

Morphometric analysis of calcaneum in Indian population

Arpan Haldar¹, Manisha R Gaikwad², Amit P Tirpude³, Soumya C Bhattacharya⁴, Provas Banerjee⁵

¹ Senior Resident, Department of Anatomy, AIIMS Bhubaneswar, Orissa, India

² Additional Professor & HOD, Department of Anatomy, AIIMS Bhubaneswar, Orissa, India

³ Assistant Professor, Department of Anatomy, AIIMS Bhubaneswar, Orissa, India

⁴ Professor & HOD, Department of Anatomy, ESI-PGIMS Joka, Kolkata, Orissa, India

⁵ Professor & HOD, Department of Anatomy, Hi-Tech Medical College & Hospital, Bhubaneswar, Orissa, India

Abstract

Measurements of bones give us information about the individual and the population it belongs to. In the present study, 30 (15 male-15 female) well-preserved calcaneus bones were evaluated in Department of Anatomy, AIIMS Bhubaneswar. With these bones, 7 linear measurements were measured. In calcaneus measurements, right-left side difference was determined in body height (BH) of the bone ($P < 0.05$). 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, osteology

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 researcher 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 the analyses for 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].

Normally there are three facets for synovial joints between calcaneus and talus, Anterior, Middle and Posterior. The anterior and the posterior facets are situated on the body and

the middle is situated on the sustentaculum tali. There is considerable variation in the number and arrangement of these facets. Bunning and Barnett (1963) have observed that there are three types of variations in the arrangement of facets. They have classified these variations as follows: Type-A: There are three facets separated by variable intervals. Type-B: There are two facets anterior and middle which are either continuous or have a notch between them. Type-C: There is only one facet i.e. the three form a continuum. Few Indian workers have also worked on this subject. Jha *et al.* (1972) have reported that type-B calcanei are common amongst the population in Uttar Pradesh and have classified type-B calcanei into four subgroups: Subgroup-1: Anterior and middle articular facets completely fused and form a single facet. Subgroup-2: Anterior and middle articular facets incompletely separated from each other by means of a notch. Subgroup-3: Anterior and middle articular facets separated from each other but with no non-articular area intervening. Subgroup-4: Absence of anterior articular facet. Only middle and posterior articular facets were being present. Gupta *et al.* (1977) have classified the calcanei in numerical types as follows: Type-I (1): Corresponds to type-B of the Bunning and Barnett classification (1963). Type-II (2): Corresponds to type-A of the Bunning and Barnett classification (1963). Type-III (3): Has only two facets, not corresponding to any type of Bunning and Barnett. The anterior facet is absent. Only the middle and the posterior facets are present. Type-IV (4): Corresponds to type-C of the Bunning and Barnett classification (1963).

Materials and Methods

In our study, totally 30 well-preserved calcaneus bones (15 male, 15 female) in Department of Anatomy, AIIMS Bhubaneswar were used. In calcaneus analyses, 7 measurements were made including (Figure 1) which were

Maximum anteroposterior length (MAXL), maximum height (MAXH), cuboidal facet height (CFH), body height (BH), load arm 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 Length of Sulcus Calcanei (LSC). A sliding caliper with sensitivity of 0.1 mm was used in linear measurements. All calcaneus data was analysed to determine right left differences in males and females. Correlation of 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 21) was used.

Results

When right-left difference in males and females was evaluated from calcaneus data, Maximum anteroposterior length (MAXL), maximum height (MAXH), cuboidal facet height (CFH), body height (BH), load arm 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 Length of Sulcus Calcanei (LSC) shows a statistically significant difference between right and left calcaneus ($P < 0.05$) (Table). The correlation between male and female calcaneus was also significant.

