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Original Research Article

Bilateral Symmetry of Linear Morphometric Parameters of Human Talus: A Comprehensive Cross-Sectional Osteometric Study in Udaipur Population of Rajasthan, India

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Abstract:

Background: The talus is a structurally unique tarsal bone serving as the primary conduit for body weight transmission from tibia to foot. Approximately sixty percent of its surface is covered by articular cartilage, and the bone lacks muscular attachments, relying entirely on ligamentous support. These characteristics render the talus vulnerable to traumatic injuries and avascular necrosis. Assessment of bilateral symmetry has important implications for orthopedic reconstruction using contralateral templating and forensic pair-matching of commingled skeletal remains. Despite its clinical significance, population-specific morphometric data for Indian populations remain limited.

Objective: To evaluate bilateral symmetry of linear morphometric parameters including anteroposterior length, transverse width, and vertical height of human talus in Udaipur population of Rajasthan.

Materials and Methods: This cross-sectional descriptive osteometric study was conducted on 800 dry adult human tali (400 right, 400 left) from Department of Anatomy, Pacific Medical College and Hospital, Udaipur. The study was approved by Institutional Ethics Committee (Protocol No. IEC/2023/12, dated 24/03/2023). Linear measurements were recorded using digital Vernier caliper with accuracy of ±0.01 millimeters. Bilateral symmetry was assessed using independent samples t-test. Absolute and relative bilateral asymmetry indices were calculated.

Results: Mean anteroposterior length was 50.12±0.38 millimeters for right and 50.08±0.31 millimeters for left talus (t=1.48, p=0.140). Mean transverse width was 36.09±0.36 millimeters for right and 36.05±0.32 millimeters for left (t=1.84, p=0.066). Mean vertical height was 28.13±0.35 millimeters for right and 28.15±0.34 millimeters for left (t=-0.83, p=0.404). No statistically significant bilateral differences were observed (all p>0.05). Relative bilateral asymmetry ranged from 0.07% to 0.12%, indicating near-perfect bilateral equivalence.

Conclusion: All three linear morphometric parameters demonstrated robust bilateral symmetry with relative asymmetry indices below 0.15%. These findings validate contralateral templating for orthopedic surgical planning, prosthetic design, and forensic pair-matching applications in Udaipur population.

Keywords: Talus, Morphometry, Bilateral Symmetry, Osteometry, Ankle Joint, Orthopedics, Forensic Anthropology, Udaipur.

Introduction

The talus, also known as the astragalus, is a uniquely positioned tarsal bone that occupies a pivotal role in lower limb biomechanics. Situated at the apex of the tarsal skeleton, the talus articulates superiorly with the tibia and fibula to form the talocrural joint, inferiorly with the calcaneus to form the subtalar joint, and anteriorly with the navicular bone to constitute the talonavicular component of the transverse tarsal joint. [1,2] This strategic anatomical position enables the talus to function as the primary conduit for transmission of body weight from the lower leg to the foot, making it indispensable for maintaining postural stability and facilitating efficient bipedal locomotion. [3]

The anatomical characteristics of the talus are distinctive among tarsal bones. Approximately sixty percent of its surface is covered by hyaline articular cartilage, a proportion exceeded by no other bone in the human body.[4] Furthermore, the talus is devoid of any muscular attachments and derives its stability entirely from ligamentous support and the congruity of its articular surfaces

with adjacent bones.[5] These features, combined with a relatively tenuous and predominantly extraosseous blood supply entering through non-articular surfaces, render the talus particularly vulnerable to avascular necrosis following traumatic injuries, especially fractures of the talar neck.[6,7]

Morphometric analysis of skeletal elements provides objective, quantitative data regarding bone dimensions and forms the scientific foundation for clinical decision-making, prosthetic design, and forensic identification.[8] Among paired skeletal elements, the assessment of bilateral symmetry assumes particular significance. Bilateral symmetry refers to the degree of correspondence or similarity between homologous right and left bones, while bilateral asymmetry denotes deviations from perfect mirror-image equivalence.[9] Such asymmetry may arise from a variety of genetic, developmental, biomechanical, environmental, nutritional, or occupational factors that differentially influence bone growth and remodeling on opposite sides of the body.[10]

