

Morphometric study of calcaneus and talus bones of a Nigerian population

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ABSTRACT

The calcaneus and talus are unique tarsal bony elements that contribute to the structure, function, and biomechanics of the human foot. Various reports have shown racial differences in the morphometry of articular facets of dry calcaneus and talus bones. This study was done to examine the morphometry of the calcaneus and talus of a Nigerian population. A total of 84 (right 47 and left 37) dry calcanei and 65 (right 28 and left 37) dry tali of unknown gender were obtained from the Anatomical Museum of the Department of Anatomy, University of Port Harcourt, Nigeria, and measured for various linear parameters. All metric values were collected with a digital vernier caliper and measured to the nearest 0.01mm. Data gotten were analyzed using Statistical Package for the Social Sciences (SPSS IBM version 23.0). Significant differences ($p < 0.05$) were found between the right and left mean maximum anterior-posterior length of the calcanei and between the right and left mean trochlear length of the tali. Conclusively, morphometric evaluation of the calcanei and talus bones was shown to provide their morphological and forensic applications for a Nigerian population.

Keywords: Biomechanics, articular facets, calcaneus, talus, morphometry, Nigerian

INTRODUCTION

The calcaneus and talus are unique tarsal bony elements that contribute to the structure, function, and biomechanics of the human foot (DeSilva et al., 2013). The calcaneal bone is located postero-

inferiorly to the talus (Anjaneyulu et al., 2014). The talus bone forms the bridge between the ankle joint and the foot (Bykov, 2014). As the largest tarsal bone, the calcaneus bears the weight of the body and enables the attachment of calf muscles to the foot for biomechanical activities such as running, walking, etc (Moore et al., 2015). The firmness of the ankle is highly aided by the talocalcaneonavicular and subtalar joints, which provide facets of articulation for the talus and the calcaneus respectively (Snell, 2012). Clinically, few studies have revealed that people with unique morphological variations of calcaneal facets for the talus are prone towards suffering from mild to severe cases of subtalar arthritis (Muthukumaravel et al., 2011; Garg et al., 2013).

The application of radiographic techniques has been used to provide morphometric information of the tarsal bones in a vast number of studies; however, few have been able to validate the precision of the linear measurements obtained from these osteological radiographs. Anatomically, the relevance of obtaining these linear measurements from dry tarsal bones provides a better understanding on the morphological and morphometric variations of the calcaneus and talus bones across various racial populations compared to the use of radiography. (Lautzenheiser & Kramer, 2013). Racial and individual differences in the morphometry of articular facets of dry calcaneus and talus bones have been reported and these differences play significant roles in the biomechanical functioning of the ankle and foot (Uygur et al., 2009; Boyan et al., 2016; Laxmi et al., 2018; Prasad & Rajasekhar, 2018; Vucinic et al., 2020).

The aim of this study was to examine the morphometry of the calcaneus and talus of a Nigerian population. The study will be highly significant towards solving local medico-legal issues, and aid forensic anthropologists to investigate, present and resolve forensic evidence such as possible identification of the calcaneus and talus of Nigerians.

MATERIALS AND METHODS

Upon an approval gotten from the Research Ethics Committee of the University of Port Harcourt, a total of 84 (right 47 and left 37) dry calcanei and 65 (right 28 and left 37) dry tali of unknown gender were obtained from the Anatomical Museum of the Department of Anatomy, University of Port Harcourt, Nigeria. This study was conducted between the period of January and March of 2022. These sample bones were strictly of Nigerian origin, ossified and devoid of damage or any form of pathological feature.

The morphometric parameters of the calcaneus are as follows;

- (1) **Maximum Anteroposterior Length (MAXL)** – the measured linear distance between the most anterior point of the calcaneus and the most posterior point on the calcaneal tuberosity (Figure 1).
- (2) **Body Height (BH)** – the measured linear distance between the superior and inferior surfaces of the body of the calcaneus taken in the coronal plane, at the midpoint between the most posterior point of the posterior articular facet and the most anterior point of the calcaneal tuberosity (Figure 2).
- (3) **Maximum Height (MAH)** – the measured linear distance between the most superior and the most inferior points on the posterior calcaneal tuberosity (Figure 3).
- (4) **Cuboidal Facet Height (CFH)** – the measured linear distance between the most superior and the most inferior points on the cuboidal articular facets (Figure 4).
- (5) **Load Arm Length (LAL)** – the measured linear distance between the most anterior point of the calcaneus and the most posterior point on the posterior articular facet (Figure 5).