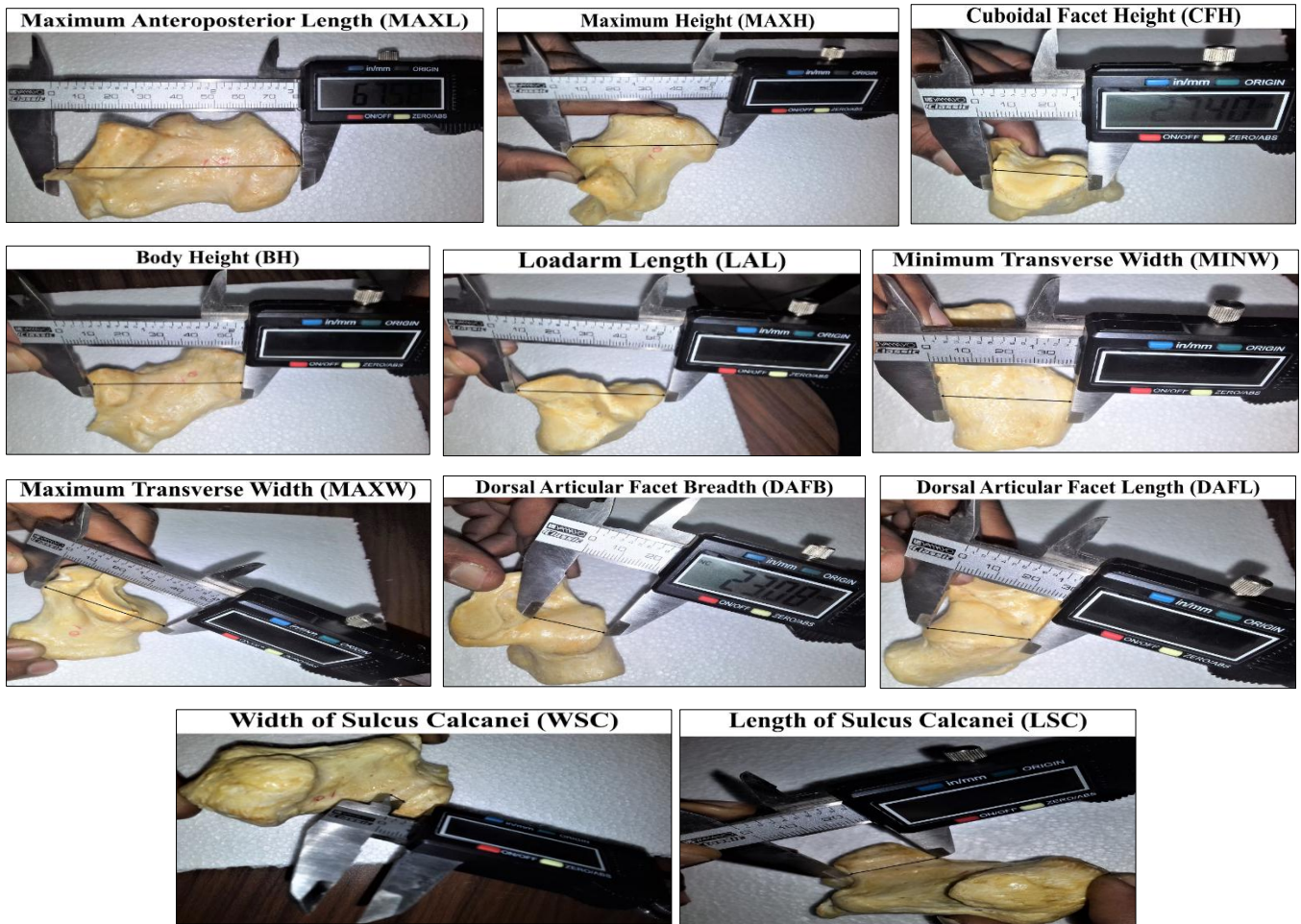


Fig 1

Table 1

	CFH	MAXH	MAXL	BH	LAL	MINW
Valid	30	30	30	30	30	30
Missing	0	0	0	0	0	0
Mean	25.10	40.96	73.68	46.93	44.40	34.59
Std. Error of Mean	.440	.656	.852	1.028	.598	.432
Median	25.50	40.55	72.30	46.50	44.50	34.40
Mode	27	40	72	44 ³	45 ³	36
Std. Deviation	2.412	3.592	4.665	5.632	3.276	2.366
Variance	5.817	12.901	21.760	31.720	10.731	5.596
Skewness	-.394	-.031	-.134	1.673	.476	-.065
Std. Error of Skewness	.427	.427	.427	.427	.427	.427
Kurtosis	-.792	-.703	-.426	4.578	1.379	-.794
Std. Error of Kurtosis	.833	.833	.833	.833	.833	.833