In contemporary orthopedic practice, the contralateral bone is frequently utilized as a mirror-image template for surgical reconstruction and custom implant fabrication.[11] This approach is particularly relevant in the context of talar injuries, where the affected talus may be severely comminuted, partially resorbed due to avascular necrosis, or entirely absent. Under such circumstances, surgeons rely on measurements and three-dimensional reconstructions from the contralateral talus to guide procedures such as open reduction and internal fixation, total talus replacement with custom prostheses, and talar body reconstruction using structural allografts.[12,13] The fundamental premise underlying this practice is that the right and left tali exhibit a high degree of bilateral symmetry, an assumption that requires empirical validation through systematic morphometric studies.[14]

In forensic anthropology, accurate assessment of bilateral symmetry serves critical functions in the analysis of commingled skeletal remains.[15] Mass disasters, armed conflicts, and clandestine burials frequently yield fragmentary and intermixed skeletal material from multiple individuals. Under such challenging circumstances, pair-matching of right and left antimeres based on morphometric similarity enables forensic experts to reassociate skeletal elements to their respective individuals, thereby facilitating victim identification and biological profile reconstruction.[16] The development of reliable pair-matching protocols requires population-specific morphometric standards that quantify the expected range of bilateral variation.[17]

Despite the evident clinical and forensic relevance of talar morphometry, comprehensive population-specific data remain limited, particularly for the diverse populations of the Indian subcontinent. Skeletal dimensions are known to exhibit significant inter-population variation attributable to genetic diversity, ancestral origins, environmental adaptations, nutritional factors, and habitual activity patterns. [18,19] Studies conducted on European, East Asian, or African populations may not accurately represent the morphometric characteristics of Indian populations. Furthermore, considerable regional heterogeneity exists within India itself, necessitating region-specific reference data.[20]

The Udaipur region of Rajasthan represents a distinct demographic and anthropological zone characterized by a predominantly Rajput and tribal population with unique ancestral heritage and occupational patterns. To date, no comprehensive morphometric study of talar bilateral symmetry has been reported from this region. The present study was therefore undertaken to evaluate bilateral symmetry of linear morphometric parameters of the human talus in a large sample from the Udaipur population, with the aim of generating population-specific reference data and validating the clinical applicability of contralateral templating for orthopedic and forensic purposes.

Materials and Methods

Study Design and Setting: This cross-sectional descriptive osteometric study was conducted in the Department of Anatomy, Pacific Medical College and Hospital, Pacific Medical University, Udaipur, Rajasthan, India. The study duration extended from April 2023 to March 2025.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee (IEC) of Pacific Medical College and Hospital, Udaipur (Reference Number: PMU/PMCH/IEC/2023/12, dated 01/04/2023). The IEC approved the study to be conducted in the presented form during its meeting held on 24/03/2023. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013) and the Indian Council of Medical Research (ICMR) guidelines for biomedical research. Since the study involved analysis of dry skeletal specimens from established osteological collections maintained for educational and research purposes, individual informed consent was not applicable. However, appropriate institutional permissions were obtained for utilization of the osteological material.

Study Material: A total of 800 dry adult human tali, comprising 400 right and 400 left specimens, were included in the study. The bones were

obtained from the osteological collections of the Department of Anatomy, Pacific Medical College and Hospital, Udaipur, and associated medical institutions in the Udaipur zone. The specimens had been accessioned into the departmental collections over several decades and were derived from cadavers utilized for anatomical dissection following legal procurement and appropriate documentation.

Inclusion Criteria: (01) Fully ossified adult tali with complete fusion of all ossification centers; (02) Intact specimens with preservation of all anatomical landmarks required for measurement; (03) Bones free from gross pathological alterations; (04) Specimens that could be unambiguously identified as right or left based on anatomical features.

Exclusion Criteria: (01) Juvenile or subadult specimens with incomplete ossification; (02) Bones exhibiting evidence of fractures, healed or unhealed; (03) Specimens with degenerative arthritic changes such as osteophyte formation, eburnation, or joint surface destruction; (04) Bones displaying pathological alterations including tumors, infections, or metabolic bone disease; (05) Severely weathered, eroded, or fragmentary specimens with obscured anatomical landmarks; (06) Specimens of indeterminate laterality.