The morphometric parameters of the talus are as follows;

- (1) **Maximum Anteroposterior Length (MAPL)** – the measured linear distance between most anterior point on the head and most posterior point on the body (Figure 6).
- (2) **Maximum Transverse Width (MTW)** – the measured linear distance between most medial and most lateral points on the body (Figure 7).
- (3) **Trochlear Length (TL)** – the distance between the anterior and the posterior margin of the trochlea (Figure 8).
- (4) **Length of the Sulcus Tali (LST)** – the distance between the most medial end and the lateral end of the sulcus (Figure 9).



Fig. 1: Maximum Anteroposterior Length



Fig. 2: Body Height



Fig. 3: Maximum Height



Fig. 4: Cuboidal Facet Height



Fig. 5: Load Arm Length



Fig.6: Maximum Anteroposterior Length



Fig. 7: Maximum Transverse Width



Fig.8: Trochlear Length



Fig. 9: Length of the Sulcus Tali

All metric values were collected with a digital vernier caliper and measured to the nearest 0.01mm. These bone measurements were taken in reference to the standards as done by Krogman and Iscan (1986). With the aid of a digital camera, photographs of measurements of bones were obtained. Data were analyzed using Statistical Package for the Social Sciences (SPSS IBM version 23.0) and Microsoft Excel 2019 edition. Descriptive statistics was employed and values were expressed as mean and standard deviation. Independent sample t-test was used to determine side differences in measured parameters. Confidence interval was set at 95%.

RESULTS

Linear Morphometric parameters for the Calcaneum

There was a significant difference of MAXL at ($p < 0.05$) showing asymmetry between the right and left calcaneum. All other calcaneal parameters did not show a significant difference between sides.

Linear Morphometric parameters for the Talus

It was observed that there was a significant difference of TL only at ($p < 0.05$) between the right and left talus. However, no other significant differences were seen in other talar parameters between sides in this study

Table 1: Descriptive statistics and side differences in the measured parameters for calcaneus

Parameter	Right [N=47]			Left[N=37]		
	Min	Max	Mean±SD	Min	Max	Mean±SD
MAXL(mm)	47.82	93.81	79.22±6.97	73.81	88.99	82.29±3.84
MAXH(mm)	35.39	49.14	42.62±3.35	34.37	48.57	43.63±3.56
CFH(mm)	20.07	34.96	26.32±3.53	14.29	45.81	28.05±4.85
BH(mm)	23.40	59.79	51.17±5.76	27.99	66.27	52.87±6.30
LAL(mm)	35.22	54.80	48.89±3.33	24.35	54.41	48.95±4.96

Min = Minimum, *Max* = Maximum, *SD* = Standard Deviation, *N* = Sample size, *MAXL* = Maximum anterior-posterior length, *MAXH* = Maximum height, *CFH* = Cuboidal facet height, *BH* = Body height, *LAL* = Load arm length

Table 2: Side differences in measured parameters for calcaneus compared using t-test

Parameters	MD	SEMD	95% C.I of the Difference		Df	t-value	p-value
			Lower	Upper			
MAXL(mm)	-3.07	1.28	-5.61	-0.53	82.00	-2.40	0.02*
MAXH(mm)	-1.01	0.76	-2.51	0.50	82.00	-1.33	0.19
CFH(mm)	-1.72	0.91	-3.54	0.10	82.00	-1.89	0.06
BH(mm)	-1.70	1.32	-4.33	0.93	82.00	-1.29	0.20
LAL(mm)	-0.06	0.91	-1.86	1.75	82.00	-0.06	0.95

MD = Mean Difference, *SEMD* = Standard Error of Mean Difference, *C.I* = Confidence Interval, *MAXL* = Maximum anterior-posterior length, *MAXH* = Maximum height, *CFH* = Cuboidal facet height, *BH* = Body height, *LAL* = Load arm length

Table 3: Descriptive statistics and side differences in the measured parameters for talus

