

# Morphometric Study of Sulci Tali and Calcanei and its Clinical Significance: A Cross-sectional Analytical Study

SULEKHA MANGESH KOLAP<sup>1</sup>, SIDDHESH PRAKASH PRABHU<sup>2</sup>, UDAY NARAYAN KUDALKAR<sup>3</sup>

## ABSTRACT

**Introduction:** Knowledge of the vascular anatomy of the talus and calcaneus, particularly the sinus tarsi in the foot, is important for orthopaedic and vascular surgeons performing surgical procedures.

**Aim:** The aim of this study was to measure and compare the dimensions of the right and left tali and calcanei, as well as the right and left sulci tali and calcanei.

**Materials and Methods:** A cross-sectional analytical study was conducted at the Department of Anatomy, Goa Medical College, Bambolim, Goa, India, from March 2020 to August 2022. The study included 62 calcanei (32 left, 30 right) and 50 tali (26 left, 24 right) of unspecified gender/age. Measurements of the length and width of the tali and calcanei, as well as the dimensions of the sulci tali and calcanei, were obtained using digital Vernier calipers. The number of vascular foramina was also recorded. Statistical analysis including mean, standard deviation (SD), and p-values was performed using Statistical Package for the Social Sciences (SPSS) software version 22.0.

**Results:** The length of the right and left tali was measured as 50.85±3.44 mm and 51.87±3.86 mm, respectively (p-value=0.32), while the width of the right and left tali was measured as 36.92±4.0 mm and 38.51±2.65 mm, respectively (p-value=0.10). The length of the right and left sulcus tali was measured as 31.44±2.82

mm and 32.01±2.78 mm, respectively (p-value=0.47), with the width of the right and left sulcus tali measured as 10.08±3.47 mm and 10.9±3.45 mm, respectively (p-value=0.40), and the depth of the right and left sulcus tali measured as 4.65±0.82 mm and 5.01±1.33 mm, respectively (p-value=0.24). The length of the right and left calcanei was measured as 72.58±5.77 mm and 72.75±5.44 mm, respectively (p-value=0.90), with the width of the right and left calcanei measured as 28.56±2.52 mm and 27.76±2.42 mm, respectively (p-value=0.21). The length of the right and left sulcus calcanei was measured as 34.62±2.59 mm and 34.8±3.3 mm, respectively (p-value=0.81), with the width of the right and left sulcus calcanei measured as 10.85±2.12 mm and 10.69±2.07 mm, respectively (p-value=0.75), and the depth of the right and left sulcus calcanei measured as 2.64±0.77 mm and 2.93±0.83 mm, respectively (p-value=0.17). A total of 232 and 335 vascular foramina were found in the sulci tali on the right and left sides, respectively. A total of 172 and 168 vascular foramina were found in the sulci calcanei on the right and left sides, respectively.

**Conclusion:** The dimensions of the left side were generally higher compared to the right for most of the measured variables. This study provides valuable insights for clinicians from a surgical perspective and in the context of fracture healing and foot rehabilitation procedures.

**Keywords:** Fractures, Rehabilitation, Surgeons, Vascular

## INTRODUCTION

The foot comprises the tarsus, metatarsus, and phalanges. The seven tarsal bones occupy the proximal half of the foot. The proximal row consists of the talus and calcaneus. The talus serves as the osseous link between the foot and leg through the ankle joint. The calcaneus is the largest bone and projects posteriorly to the tibia and fibula, acting as a short lever for the calf muscles attached to its posterior surface [1].

The medial plantar surface of the talus neck has a deep sulcus tali, which forms the roof of the tarsal sinus. The superior surface of the calcaneus features a rough depression, the calcaneal sulcus, which completes the tarsal sinus with the talus. The dorsalis pedis artery supplies branches to the superior aspect of the talar neck and also gives off the artery of the tarsal sinus. This artery anastomoses with the artery of the tarsal canal [1].