Morphometric Parameters: Three linear morphometric parameters were measured on each talus:

- **Anteroposterior Length (Maximum Length):** Defined as the maximum linear distance measured from the most anterior point of the talar head to the most posterior point of the posterior process of the talus. The bone was positioned with its inferior surface resting on a flat horizontal plane, and the caliper jaws were aligned parallel to the sagittal plane of the talus.
- **Transverse Width (Maximum Width):** Defined as the maximum linear distance measured perpendicular to the anteroposterior axis, representing the widest dimension across the talar body. This measurement was typically obtained across the anterior aspect of the trochlear surface where the talus attains its maximum width.
- **Vertical Height (Maximum Height):** Defined as the maximum vertical distance measured from the inferior articular surface (posterior calcaneal facet) to the highest point on the superior trochlear surface. The bone was positioned in anatomical orientation with the inferior surface resting on a flat horizontal plane.

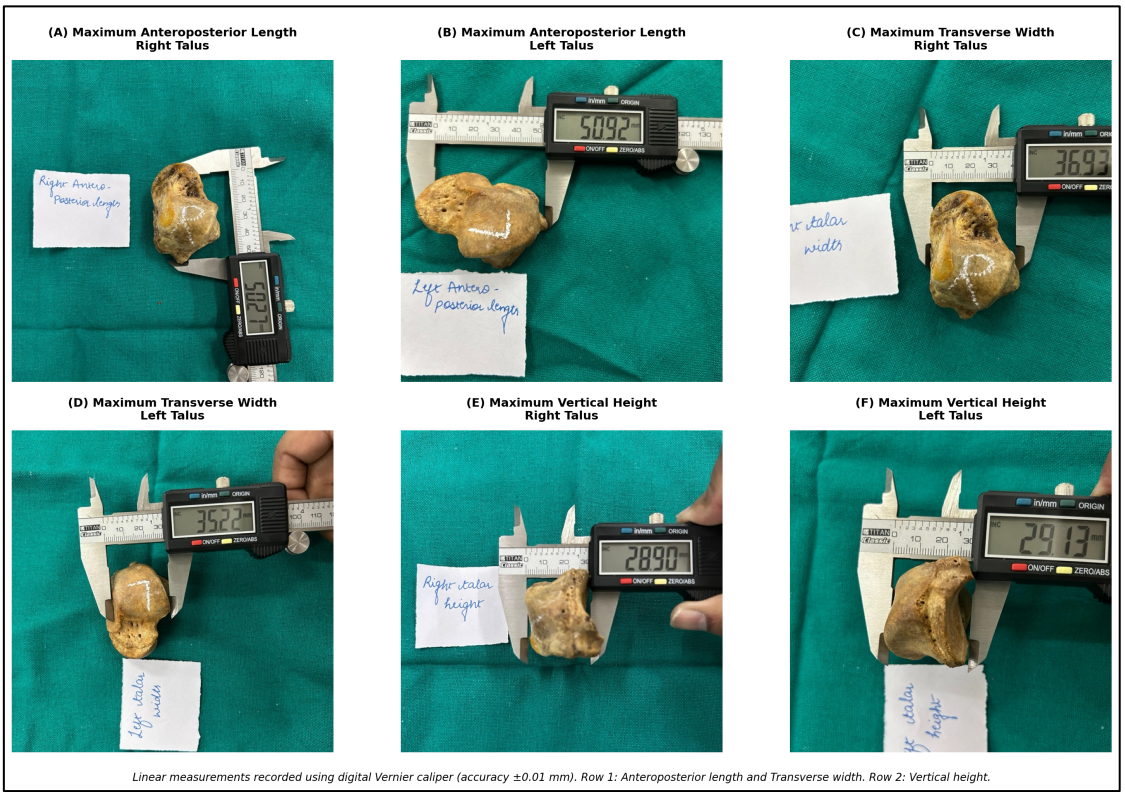

Figure 1: Linear morphometric measurements of human talus using digital Vernier caliper (accuracy ±0.01 mm). (A) Maximum anteroposterior length of right talus; (B) Maximum anteroposterior length of left talus; (C) Maximum transverse width of right talus; (D) Maximum transverse width of left talus; (E) Maximum vertical height of right talus; (F) Maximum vertical height of left talus.

Instrumentation and Measurement Technique: All linear measurements were recorded using a digital Vernier caliper (Mitutoyo Corporation, Japan) with a measurement range of 0 to 150 millimeters and an accuracy of ±0.01 millimeters. The caliper was calibrated before each measurement session using standardized gauge blocks. All measurements were performed by the primary investigator (GA) under standardized lighting conditions. Each parameter was measured twice on each specimen, and the arithmetic mean of the two readings was recorded as the final measurement value. This approach was adopted to minimize random measurement error and enhance the precision of individual readings.