Table 2

	MAXW	DAFB	DAFL	WSC	WSL
Valid	30	30	30	30	30
Missing	0	0	0	0	0
Mean	48.65	20.25	26.98	6.40	29.50
Std. Error of Mean	.956	.380	.410	.199	.536
Median	48.55	20.40	26.60	6.45	30.00
Mode	52	21	29	6 ^a	30 ³
Std. Deviation	5.235	2.079	2.247	1.088	2.933
Variance	27.401	4.321	5.051	1.184	8.603
Skewness	-.233	.148	.867	.056	-.769
Std. Error of Skewness	.427	.427	.427	.427	.427
Kurtosis	-.767	1.342	.507	-.565	1.137
Std. Error of Kurtosis	.833	.833	.833	.833	.833

Table 3

		Anova Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	2.352	1	2.352	.105	.749
MAXL	Within Groups	628.676	28	22.453		
	Total	631.028	29			
	Between Groups	.560	1	.560	.042	.839
MAXH	Within Groups	373.573	28	13.342		
	Total	374.134	29			
	Between Groups	40.833	1	40.833	8.942	.006
CFH	Within Groups	127.867	28	4.567		
	Total	168.700	29			
	Between Groups	104.533	1	104.533	3.590	.069
BH	Within Groups	815.333	28	29.119		
	Total	919.867	29			
	Between Groups	6.533	1	6.533	.600	.445
LAL	Within Groups	304.667	28	10.881		
	Total	311.200	29			
	Between Groups	1.121	1	1.121	.195	.662
MINW	Within Groups	161.153	28	5.755		
	Total	162.275	29			

Table 4

		Anova Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	14.145	1	14.145	.507	.482
MAXW	Within Groups	780.469	28	27.874		
	Total	794.615	29			
	Between Groups	1.587	1	1.587	.359	.554
DAFB	Within Groups	123.728	28	4.419		
	Total	125.315	29			
	Between Groups	1.680	1	1.680	.325	.573
DAFL	Within Groups	144.793	28	5.171		
	Total	146.474	29			
	Between Groups	5.292	1	5.292	5.101	.032
WSC	Within Groups	29.048	28	1.037		
	Total	34.340	29			
	Between Groups	32.033	1	32.033	4.124	.052
WSL	Within Groups	217.467	28	7.767		
	Total	249.500	29			

Table 5

SEX		MAXL	MAXH	CFH	BH	LAL	MINW
	Chi-Square	1.800a	1.800a	4.133b	3.667c	7.867b	1.800a
Male	df	11	11	6	7	6	11
	Asymp. Sig.	.999	.999	.659	.817	.248	.999
	Chi-Square	1.800a	3.333d	2.200e	3.000f	6.000g	1.800a
Female	df	11	10	5	9	8	11
	Asymp. Sig.	.999	.972	.821	.964	.647	.999
SEX		MAXW	DAFB	DAFL	WSC	WSL	
	Chi-Square	1.800a	1.800a	3.333b	1.867c		5.400b
Male	df	11	11	10	10		5

	Asymp. Sig.	.999	.999	.972	.997		.369
	Chi-Square	1.800a	3.333d	1.800e	1.867f		4.733g
Female	df	11	10	11	10		7
	Asymp. Sig.	.999	.972	.999	.997		.692

Table 6

Intraclass Correlation Coefficient						
Sex	Intraclass Correlation					
		Lower Bound	Upper Bound	Value		df1
		.253a	.114	.501	4.734	14
	Single Measures					
Male		.789c	.586	.917	4.734	14
	Average Measures					
		.320a	.163	.572	6.168	14
	Single Measures					
Female		.838c	.682	.936	6.168	14

Average Measures

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C. intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

