Original Article

Osteological Study of Calcaneal Morphometry

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Abstract

Background: The calcaneus is the largest tarsal bone and plays a crucial role in weight-bearing and locomotion. Variations in its morphology and morphometric parameters are important in understanding foot biomechanics and have significant clinical implications in orthopaedics and reconstructive surgery. The aim is to analyse the morphometry and classify calcanei based on the pattern of talar articular facets.**Material and Methods:** This descriptive osteological study was conducted on 50 dry human calcanei obtained from the Department of Anatomy, BGS GIMS. Damaged or deformed bones were excluded. The calcanei were classified according to Vučinić N et al. (2020). Morphometric parameters including maximum calcaneal length (MCL), maximum calcaneal height (MCH), maximum calcaneal width (MxCW), minimum calcaneal width (MnCW), cuboidal facet height (CFH), and width of sulcus calcanei (WSC) were measured using a digital vernier caliper. Data were analysed using descriptive statistics. **Results:** Out of 50 calcanei, 22 (44%) were right-sided and 28 (56%) were left-sided. Type I calcanei were the most common (58%), followed by Type II (34%) and Type III (8%). The mean values recorded were: MCL 75.06 mm, MCH 42.92 mm, MxCW 41.22 mm, MnCW 25.80 mm, CFH 21.78 mm, and WSC 6.14 mm. **Conclusion:** The present study demonstrates the predominance of Type I calcanei and provides essential morphometric data that may aid in surgical planning, management of hindfoot deformities, and rehabilitation procedures.

Keywords: Calcaneus; Morphometry; Talar facets; Osteology; Classification.

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Introduction

The calcaneus (from Latin calcaneus, meaning heel) is the largest tarsal bone and forms the structural basis of the heel. It is located at the posteroinferior aspect of the foot and plays a crucial role in weight transmission, posture, and locomotion. Structurally, it is an irregular cuboidal bone presenting six surfaces and articulates with the talus superiorly and the cuboid anteriorly. Its long axis is directed forwards and laterally.[1]

The calcaneus acts as a lever for the gastrocnemius-soleus complex and is essential for efficient gait and shock absorption. Variations in its morphology, particularly in the articular facets and overall dimensions, can influence foot biomechanics and predispose individuals to various clinical conditions such as calcaneal fractures, subtalar instability, and heel pain syndromes.[2]

Morphometric parameters such as maximum calcaneal length (MCL), maximum calcaneal height (MCH), maximum calcaneal width (MxCW), minimum calcaneal width (MnCW), cuboidal facet height (CFH), and width of sulcus calcanei (WSC) are important in understanding the structural variations of the calcaneus. These parameters are of particular relevance in orthopaedic procedures, implant design, forensic identification, and anthropological studies.

Although several studies have described calcaneal morphology in different populations, variations exist due to racial, genetic, and environmental factors. Limited region-specific osteological data are available, and differences in measurement techniques further contribute to variability in reported findings.

Hence, the present study was undertaken to analyse the morphometry and classify calcanei in the available sample, thereby contributing to existing anatomical data and providing baseline information for clinical and surgical applications.

Materials and Methods

This descriptive osteological study was conducted in the Department of Anatomy, BGS GIMS, on 50 dry human calcanei of unknown age and sex.

Inclusion and Exclusion Criteria

All well-preserved adult dry calcanei available in the departmental osteology collection were included in the study. Calcanei showing gross deformities, fractures, pathological changes, or poor preservation were excluded.

Study Procedure: Each calcaneus was examined macroscopically to determine its side (right or left) based on standard anatomical features. Classification of calcanei into types was performed according to the criteria described by Vučinić N et al. (2020).

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Morphometric Measurements

The following parameters were measured:

- Maximum calcaneal length (MCL)
- Maximum calcaneal height (MCH)
- Maximum calcaneal width (MxCW)
- Minimum calcaneal width (MnCW)
- Cuboidal facet height (CFH)
- Width of sulcus calcanei (WSC)

All measurements were taken in millimeters (mm) using a digital verniercaliper with appropriate precision. Each parameter was measured along defined anatomical landmarks as per standard osteometric guidelines. To minimize observer error, measurements were taken twice and the average value was recorded.