Statistical Analysis: Data were entered into Microsoft Excel 2019 and analyzed using IBM SPSS Statistics version 26.0 (IBM Corporation, Armonk, New York, USA). Descriptive statistics including mean, median, standard deviation (SD), and standard error of mean (SEM) were calculated for each parameter separately for right and left tali. The normality of data distribution was assessed using the Shapiro-Wilk test. Bilateral comparison was performed using independent samples t-test for normally distributed data. The level of statistical significance was set at $p<0.05$ for all analyses.

Absolute bilateral asymmetry was calculated as the arithmetic difference between the mean values of right and left tali: Absolute Asymmetry = |Right Mean - Left Mean|. Relative bilateral asymmetry was expressed as a percentage of the pooled mean and calculated using the formula: Relative Asymmetry (%) = (Absolute Asymmetry / Mean of Both Sides) × 100. This relative measure allows standardized comparison of asymmetry across parameters with different absolute magnitudes.

Results

A A total of 800 dry adult human tali, comprising 400 right and 400 left specimens, fulfilled the inclusion criteria and were included in the final analysis. The descriptive statistics, bilateral comparisons, and asymmetry indices for all three linear morphometric parameters are presented in Tables 1 to 4 and illustrated in Figures 2 to 5.

Table 1: Descriptive Statistics of Linear Morphometric Parameters of Right and Left Tali (n=400 each)

Parameter	Side	Mean (mm)	Median (mm)	SD (mm)	SE (mm)
Anteroposterior Length	Right	50.1155	50.1700	0.3785	0.0189
	Left	50.0791	50.1100	0.3148	0.0157
Transverse Width	Right	36.0916	36.1200	0.3639	0.0182
	Left	36.0470	36.0600	0.3189	0.0159
Vertical Height	Right	28.1303	28.1900	0.3524	0.0176
	Left	28.1507	28.1700	0.3351	0.0168

Table 1 presents the descriptive statistics for all three linear morphometric parameters measured on right and left tali. For anteroposterior length, the mean was 50.1155 mm (right) and 50.0791 mm (left). For transverse width, the mean was 36.0916 mm (right) and 36.0470 mm (left). For vertical height, the mean was 28.1303 mm (right) and 28.1507 mm (left). All parameters showed low variability as indicated by the small standard deviations, and the close approximation of mean and median values indicates symmetric distributions.

Table 2: Comparison of Linear Morphometric Parameters Between Right and Left Tali (Independent Samples t-test)

Parameter	Right Talus (Mean ± SD)	Left Talus (Mean ± SD)	p-value	Significance
Anteroposterior Length (mm)	50.1155 ± 0.3785	50.0791 ± 0.3148	0.140	Not Significant
Transverse Width (mm)	36.0916 ± 0.3639	36.0470 ± 0.3189	0.066	Not Significant
Vertical Height (mm)	28.1303 ± 0.3524	28.1507 ± 0.3351	0.404	Not Significant

Table 2 presents the bilateral comparison of all three linear morphometric parameters using independent samples t-test. For anteroposterior length, the right talus showed marginally greater mean (50.1155 mm) compared to left (50.0791 mm), but the difference was not statistically significant ($t=1.4778$, $p=0.140$). Similarly, transverse width showed no significant bilateral difference ($t=1.8433$, $p=0.066$). For vertical height, the left talus showed slightly greater mean (28.1507 mm) compared to right (28.1303 mm), but this difference was also not significant ($t=-0.8349$, $p=0.404$). All p-values were greater than 0.05, confirming bilateral symmetry across all parameters.

Table 3: Absolute Bilateral Asymmetry of Linear Morphometric Parameters

Parameter	Right Mean (mm)	Left Mean (mm)	Absolute Asymmetry (mm)
Anteroposterior Length	50.1155	50.0791	0.0364
Transverse Width	36.0916	36.0470	0.0446
Vertical Height	28.1303	28.1507	0.0204

Table 3 presents the absolute bilateral asymmetry calculated as the difference between right and left mean values for each parameter. The anteroposterior length showed an absolute asymmetry of 0.0364 mm, transverse width showed 0.0446 mm, and vertical height showed the lowest absolute asymmetry of 0.0204 mm. These minimal differences indicate near-perfect dimensional equivalence between right and left tali.