The primary blood supply to the talus comes from the anastomotic ring of blood vessels, with osseous vessels entering its neck and running posterolaterally within the bone to supply its body. Fractures occurring through the neck can often result in the interruption of blood supply to the talus body. The avascular fragment fails to unite with the rest of the bone, gradually collapsing and leading to bone deformation and eventually ankle osteoarthritis [2].

In recent times, there has been a growing trend of surgically restoring the articular surface, height, and width of the calcaneus [2].

In 2016, Boyan N et al. conducted a study on the Anatolian population of Turkey, examining 49 tali and 57 calcanei to measure the anteroposterior length and width of the talus and calcaneus, as well as the width, length, and depth of the sulcus tali and sulcus calcanei [3].

In 2019, Prasad SA and Rajasekhar SSSN conducted a study in Puducherry, India, involving 92 tali and 49 calcanei to calculate the anteroposterior length and transverse width of the tali, as well as the length, width, and depth of the sulcus tali. They also measured the length, transverse width of the calcanei, and the length, width, and depth of the sulcus calcanei [4].

The present study provides information on the dimensions of the talus and calcaneus, as well as the sulci tali and calcanei, which can serve as guidelines for the use of prostheses. Additionally, it depicts the pattern of vascular foramina in the talus and calcaneus, which can act as a guide for predicting bone healing following fractures. This type of study has not been previously conducted on bones obtained from the region of Goa, India. Hence, the purpose of the present study was to identify regional differences. The aim was to measure and compare the dimensions of the right and left tali and calcanei, as well as the right and left sulci tali and calcanei.

## MATERIALS AND METHODS

The present cross-sectional analytical study was conducted at the Department of Anatomy, Goa Medical College, Bambolim, Goa, India, from March 2020 to August 2022. The study included 62 dry calcanei (32 left, 30 right) and 50 dry tali (26 left, 24 right). The study was approved by the Institutional Ethics Committee on 6/2/2020, prior to its initiation (certificate number GMC-IEC/Feb-20/13).

**Inclusion criteria:** The study included bones of unknown gender and age, without any bony deformities or fractures, obtained from cadavers.

**Exclusion criteria:** Damaged and broken bones were excluded from the study.

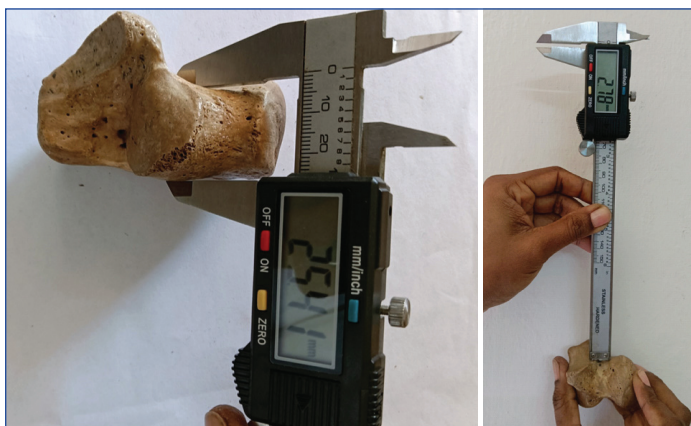
### Study Procedure

An automated Vernier calipers (accuracy of 0.01 mm) was used to measure the length, width, and depth of tali and calcanei. The anteroposterior length of the talus [Table/Fig-1] and calcaneus was measured as the maximum span between the anterior limit of facets for the navicular and cuboid bones and the posterior surfaces of the talus and calcaneus, respectively. The width of the talus and calcaneus [Table/Fig-2] was measured as the maximum span between the medial and lateral surfaces of the respective bones.

The depth of the sulci tali and calcanei was measured by vertically placing the depth probe or rod in the deepest part of the sulcus, with the edge of the main scale of the digital Vernier calipers (opposite to the end with internal and external screws) aligned with the margins of the sulci. The readings on the Liquid-crystal Display (LCD) of the Vernier calipers were noted [Table/Fig-3].



