treatment in orthopedic surgery. Decrease of Boehler's angle is important for breaks. If the Boehler's angle belonging to the populations cannot be determined, many variations can be observed in angle measurement after operation [18]. In our study, we found Boehler's angle between 20-40°. Boehler's angle was found between 25-40° in the study performed in Caucasia region [19], between 28-38° in Nigeria [20] and between 20-50° in Uganda [21]. It is seen that Boehler's angle varies among populations. We researched relationship of Boehler's angle with other measurements of calcaneus bone (Table 2). Boehler's angle displays a significant relationship only with MINW among calcaneus measurements. There is no statistically significant correlation with other calcaneus measurements.

When correlation of antero-posterior maximum length of calcaneus with other measurements of the bone is examined, we determined that it had a significant relationship with other calcaneus measurements except for calcaneal sulcus width and Boehler's angle (Table 3). This relationship between calcaneus measurements shows that the bone preserves its general morphology in spite of the variations in its morphological measurements of the bone.

In simple regression analysis, it was determined that antero-posterior length of calcaneus bone had a significant regression with MAXH, CFH, BH, LAL, MINW, MAXW, DAFB and DAFL measurements (Table 4). These findings show that antero-posterior length of calcaneus bone can sometimes be calculated with a difference of 1 mm from other measurements of the bone.

We are in the opinion that our morphometrical studies and evaluations on calcaneus bone among skeleton remains provide useful information for anthropologists and forensic scientists in Anatolia region as well as contributing to the researchers in anatomic literature and clinical field.

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