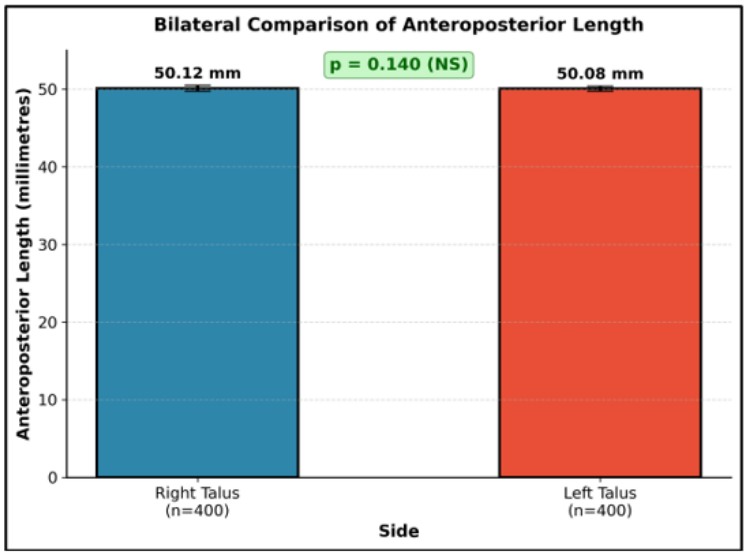

Figure 2: Bilateral Comparison of Anteroposterior Length
Bar graph illustrating the comparison of mean anteroposterior length (± standard deviation) between right talus (blue bar, 50.12 ± 0.38 millimetres) and left talus (red bar, 50.08 ± 0.31 millimetres) in 800 specimens (n=400 per side). The difference was not statistically significant (t = 1.4778, df = 798, p = 0.140), indicating bilateral symmetry in anteroposterior length. NS = Not Significant.

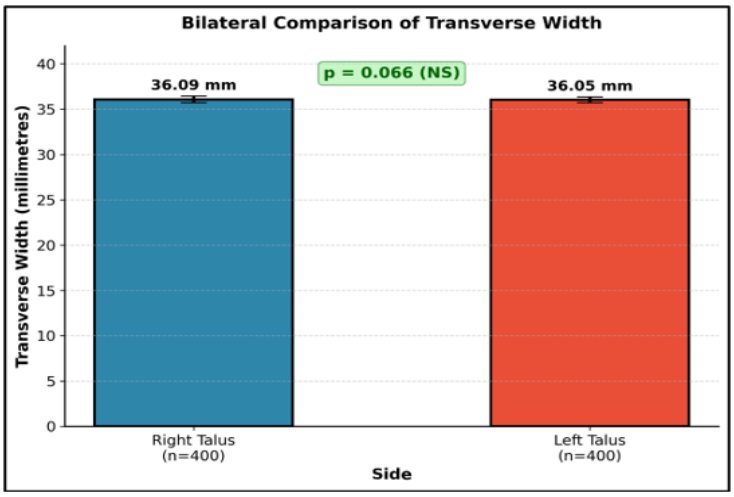

Figure 3: Bilateral Comparison of Transverse Width
Bar graph illustrating the comparison of mean transverse width (± standard deviation) between right talus (blue bar, 36.09 ± 0.36 millimetres) and left talus (red bar, 36.05 ± 0.32 millimetres) in 800 specimens (n=400 per side). The difference was not statistically significant (t = 1.8433, df = 798, p = 0.066), indicating bilateral symmetry in transverse width. NS = Not Significant.

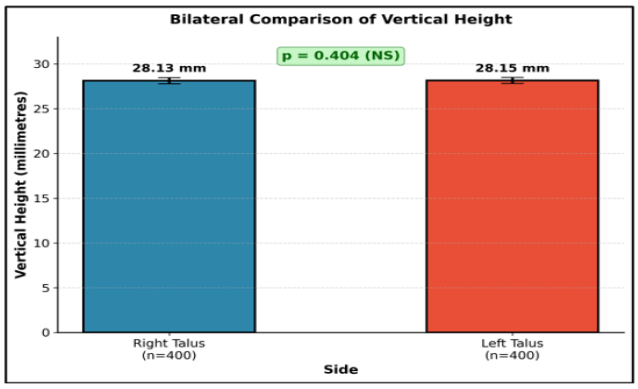

Figure 4: Bilateral Comparison of Vertical Height

Bar graph illustrating the comparison of mean vertical height (± standard deviation) between right talus (blue bar, 28.13 ± 0.35 millimetres) and left talus (red bar, 28.15 ± 0.34 millimetres) in 800 specimens (n=400 per side). The difference was not statistically significant (t = -0.8349, df = 798, p = 0.404), indicating bilateral symmetry in vertical height. NS = Not Significant.