[Table/Fig-1]: Measurement of anteroposterior length of talus using digital Vernier caliper.



[Table/Fig-2]: Measurement of width of calcaneus using digital Vernier callipers.

[Table/Fig-3]: Measurement of depth of sulcus talus using the depth measuring blade (depth probe) of digital Vernier callipers. (Images from left to right)

The number of vascular foramina in the sulci tali and calcanei was observed using a magnifying hand lens. For the calcaneus, the reference point was the posterior limit of the sustentaculum tali medially, where the sulcus calcanei narrows into a groove, and the junction of the lateral limit of sulcus calcanei with the lateral

surface of the calcaneus. For the talus, the reference point was the medialmost limit of sulcus tali on the plantar surface of the neck of the talus, and the lateral limit was an imaginary anteroposterior line passing through the lateral margin of the middle calcaneal articular facet on the plantar surface of the head of the talus. The counting of foramina started from the reference point as number one and proceeded away from the reference point as two, three, and so on.

## STATISTICAL ANALYSIS

Data analysis was performed using SPSS software version 22.0. Student's t-test (2 sample assuming unequal variances) was used to compare the variables such as the length and width of tali and calcanei, as well as the length, width, and depth of sulci tali and calcanei between the right and left sides. A p-value of  $\leq 0.05$  was considered significant.

## RESULTS

The length of the left tali was measured higher than the right side (p-value=0.32, not significant). The width of the tali was higher on the left than the right side (p-value=0.10, not significant). The length of the sulci tali was greater on the left than the right side (p-value=0.47, not significant). Similarly, the width and depth of the sulci tali were greater on the left than the right side (p-values=0.40 and 0.24, respectively, not significant). More vascular foramina were observed in the left sulci tali [Table/Fig-4].

Parameters	Right (n=24)* Mean±SD (mm)	Left (n=26)* Mean±SD (mm)	p-value
Length of sulcus tali	31.44±2.82	32.01±2.78	0.47
Width of sulcus tali	10.08±3.47	10.9±3.45	0.40
Depth of sulcus tali	4.65±0.82	5.01±1.33	0.24
Length of talus	50.85±3.44	51.87±3.86	0.32
Width of talus	36.92±4.0	38.51±2.65	0.10
Number of vascular foramina in sulci tali	n=232**	n=335**	

[Table/Fig-4]: Dimensions of tali and sulci tali.

n\* is number of tali; n\*\* is number of vascular foramina in sulci tali

The length of the left calcanei was measured higher than the right side (p-value=0.90, not significant). However, the width of the right calcanei was higher than the left side (p-value=0.21, not significant). The length and width of the sulci calcanei showed no significant differences between the right and left sides (p-values=0.81 and 0.75, respectively). The depth of the left sulci calcanei exceeded that of the right sulci calcanei but was not statistically significant (p-value=0.17). More vascular foramina were observed in the right sulci calcanei [Table/Fig-5].

Parameters	Right (n=30)* Mean±SD (mm)	Left (n=32)* Mean±SD (mm)	p-value
Length of sulcus calcanei	34.62±2.59	34.8±3.3	0.81
Width of sulcus calcanei	10.85±2.12	10.69±2.07	0.75
Depth of sulcus calcanei	2.64±0.77	2.93±0.83	0.17
Length of calcaneus	72.58±5.77	72.75±5.44	0.90
Width of calcaneus	28.56±2.52	27.76±2.42	0.21
Number of vascular foramina in sulci calcanei	n=172**	n=168**	

