Original Article

Morphometric Analysis of Calcaneus Bone: A Single Centre Study

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Abstract

Background: The calcaneus is the largest tarsal bone, which is very crucial in the support of weight and locomotion. The morphology of the articular facet and its morphometric variations are of great clinical importance, especially in the orthopaedic field, anthropology, and forensic sciences. Although this is a significant area of study, in-depth morphometric analyses of the calcaneus have not yet been conducted; therefore, further studies are needed to document the distribution and size of the articular facets. The current research was intended to categorise the articular facets of the calcaneus, measure the morphometric dimensions of the calcaneus, and evaluate the connection of the calcaneus to the cuboid. **Material and Methods:** It is a descriptive, observational study conducted in the postgraduate department of Anatomy at Government Medical College, Srinagar. We analysed 50 calcanei from both genders, and none showed gross abnormalities. The articular facet was graded according to the system of Bunning and Barnett (1963), and different morphometric parameters were be quantified. Results: Type B2 facets (no separation) were the most common, accounting for 52% of the sample, followed by B1 (incomplete separation) at 26%. Facets of A-type were not common, whereas C-type were not found. Morphometry indicated that the average anteroposterior length was 77.10 ± 4.89 mm, the transverse diameter was 46.50±4.50 mm, and the sulcus calcanei width was 5.70±1.10 mm. Also, morphometric analysis revealed an anatomical association between the calcaneal facet and the cuboid, with implications for load transmission and foot biomechanics. **Conclusion:** The research article highlighted the dominance of B-type facets and the absence of C-type facets, and morphometric values that are remarkably similar to those observed among Indian populations. These results provide significant baseline data for clinical and forensic practice and support the importance of regional anatomical studies.

Keywords: Calcaneus, Articular facet, Morphometry, Bone anatomy, B-type facets, Population-specific variations, Orthopaedic applications, Forensic anatomy.

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Introduction

The heel bone (or calcaneus), the tarsal bone of the human foot, is the largest and most structurally important bone, playing a key role in weight-bearing and locomotion. The Calcaneus, which constitutes the posterior part of the foot, has three facets on its superior surface: the anterior, middle, and posterior ones.[3] These three, and their matching facets on the talus, make up the structure of the talocalcaneonavicular and subtalar joints. The anatomical features of these facets are significant in terms of the stability and functioning of these joints because the posterior tapering of the calcaneus, leading to the tuber calcanei, is a critical weight-bearing structure that helps to transmit most of the body weight through the ground during locomotion. It is also important to note that the presence, size, and position of the anterior, middle, and posterior calcaneal facet is commonly variable and is significant to understanding anatomy of the population and the application of this structure in orthopaedic implants as well as reconstructive foot surgery The length, width, height, and the orientation of the articular facets have been examined with a view of examining differences depending on gender and ethnicity, as well as on geographical distribution.[7]

Although morphometric data on the calcaneus from many populations, including India and its sub-regions, have been widely reported, there is a dearth of information on some ethnic groups that represent the interests of clinical practice and anthropological studies. Comparative studies and standardised testing may be effective for streamlining surgical strategies and artificial implant designs and for improving understanding of skeletal adaptations across populations.

Materials and Methods

The research was conducted at the Postgraduate Department of Anatomy at the Government Medical College in Srinagar. The study used a descriptive, observational design to examine the morphological and morphometric features of 50 calcanei bones. Bones used in the study were of unknown gender and were part

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of the departmental collection. They were also in good condition and free of physical damage. Articular facet classification of the calcaneus was performed according to the system described by Bunning and Barnett (1963).