Parameters	Right [N = 28]			Left [N = 37]		
	Min	Max	Mean±SD	Min	Max	Mean±SD
MAPL	46.41	66.99	58.00±4.55	51.05	67.29	58.62±3.81
MTW	16.61	48.43	40.81±5.31	18.43	46.41	39.87±4.93
TL	29.15	45.77	36.98±4.62	29.55	67.08	40.16±6.13
LST	12.19	36.79	23.29±6.35	14.23	35.86	25.78±5.15

Min = Minimum, *Max* = Maximum, *SD* = Standard Deviation, *N* = Sample size, *MAPL* = Maximum anterior-posterior length, *MTW* = Maximum transverse width, *TL* = Trochlear length, *LST* = Length of sulcus talus

Table 4: Side differences in measured parameters for talus compared using t-test

Parameters	MD	SEMD	95% C.I of the Difference		t-value	df	p-value
			Lower	Upper			
MAPL(mm)	-0.62	1.04	-2.70	1.45	-0.60	63.00	0.55
MTW(mm)	0.93	1.28	-1.62	3.48	0.73	63.00	0.47
TL(mm)	-3.18	1.39	-5.95	-0.41	-2.30	63.00	0.03*
LST(mm)	-2.49	1.43	-5.34	0.36	-1.75	63.00	0.09

MD = Mean Difference, *SEMD* = Standard Error of Mean Difference, *C.I* = Confidence Interval, *MAPL* = Maximum anterior-posterior length, *MTW* = Maximum transverse width, *TL* = Trochlear length, *LST* = Length of sulcus talus, * = significant at $p < 0.05$

DISCUSSIONS

This study evaluated the linear morphometric measurements of the calcaneus and talus dry bones of a Nigerian population. Such morphometric information could be used to develop a database for the purpose of biomedical research, prosthetic surgeries and forensic investigations (Bonnell et al.,

2011). Various reports suggest that there are ethnic and racial differences in calcaneal and talar measurements (Uygur et al., 2009; Garg et al., 2015; Boyan et al., 2016).

Current study mean values for right and left maximum anterior-posterior length were almost higher compared to studies done by Boyan et al. (2016) on Anatolians, Laxmi et al. (2018) on Indians and Prasad & Rajasekhar (2018) on South Indians. There was a significant difference ($p < 0.05$) between the right and left maximum anterior-posterior length in this current study. In comparison to the study done by Otag et al. (2017), the present study mean values for right and left calcaneal measurements for maximum height, body height, cuboidal facet height and load arm length were slightly similar. Also, similar observations were noticed in the mean right and left maximum height values between this study and that done by Gualdi-Russo (2007). However, this current study did not show any significant difference between the right and left calcaneal measurements apart from maximum anterior-posterior length ($p < 0.05$). The findings from Laxmi et al. (2018) on the statistical difference between right and left maximum height strongly agree with this present study.

Furthermore, the mean values of talar measurements for this study were also compared with other related studies. The right and left maximum anterior-posterior length values of this study was much higher as compared to studies done by Koshy et al. (2002), Lee et al. (2012) on Koreans, Boyan et al. (2016) and Prasad & Rajasekhar (2018). Also, the mean values of maximum transverse width of this present study are similar to studies done by Lee et al. (2012) and Boyan et al. (2016), although studies carried out by Koshy et al. (2002) and Prasad & Rajasekhar (2018) had slightly lesser mean values compared to this present study. The mean trochlear length for right and left tali in this study was much higher when compared to that of studies done by Peckmann et al. (2015) on Greeks and Pai et al. (2021) on South Indians. The mean right and left length of the sulcus talus of studies done by Boyan et al. (2016) was almost similar to this present study, however, Koshy et al. (2002) reported a much higher mean value while Prasad & Rajasekhar (2018) had a much lower mean value compared to this present study. This present study further reported that there was a significant difference ($p < 0.05$) between the right and left trochlear length, however, other talar measurements did not show any significant difference statistically.

CONCLUSIONS

Conclusively, evaluation of the calcaneus and talus bone with reference to their various linear parameters was carried out to provide their morphological and clinical applications. The present

study therefore analyzed their morphometry in a Nigerian population and their comparisons with other racial values, hence, contributing to the determination of the racial origins of skeletal remains from archeological sites, as well as having potential applications for physical anthropology.

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AUTHORS' CONTRIBUTIONS

The first author designed the study, wrote its protocol and the first manuscript, while other authors managed the literature research, assisted in collection of data and statistical analysis. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

There is no conflict of interest.

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