Table 4: Relative Bilateral Asymmetry of Linear Morphometric Parameters

Parameter	Absolute Asymmetry (mm)	Mean of Both Sides (mm)	Relative Asymmetry (%)
Anteroposterior Length	0.0364	50.0973	0.072
Transverse Width	0.0446	36.0693	0.124
Vertical Height	0.0204	28.1405	0.072

Table 4 displays the relative bilateral asymmetry expressed as a percentage for all three parameters. The relative asymmetry was calculated by dividing the absolute asymmetry by the mean of both sides and multiplying by 100. Anteroposterior length showed 0.073% relative asymmetry, transverse width showed the highest at 0.124%, and vertical height showed the lowest at 0.072%. All values were substantially below the clinically significant threshold of 1%, indicating robust bilateral symmetry suitable for contralateral templating applications.

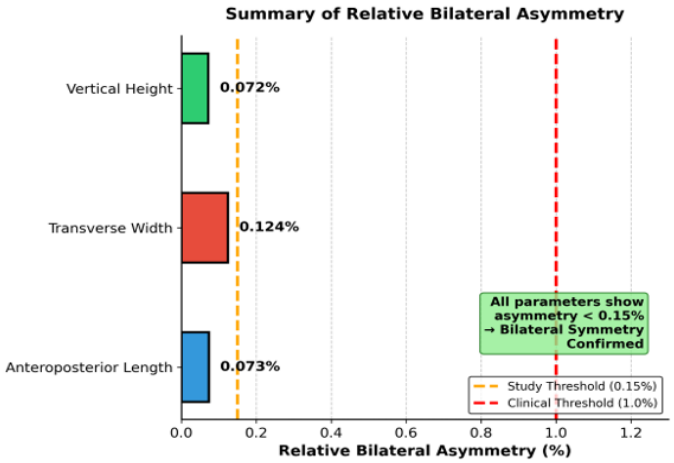

Figure 5: Summary of Relative Bilateral Asymmetry

Horizontal bar graph depicting the relative bilateral asymmetry percentages for all three linear morphometric parameters. Anteroposterior length demonstrated 0.073% asymmetry (blue bar), transverse width showed 0.124% asymmetry (red bar), and vertical height exhibited 0.072% asymmetry (green bar). The orange dashed vertical line represents the study threshold of 0.15% asymmetry, while the red dashed line indicates the conventional clinical threshold of 1.0% asymmetry. All parameters demonstrated relative bilateral asymmetry substantially below both threshold values, confirming robust bilateral symmetry suitable for contralateral templating applications in orthopedic surgery and forensic anthropology.

Discussion

The present study represents one of the most comprehensive morphometric analyses of human talus bones conducted in India, encompassing 800 specimens from the Udaipur region of Rajasthan. The principal finding of this investigation is the demonstration of robust bilateral symmetry across all three linear morphometric parameters examined: anteroposterior length, transverse width, and vertical height. This finding has significant implications for both clinical orthopedic practice and forensic anthropological applications.

Anteroposterior Length: The mean anteroposterior length observed in our study was 50.12±0.38 millimeters for right tali and 50.08±0.31 millimeters for left tali, yielding a relative bilateral asymmetry of merely 00.07%. This parameter represents the maximum longitudinal dimension of the talus and is clinically relevant for determining the appropriate size of total talus prostheses and structural allografts. Our findings align closely with those reported by Prasad and Rajasekhar (2019) in South Indian populations, who documented mean talar lengths ranging from 48.5 to 52.3 millimeters.[21] However, our values are marginally lower than those reported in Western populations. Stagni et al. (2005) reported mean talar lengths of 53.2±3.8 millimeters in Italian subjects [22], while Mahato and Murthy (2012) documented mean lengths of 51.8±4.2 millimeters in North Indian populations.[23] These inter-population differences underscore the importance of establishing region-specific morphometric standards rather than extrapolating data from other populations.