Vernier callipers were then used to measure morphometric measurements to a high degree of accuracy. Parameters which were measured were: anteroposterior length, which was a distance between the most anterior point on the anterior surface of the calcaneus and the most posterior point on the posterior surface, and transverse width, which was a distance between the most medial point on the medial surface of the calcaneus and the most lateral point on the lateral surface. The distance between the medial and lateral margins of the sulcus was taken as the sulcus calcanei width, and the distance between the anterior and posterior margins of the sulcus was taken as the sulcus calcanei length. The data were recorded and evaluated using MS Office applications. The mean and standard deviation (SD) of each parameter were calculated as descriptive statistics. Ethical clearance was not required because the research was conducted on dry bone specimens rather than living subjects. Nevertheless, there were ambitious standards in the handling and management of the anatomical specimen. This was a holistic approach to the study that facilitated proper recording and analysis of calcaneal morphometry and facet changes, which are beneficial in clinical, orthopaedic, and forensic practice.

Results

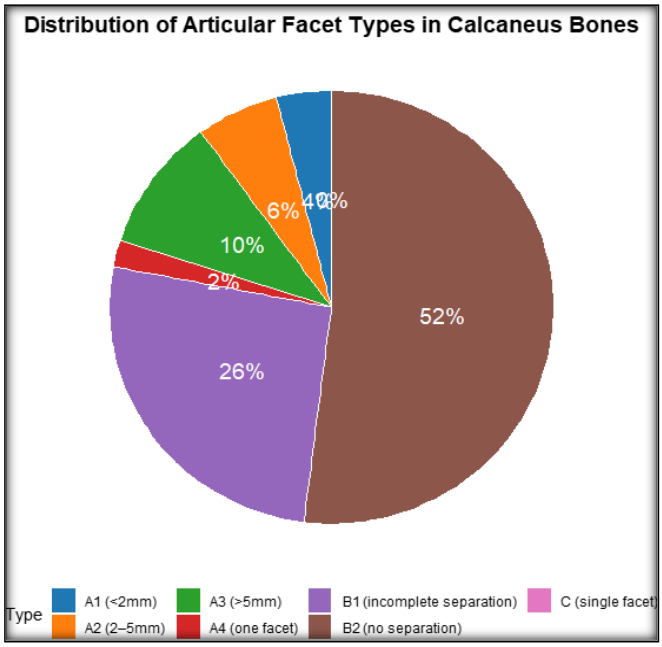
A study of the morphological traits of articular facets of 50 calcanei bones revealed that there was a large variation in the distribution of diverse types of articular facets. The type of facet that occurred the most frequently was B2 (no separation) with 26 bones, which made 52% of the complete sample. This was followed by B1 (incomplete separation), observed in 13 bones, corresponding to 26%. Bones with type A3 facets (more than 5mm) were found in 5 (10%), and those with A2 facets were 3 (6.0%). Facets on which the measurement was less than 2mm (type A1) were considered uncommon, appearing in 2 bones (4%). Likewise, A4 facets, when there existed only one facet, had 1 bone (2.0%). Particularly, no cases of C-type facets (single facet) were found in this research. The distribution provides vital details on the morphological variation of calcanei in this population.

Table 1: Distribution of Articular Facet Types in Calcaneus Bones

Type of Articular Facet	Number	Percentage
A1 (less than 2mm)	2	4.00%
A2 (2–5mm)	3	6.00%
A3 (> 5mm)	5	10.00%
A4 (only one facet)	1	2.00%
B1 (incomplete separation)	13	26.00%
B2 (no separation)	26	52.00%
C (single facet)	0	0%

Table 2: Calcaneal Morphometric Parameters in Study Population

Parameters (mm)	Mean ± Std
Anteroposterior length	77.10 ± 4.89
Transverse diameter	46.50 ± 4.50
Sulcus calcanei length	33.20 ± 3.85
Sulcus calcanei width	5.70 ± 1.10