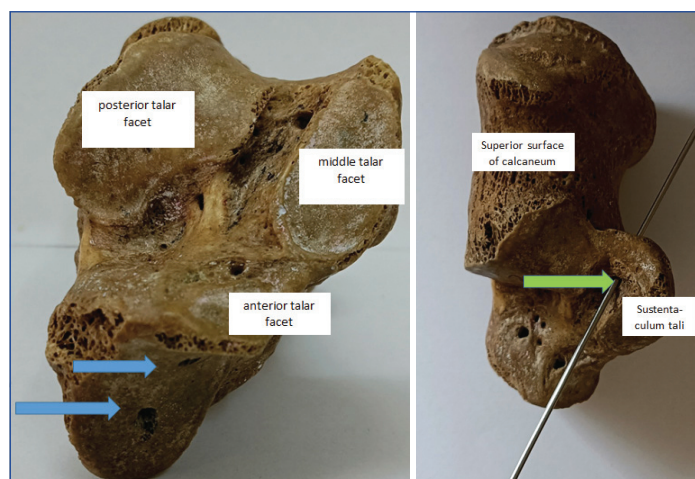
[Table/Fig-5]: Dimensions of the calcanei and sulci calcanei.

n\* is number of calcanei; n\*\* is number of vascular foramina in sulci calcanei

The highest number of vascular foramina observed in the sulci calcanei and tali was 15 and 27, respectively. Two calcanei showed no vascular foramina in the sulci calcanei. The least number of vascular foramina observed in the sulci tali was three. Other features observed included a calcaneus showing two vascular foramina opening onto the facet for the cuboid bone [Table/Fig-6], a foramen opening onto the inferior surface of the sustentaculum tali [Table/



Fig-7], a vascular foramen in the sulcus calcanei separated by a bar of bone [Table/Fig-8]. The authors also observed two vascular foramina separated by a bar of bone on the superior surface of the calcaneus. One vascular foramen had two compartments divided by a bar of bone [Table/Fig-9].



**[Table/Fig-6]:** Calcaneus showing two vascular foramina (blue arrows) opening onto facet for cuboid bone. **[Table/Fig-7]:** Probe passing through foramen in sulcus calcanei that opens on the inferior surface of the sustentaculum tali (green arrow). (Images from left to right)



**[Table/Fig-8]:** Vascular foramen in sulcus calcanei on superior surface of calcaneus (blue arrow) separated by a bar of bone. **[Table/Fig-9]:** Vascular foramen in sulcus calcanei on superior surface of calcaneus (green arrow) separated from another vascular foramen (blue arrow) by a broad bar of bone. Vascular foramen (blue arrow) divided into two by a bar of bone. (Images from left to right)

## DISCUSSION

Recently, knowledge about the affinities of populations and determinations of sex, race, age, and stature has significantly increased [5]. The dimensions of tali and calcanei for the mentioned variables were noted to be higher on the left side, but the differences were not statistically significant.

Namburu BSP et al. conducted a study on 84 tali in 2017 in Guntur, Andhra Pradesh and found the mean length of the talus to be 5.33 cm (53.3 mm), the mean width of the talus to be 3.79 cm (37.9 mm), and the mean height to be 2.52 cm (25.2 mm) [5]. Gautham K et al. conducted a study on 100 tali in 2013 in Mangalore and found the mean anteroposterior length on the right side to be 5.23 mm and 5.29 mm on the left side [6]. The mean transverse width on the right side measured 3.79 mm and 3.68 mm on the left side. The mean length of the sulcus tali on the right side measured 2.01 mm and 2.04 mm on the left side. The mean width of the sulcus tali on the right side measured 0.69 mm and 0.68 mm on the left side. Wakode N et al. conducted a study in 2018 in Bhubaneswar on 118 calcanei and found a total of 3112 vascular foramina on the right and left calcanei [7]. Prasad SA and Rajasekhar SSSN conducted a study in 2019 in Puducherry on 92 dry tali and 49 dry calcanei and