Table 7

Test Statistics ^a						
	MAXW	DAFB	DAFL	WSC	WSL	
Mann-Whitney U	96.000	100.500	88.000	63.500	83.500	
Wilcoxon W	216.000	220.500	208.000	183.500	203.500	
Z	-.685	-.498	-1.017	-2.036	-1.227	
Asymp. Sig. (2-tailed)	.493	.618	.309	.042	.220	
Exact Sig. [2*(1-tailed Sig.)]	.512b	.624b	.325b	.041b	.233b	
	MAXL	MAXH	CFH	BH	LAL	MINW
Mann-Whitney U	97.000	111.000	49.500	76.000	79.000	103.000
Wilcoxon W	217.000	231.000	169.500	196.000	199.000	223.000
Z	-.644	-.062	-2.638	-1.521	-1.401	-.394
Asymp. Sig. (2-tailed)	.520	.950	.008	.128	.161	.693
Exact Sig. [2*(1-tailed Sig.)]	.539b	.967"	.008b	.137b	.174b	.713b

Discussion

A foot is divided into three parts: forefoot, mid foot and hind foot. The joint between inferior surface of talus and superior surface of calcaneus is known as subtalar joint and inversion and eversion movements of hind foot occur here. Calcaneus breaks are the most common tarsal breaks. Many breaks are obviously distinct. 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. 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.

Conclusion

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

talocalcaneal arteritis 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 (P<0.05). In their study, Ari 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.

Acknowledgement

The corresponding author acknowledges the support and guidance received from Prof. Dr. Dipti Basu.

Conflicts of Interests- None

References

1. Thomas P. Talkingbones: the science of forensic anthropology. New York, Facts on Files, 1995, 136.
2. Iscan MY, Steyn M. Craniometric determination of population affinity in South Africans. Int. J. LegMed.

- 1999; 112:91-97.
3. Patriquin ML, Steyn M, Loth SR. Metric assessment of race from the pelvis in South Africans. *Forensic Sci. Int.* 2002; 127:104-113.
 4. Vettivel S, Selvaraj KG, Chandi JM, Indrasingh I, Chandi G. Intertubercular sulcus of the humerus as an indicator of handedness and humeral length. *Clin. Anat.* 1995; 8:44-50.
 5. Otağ İ, Çimen M. Sex Determination from Femur by Morphometric Methods. *Cumhuriyet Med. J.* 2003; 25(4):165-170.
 6. Koshy S, Vettivel S, Selvaraj KG. Estimation of length of calcaneum and talus from their bony markers. *Forensic Sci. Int.* 2002; 129:200-204.
 7. Kidd RS, Oxnard CE. Patterns of morphological discrimination in selected human tarsal elements. *Am. J. Phys. Antropol.* 2002; 117:169-181.
 8. Bidmos MA, Asala SA. Sexual dimorphism of the calcaneus of South African black. *J Forensic Sci.* 2004; 49(3):446-450.
 9. Holland T. Estimation of adult stature from the calcaneus and talus. *Am. J Phys. Antropol.* 1995; 96:315-320.
 10. Zwipp H, Rammelt S. Subtalarearthrodesemite calcaneus-osteotomie. *Orthopade.* 2006; 35(4):387-406.
 11. Doğan A, Albayrak M, Akman YE, Zorer G. The results of calcaneal lengthening osteotomy for the treatment of flexible pes planovalgus and evaluation of alignment of the foot. *Acta Orthop. Traumatol. Turc.* 2006; 40(5):356-366.
 12. Kwak YH, Park KB, Park HW, Kim HW. Use of allograft in skeletally immature patients for calcaneal neck lengthening osteotomy. *Yonsei Med. J.* 2008; 49(1):79-83.
 13. Ari I, Kafa IM. Bone Length Estimation and Population-Specific Features of Calcaneus and Talus Bones of the Late Byzantine Era. *Coll. Antropol.* 2009; 33(2):613-618.
 14. Gualdi-Russo E. Sex determination from the talus and calcaneus measurements. *Forensic Sci. Int.* 2007; 171:151-156.