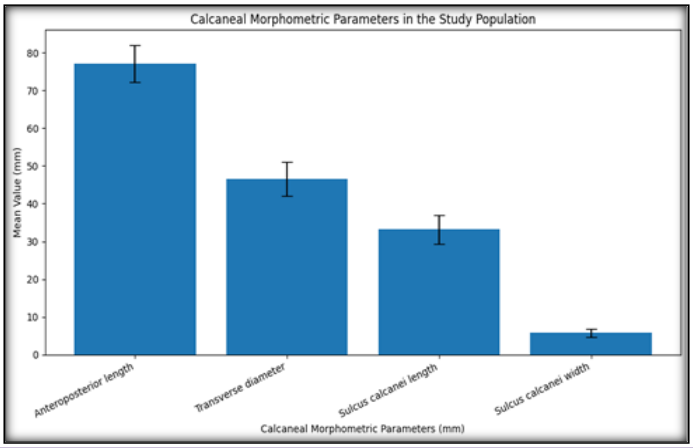


Figure 1: Bar chart diagram showing morphometric parameters of Calcaneal bone

In the current study involving 50 calcanei, the morphometric parameters were carefully measured and analysed. The mean anteroposterior length was found to be 77.10 ± 4.89 mm, while

the transverse diameter measured 46.50 ± 4.50 mm. The sulcus calcanei length averaged 33.20 ± 3.85 mm, and the sulcus calcanei width was 5.70 ± 1.10 mm. These measurements will give useful data on the anatomical features of the calcaneus of the population under study, which could be used in clinical examination, orthopaedics, and forensic analysis.

Discussion

The morphological modifications of the calcaneus analysed in the present research included the articular facet type and morphometric assessment. The most common was B2 (no separation) with 26 bones (52%), followed by B1 (incomplete separation) with 13 bones (26%). These results are comparable to studies on North Indian and South Indian populations, such as those by Sarvaiya et al. (2012) and Kullar et al. (2015), in which B2 was the predominant B2 facet (68.8% and 72.5%, respectively). [10,11] Jyotsna G discovered that B2 facets were the most common (53.06%) and indicated an anatomic factor that made the subtalar joints. The skeletal developmental aspects and genetic effects on skeletal development may be pertinent factors in maintaining the skeletal anatomical pattern across the various regional groups.