found that the anteroposterior length of the left talus measured more than the right talus, while the transverse width of the right and left talus had equal measurements [4]. They found the length of the right sulcus tali to be more than the left sulcus tali, and the width and depth of the right and left sulcus tali to be equal. They also noted that the transverse width of the right calcaneus measured more than the left calcaneus. The width and depth of the right and left sulcus calcanei showed no side differences. They found the length of the right sulcus calcanei to be more than the left sulcus calcanei (p-value=0.036). Vani PC et al. conducted a study in 2020 in New Delhi on 56 tali and found vascular foramina on the superior and inferior surfaces of the neck and medial surface of the talar body in all bones [8]. Their study mentions that the number of vascular foramina existed significantly greater on the inferior surface of the neck and medial surface of the body and ranged from 0 to 25.

Singh A and Singh A conducted a study in 2022 on 66 tali in Bareilly, Uttar Pradesh, and found the mean length, width, and height of the talus to be 52.74±4.39 mm, 31.45±2.74 mm, and 25.93±2.64 mm, respectively [9]. The width, length, and depth of the sulcus tali were reported as 5.9±1.02 mm, 21.88±3.07 mm, and 5.52±1.25 mm, respectively.

When comparing the findings of the present study with previous studies, the length of the sulcus calcanei in this study and that of Boyan N et al. in 2016 are similar [Table/Fig-10] [3,10-14]. The measurements obtained for the anteroposterior length and width of the talus are consistent with the findings of Boyan N et al. [3]. The depth of the sulcus tali can be compared to the dimensions recorded by Boyan N et al. in 2016 [Table/Fig-11] [3,5,9,11,13,15].

The anteroposterior length, width of calcanei, length, and width of sulci calcanei are similar to the data noted by Sarvaiya BJ et al. in 2012 in Gujarat on a sample size of 250 calcanei, Jung MH et al. in 2015 in the Republic of Korea on a sample size of 118 tali and calcanei, Boyan N et al. in 2016 in an Anatolian population of Turkey on a sample size of 57, and Jyotsna G and Mamidi A in Hyderabad, Telangana on a sample size of 98 calcanei [3,10-12]. The anteroposterior length and depth of sulci calcanei match with that of Garg S et al. in Rohtak in 2022 on a sample size of 50 [Table/Fig-10] [3,10-14].

Author, n, year and place of the study	Antero-posterior length of calcaneus (mm)	Transverse width of calcaneus (mm)	Width of sulcus calcanei (mm)	Length of sulcus calcanei (mm)	Depth of sulcus calcanei (mm)
Sarvaiya BJ et al., [10], n=250, 2012, Gujarat, India	74.36±6.6	38.57±3.12	15.28±1.94	10.44±1.66	4.36±1.0
Jung MH et al., [11], n=118, 2015, Republic of Korea	-----	-----	5.16±1.16	-----	-----
Boyan N et al., [3], n=57, 2016, Turkey	75.88±6.1	44.88±4.09	5.98±1.09	32.13±2.99	4.21±0.93
Jyotsna G and Mamidi A [12], n=98, 2022, Telangana, India	76.01±5.74	45.94±4.35	5.63±1.01	32.81±3.78	-----
Laxmi V et al., [14], n=50, 2018, Punjab, India	68.94±1.89	38.73±2.63	-----	-----	-----
Garg S et al., [13], n=60, 2022, Haryana, India	70.2±4.5(L) 71±5.1(R)	40.1±3.4(L) 41.5±2.6(R)	6.1±1.2(L) 5.3±1.3(R)	46.5±3.4(L) 45.9±3.2(R)	3.8±0.7(L) 3.2±0.8(R)
Present study, n=62, 2022, Goa, India	71.55±5.56	28.15±2.48	10.77±2.07	34.16±2.98	2.79±0.81

**[Table/Fig-10]:** Comparative chart for dimensions of calcanei [3,10-14]. mm: millimetres; n: number of bones; L=left; R=right

The authors noted that the anteroposterior length and width of tali are similar to studies by Sarvaiya BJ et al. in 2012 in Gujarat on a sample size of 250, Jung MH et al. in 2015 in the Republic of Korea on a sample size of 118 tali and calcanei, Boyan N et al. in 2016 in an Anatolian population of Turkey on a sample size of 57, and Namburu BSP et al. in 2017 in Guntur, Andhra Pradesh, India on a sample size of 84 [3,5,10,11]. The depth of sulci tali matches with that of Singh A and Singh A, and Garg S et al. in Bareilly and Rohtak on a sample size of 66 and 50, respectively [Table/Fig-11] [3,5,9,11,13,15].