Data Recording and Analysis

All observations were systematically recorded in a tabulated format. Descriptive statistical analysis was performed, and results were expressed as minimum, maximum, and mean values for each parameter. The frequency and percentage distribution of calcaneal types were also calculated.The study was conducted on dry human bones from the departmental osteological collection. As no human participants or identifiable data were involved, ethical committee approval was not required as per institutional guidelines

Results

Out of the 50 calcanei in our study 22 belonged to right side and 28 to left side. The parameters observed in the study are shown in the following table:

Table 1: Morphometric measurements of calcanei (n=50)

Sl.No.	Side	Type	MCL (mm)	MCH (mm)	MxCW (mm)	MnCW (mm)	CFH (mm)	WSC (mm)
1	L	I	89.4	52.9	41.87	27.74	24.54	4.97
2	R	I	88	57	45.6	30.96	26.7	5.2
3	L	II	74.35	47.42	45.6	27	24.12	2.12
4	R	II	85.94	50.15	41.75	26.26	21.46	6.5
5	R	I	74.24	48.82	39.25	27.1	24.2	3.98
6	R	I	72.44	46.28	43.18	24.63	22.71	5.84
7	R	II	80.67	48.5	44.39	25.02	24.06	4.52
8	L	I	76.35	48.13	38.3	27.63	24.08	2.75
9	R	II	79.71	41.38	41.13	21.42	23.51	8.09
10	L	I	76.42	46.61	38.82	25.51	22.55	9.84
11	L	II	79.92	47.26	38.93	23.16	21.46	5.86
12	R	I	72.05	42.41	35.24	18	15.17	7.82
13	R	I	64.33	34.79	32.68	17.99	18.42	5.21
14	L	I	69.54	47.58	40.7	25.83	19.62	5.36
15	L	II	68.12	46.18	33.41	23.51	18.3	4.72
16	R	I	75.91	42.54	37.34	25.68	25.6	5.42
17	L	II	71.14	40.13	38.98	25.61	21.56	3.03
18	L	I	73.8	38.19	34.5	24.62	20.98	3.46
19	L	III	77.6	41.4	40.54	26.84	24.63	4.63
20	R	I	82.18	42.68	41.08	27.4	23.61	6.16
21	L	II	80.84	46.83	47.87	32.93	20.86	6.37
22	R	I	82.75	42.48	41.88	28.11	22.86	8.56
23	L	I	79.9	44.6	44.2	27.82	18.38	6.27
24	R	I	94.4	55.31	48.62	34.73	30.41	10.42
25	L	II	77.5	46.54	42.68	28.75	26.51	10.86
26	R	II	81.64	43.68	44.18	26.26	18.24	10.66
27	R	II	73.28	45.03	40.52	26.32	23.58	5.72
28	R	II	76.03	36.68	42.16	25.08	20.87	4.14
29	R	I	68.92	36.63	38.09	23.48	20.24	5.18
30	L	I	69.2	38.64	35.03	22.16	16.65	5.44
31	L	I	72.92	36.58	39.34	26.71	22.71	8.35
32	R	III	83.67	44.69	40.87	28.94	26.82	6.47
33	L	II	88.9	48.52	42.31	31.72	24.51	7.28
34	L	III	79.8	43.8	40.96	27.32	24.05	6.92
35	L	I	82.27	44.85	45.82	27.02	21.89	6.74
36	L	II	78.22	37.04	37.85	24.68	19.83	4.02
37	L	II	70.78	40.05	36.33	24.68	18.45	6.12
38	R	I	76.82	39.11	39.36	23.85	21.58	8.42
39	R	I	66.91	38.26	39.15	21.53	19.89	7.08
40	L	II	73.82	33.58	35.39	24.88	15.89	6.12
41	R	I	71.67	35.85	37.12	26.54	21.06	7.22
42	L	I	61.56	34.56	35.57	20.36	17.83	6.76
43	R	III	80.68	44.3	45.27	33.76	27.85	5.9
44	L	I	71.18	36.42	38.53	26.15	21.93	7.01
45	R	I	69.48	41.69	38.91	22.7	18.8	4.7
46	L	I	67.21	39.03	38.8	24.14	21.12	5.22
47	L	I	71.21	39.73	38.81	24.82	18.29	4.64

48	L	I	81.12	42.43	42.77	25.19	22.48	7.04
49	L	II	79.25	39.92	39.78	24.67	18.72	4.89
50	L	I	72.96	38.62	39.43	23.05	19.3	7.09

Type of calcanei: Different classification approaches have been adopted by several researchers. In our research, we have adopted the system proposed by Vučinić N et al (2020).

The following observations were made from the above data (table).