Type A faces were very uncommon in this study, occurring in only 22 bones (22% of the sample). Particularly, Type A3 (>5mm) was seen in 5 bones (10%), A2 (25mm) in 3 bones (6%), A1 (<2mm) in 2 bones (4%), and A4 (single facet) was uncommon and was seen in 1 bone (2%). It is worth noting that no instances of C-type facets were found, which is consistent with previous studies on the incidence of Type A1 (2.04%), A2 (7.14%), A3 (8.6%), and A4 (2.04%) facets, a similar pattern of rarity of these patterns was previously reported.[21] It is also possible that because of genetic, environmental or biomechanical factors, Type A facets were comparatively more rare in the current study, as they were also reported to be uncommon in several other ethnic groups. Nevertheless, it does not coincide with the data found by Bunning, Barnett, Forriol Campos, Gomez Pellico, and Ragab et al. (2003) concerning British, Spanish, and Americans, respectively.[12,21,22] The prevalence of type B facets and the absence of A1 and A4 types in this study could also be explained by a combination of genetic and environmental factors. The severe weather conditions in the region, during which the journey over snow-covered, icy, or uneven surfaces is a common challenge, might be beneficial for anatomical products that support calcaneal stability. Traditional footwear patterns that provide warmth and traction in winter conditions may affect such morphological differences. Type B calcanei have been predominantly observed in various populations, including Indians (Bunning & Barnett; Gupta et al.; Padmanabhan, 1986; Mol et al.; Sharada et al.; Garg et al.; Anjaneyulu et al.), Koreans (Jung et al.), Africans (Bunning & Barnett), Veddah (Bunning & Barnett), and Turks (Uygur et al.).[12-20] The findings of the current study align with those reported for Indian, Korean, African, Veddah, and Turkish populations. However, they differ from observations made by Bunning & Barnett, Forriol Campos & Gomez Pellico, and Ragab et al. (2003) on British, Spanish, and American populations, respectively. [12,21,22] The predominance of type B facets and the rarity of A1 and A4 types in this study may also be attributed to a combination of genetic and environmental factors. The region's harsh winter conditions, where navigating uneven, icy, or snow-covered surfaces is a routine challenge, could favor anatomical adaptations that enhance calcaneal stability. B-type facets, characterized by fused or partially fused articular surfaces, may offer biomechanical advantages for improved weight distribution and balance in such environments. Furthermore, traditional footwear practices designed for warmth and traction during the winter months might influence these morphological variations. The interaction between lifestyle, environmental demands, and genetic predispositions plays a significant role in shaping the calcaneal architecture observed in this population. These findings underscore the importance of considering both hereditary and ecological factors in understanding skeletal morphology across diverse populations. The present study, involving 50 calcanei, provides essential morphometric information on the calcaneus in the study population. The mean anteroposterior length was found to be 77.10 ± 4.89 mm, and the transverse diameter measured 46.50 ± 4.50 mm. Additionally, the sulcus calcanei length and width averaged 33.20 ± 3.85 mm and 5.70 ± 1.10 mm, respectively. These findings have implications for clinical evaluations, orthopaedic procedures, and forensic identification. When compared with other studies, the anteroposterior length and transverse diameter observed in this study closely align with those reported by Uygur et al. (2009), who reported dimensions of 77.7 ± 5.65 mm and 47.5 ± 4.2 mm in a Turkish population.[20] These similarities may suggest a degree of shared morphometric characteristics among geographically distinct populations, likely influenced by genetic and environmental factors. Jyotsna et al. also reported comparable results with an anteroposterior length of 76.01 ± 5.74 mm and a transverse diameter of 45.94 ± 4.35 mm, reinforcing the consistency of calcaneal measurements across different demographic groups.[9]The current study's findings on the sulcus calcanei dimensions (length: 33.20 ± 3.85 mm; width: 5.70 ± 1.10 mm) are also in agreement with the measurements reported by Jyotsna et al. (32.81 ± 3.78 mm and 5.63 ± 1.01 mm, respectively).[9] Uygur et al. recorded a slightly greater sulcus width (6.15 ± 2.7 mm) but a shorter sulcus length (30.4 ± 3.1 mm).[20] These variations could be attributed to differences in population-specific skeletal characteristics or measurement techniques. However, stark differences were observed compared with studies by Koshy et al. (2002). Sarvaiya et al. (2012), [10, 23]. Koshy et al. documented a significantly wider sulcus calcanei (21.1 ± 2.4 mm), while Sarvaiya et al. reported values of 15.25 ± 1.94 mm and 10.44 ± 1.66 mm for sulcus width and length, respectively. [10,23] This can result from differences in sample sizes, measurement techniques, or skeletal adaptations within a population. The comparatively unchanging results across studies on the most significant morphometric measures, such as anteroposterior length and transverse diameter, suggest that these parameters may be influenced by evolutionary processes and biomechanical factors required for both calcaneal loading and gait efficiency. On the other hand, considerable variability in the mean measurements of the sulcus calcanei could be due to anatomical variation. associated with methodological

discrepancies or adaptation to functionality. The data from this study can offer a platform for the morphometry of the calcaneus in the specified population and it will help to enhance precision during surgery for calcaneal fractures, prosthetic procedures, and forensic investigations These can be further improved in future studies with larger and more diverse sample sizes for filling gaps in population-specific research.

Conclusion

It was found that there were elevated levels of morphological diversity at the articular facets and morphometric features of calcanei. It was found that A- and C-types were quite uncommon, and Type B2 (no separation) and B1 (incomplete separation) appeared to be the most common types. These results point to a dominant distribution pattern, which may be specific to the investigated population. A morphometric study also showed that consistent measurements were obtained for parameters such as anteroposterior length, transverse diameter, and sulcus calcanei dimensions, providing a complete anatomical profile. The absence of C-type facets and the prevalence of B2 facets suggest population-specific structural peculiarities that may affect clinical, forensic, and anatomical information. In general, the work is a valuable resource for the study, serving as a baseline for the anatomical and morphological specificity of the calcanei in this population. It should be corroborated in larger, more diverse cohorts in future research to establish its clinical implications on a broader scale.

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Conflicts of interest

There are no conflicts of interest.

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