Author, n, year and place of the study	Antero-posterior length of talus (mm)	Transverse width of talus (mm)	Width of sulcus tali (mm)	Length of sulcus tali (mm)	Depth of sulcus tali (mm)
Lee JY et al., [15], n=76, 2012, Korea	53.92±3.20	40.48±2.46	-----	-----	-----
Jung MH et al., [11], n=118, 2015, Korea	-----	-----	4.76±1.0	-----	-----
Boyan N et al., [3], n=49, 2016, Turkey	51.78±4.09	39.41±3.31	5.65±1.57	21.36±3.19	5.69±1.18
Namburu BSP et al., [5], n=84, 2017, Andhra Pradesh, India	5.33±0.46 (cm) 53.3±0.46 (mm)	3.79±0.3 (cm) 37.9±0.3 (mm)	-----	-----	-----
Singh A and Singh A [9], n=66, 2022, Uttar Pradesh, India	52.74±4.39	31.45±2.74	5.9±1.02	21.88±3.07	5.52±1.25
Garg S et al., [13], n=50, 2022, Haryana, India	50.9±3.5 (L) 51.1±4.5 (R)	37.8±3.3 (L) 37.9±2.9 (R)	6.8±1.5 (L) 7.1±1.8 (R)	18.7±2.8 (L) 18.2±2.6 (R)	5.1±0.3 (L) 5.4±0.5 (R)
Present study, n=50, 2022, Goa, India	51.38±3.66	37.75±3.43	10.51±3.45	31.72±2.79	4.84±1.12

**[Table/Fig-11]:** Comparative chart for dimensions of tali [3,5,9,11,13,15]. mm=millimetres; N=number of bones; L=left; R=right

As mentioned, the calcaneus supports the talus and maintains the integrity of the joint. This knowledge is important for orthopaedic, vascular, and podiatric surgeons when performing surgeries on the hindfoot [2]. Since the talus experiences different forces during locomotion, the stress patterns across the talus affect its overall dimensions [2].

Similarly, the calcaneus, which also bears weight, is influenced by these stress patterns. This study provides guidance for orthopaedic and vascular surgeons regarding prosthetics and knowledge of vascularity for better bone healing after fractures. The higher number of vascular foramina found in the sulci tali may be explained by the presence of the tarsal canal and its blood supply. This suggests that fractures of the talus have a more favourable prognosis for healing. In some cases, fractures in certain areas can compromise the blood supply, leading to necrosis of that part, such as avascular necrosis of the body of the talus when the neck is fractured [2].

## Limitation(s)

Pathological conditions pertaining to the bony structure are not known. The clinical history of the individuals from whom the bones were obtained is not known. Gender differences when selecting bones were not considered. The study was conducted on dry bones obtained from different individuals. The sample size was small.

## CONCLUSION(S)

The present study provides insight into the gross anatomy of the talus and calcaneus, along with information regarding the vascularity of these bones. The dimensions of the left side were higher compared to the right for most of the measured variables, although not statistically significant. This could be attributed to individuals with right-sided dominance frequently using their left lower limb to initiate movements during locomotion. This study will assist clinicians in surgical planning, prosthesis design, fracture prognosis, and foot rehabilitation procedures.

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### AUTHOR DECLARATION:

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- Manual Googling: Feb 23, 2023
- iThenticate Software: Feb 27, 2023 (20%)

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