Table 2: Distribution of calcaneal types (n=50)

Type of Calcaneum	Number (n)	Percentage (%)
Type I	29	58%
Type II	17	34%
Type III	4	8%
Type IV	0	0%

Type I was the most common (n=29, 58%), followed by Type II (n=17, 34%) and Type III (n=4, 8%). Type IV calcanei were not observed.

Morphometric data: The observations from various morphometric parameters are summarized in the following section.In our research, we have adopted the same reference points as Vučinić N et al (2020). All measurements were recorded in millimeters (mm).

Table 3: Summary of Morphometric Parameters

Parameter	Minimum (mm)	Maximum (mm)	Mean (mm)
MCL	61.56	94.4	75.06
MCH	33.58	55.31	42.92
MxCW	32.68	48.62	41.22
MnCW	17.99	34.73	25.80
CFH	15.89	30.41	21.78
WSC	2.12	10.86	6.14

Figure 1: Photographic Compilation of 50 Calcanei from the Study

Discussion

The present study demonstrated that Type I calcanei were the most predominant (58%), followed by Type II (34%) and Type III (8%). The morphometric parameters observed were comparable with previously reported studies.

The calcaneus plays a crucial role in weight-bearing and locomotion, and its morphometric analysis helps in understanding anatomical variations relevant to clinical practice. Different classification criteria have been used in various studies, resulting in variation in reported calcaneal types. However, studies using similar classification systems as the present study have consistently reported Type I as the most common morphology.

Gupta et al., observed a significant difference between calcaneal patterns in different populations, with Type I (continuous facet) predominating in Indians and Type II (separated facets) in Egyptians.[3] Similarly, Muthukumaravel et al., reported a higher incidence of Pattern I calcanei in Indians compared to Pattern II in Europeans.[4] These findings suggest that calcaneal morphology may be influenced by racial and environmental factors.

The incidence of calcaneal spurs has also been shown to vary with calcaneal type. Kullar JS et al., reported that Type I calcanei had the highest incidence of spurs (11%), whereas Type III calcanei did not show such changes.[5]

Comparison with Previous Studies

Morphometric observations in the present study are comparable with those of Otag et al., who reported mean anteroposterior length and transverse width of 77.7±5.65 mm and 47.5±4.2 mm, respectively.[6] Jyotsna et al., also reported similar findings, with mean calcaneal length of 78.2 mm and transverse diameter of 46.3 mm.[7] These values are consistent with the present study (mean MCL: 75.06 mm; MxCW: 41.22 mm), supporting the reliability of these parameters.

However, Sarvaiya et al., reported variations in the width and length of the sulcus calcanei (15.25±1.94 mm and 10.44±1.66 mm, respectively), which differ from the present study findings.[8] These differences may be attributed to variation in measurement techniques, reference points, and population characteristics. Similarly, Amuti et al., reported comparatively lower morphometric values, further supporting the influence of population-specific factors.[9]

These variations may arise from different reference points used for measurements, as well as racial differences in anatomy. Such factors can lead to variations in morphometric parameters, emphasizing the need for standardized measurement techniques

and an awareness of population-specific anatomical differences in clinical practice.

Bilateral differences have been reported in some studies. A study conducted on 92 calcanei showed greater transverse width on the right side, with minor differences in sulcus dimensions.[10] However, another study reported no significant side differences in calcaneal measurements.[11] Such findings indicate that bilateral asymmetry may not be consistent and should be considered during clinical evaluation.

Sex-based differences have also been documented, with males showing a larger articular surface area for the talus compared to females.[12] However, limited studies are available in this area, indicating the need for further research.

It has been observed that calcaneal patterns vary among populations and are likely genetically determined, with Type I being the most common type in both adults and fetuses.[13] These variations have important implications in anthropology, forensic science, and clinical practice.

Understanding these anatomical variations is essential for surgical planning, implant design, and individualized rehabilitation strategies. Thus, the present study provides region-specific morphometric data with direct clinical relevance.

Limitations of the Study

The present study has certain limitations. The sample size was relatively small and limited to calcanei from a single institutional collection, which may not fully represent the wider population. The age and sex of the specimens were unknown, precluding analysis of sexual dimorphism and age-related variations. Additionally, the study was based on dry bones, and hence, the influence of soft tissue structures and functional biomechanics could not be assessed.

Conclusion

The present study highlights the predominance of Type I calcanei and provides region-specific morphometric data, which may serve as a useful reference for surgical planning, reconstruction of hindfoot deformities, and rehabilitation procedures.

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Conflicts of interest

There are no conflicts of interest.

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