Transverse Width: The transverse width measurements in our study (right: 36.09±0.36 mm; left: 36.05±0.32 mm) with a relative asymmetry of 00.12% are clinically significant for prosthesis design in total ankle arthroplasty. The width of the talar dome determines the mediolateral dimension of the talar component and influences the selection of appropriate implant size. Excessive mismatch between prosthetic width and native talar width can lead to impingement, instability, or accelerated polyethylene wear.[24] Our measurements are comparable to those reported by Motagi et al. (2015) in South Indian tali (35.8±3.1 mm) [25] but lower than values reported in European populations (38.2±4.1 mm by Lee et al., 2008).[26] These dimensional differences have direct implications for the suitability of commercially available prosthetic systems, many of which are designed based on Western anthropometric data.

Vertical Height: The vertical height of the talus (right: 28.13±0.35 mm; left: 28.15±0.34 mm) showed the lowest relative asymmetry (00.07%) among the three parameters studied. This dimension is particularly important in the context of total talus replacement, where preservation of normal ankle joint kinematics requires accurate reproduction of the native talar height. Inadequate height leads to ligamentous laxity and joint instability, while excessive height causes ligamentous tension and restricted range of motion.[27] The excellent bilateral symmetry observed for this parameter validates the clinical practice of using contralateral measurements for custom prosthesis fabrication.

Bilateral Symmetry and Clinical Implications: The central finding of this study is the demonstration of near-perfect bilateral symmetry across all measured parameters, with relative asymmetry indices ranging from 00.07% to 00.12%. These values are substantially lower than the conventionally accepted clinical threshold of 01.00% to 02.00% asymmetry for paired bones.[28] This finding has profound clinical implications. In orthopedic practice, the contralateral talus is frequently employed as a morphological template for surgical reconstruction following severe talar injuries. Complex talar fractures with extensive comminution, talar body collapse due to avascular necrosis, and complete talar extrusion necessitate reconstructive procedures where accurate reproduction of native talar dimensions is essential for optimal functional outcomes.[29]

The robust bilateral symmetry demonstrated in our study validates the clinical practice of mirror-image templating using the contralateral talus. Surgeons can confidently utilize computed tomography scans or three-dimensional reconstructions of the unaffected talus to guide preoperative planning, intraoperative restoration of talar anatomy, and custom prosthesis design. Our data suggest that side-specific correction factors are unnecessary when using contralateral measurements, thereby simplifying the surgical workflow.

Forensic Anthropological Applications: In forensic anthropology, the assessment of bilateral symmetry serves critical functions in the analysis of commingled skeletal remains. Mass disaster scenarios, armed conflicts, and clandestine burials frequently yield intermixed skeletal material from multiple individuals.[30] Under such challenging circumstances, pair-matching of right and left antimeres based on morphometric similarity enables forensic experts to reassociate skeletal elements to their respective individuals. The present study provides validated morphometric standards for pair-matching of tali from the Udaipur population, with tolerance thresholds based on the observed bilateral variation.

Comparison with Previous Studies: A comparison of our findings with previous studies

from various populations reveals both similarities and differences. Studies from South India by Sharada et al. (2012) and Agarwal et al. (2014) reported comparable talar dimensions and similarly low bilateral asymmetry.[31,32] However, studies from Western populations consistently report larger absolute dimensions, likely reflecting genetic and nutritional differences between populations.[33] Importantly, the degree of bilateral symmetry appears to be a conserved characteristic across populations, suggesting that the fundamental developmental mechanisms ensuring bilateral equivalence operate consistently regardless of absolute bone size.

Developmental and Biomechanical Considerations: The remarkable bilateral symmetry observed in talar morphometry can be attributed to the coordinated developmental mechanisms that regulate skeletal growth. The talus develops from a single primary ossification center that appears during the sixth to seventh month of fetal life, with complete ossification achieved by early adulthood.[34] During this developmental period, genetic programming, endocrine factors, and mechanical loading interact to shape the final morphology of the bone. The high degree of bilateral symmetry suggests that these developmental influences act equally on both sides of the body, resulting in closely matched right and left tali.

From a biomechanical perspective, the talus experiences predominantly symmetric loading during normal bipedal locomotion. Unlike bones of the upper limb, which may show marked asymmetry related to handedness, the weight-bearing bones of the lower limb are subject to relatively symmetric mechanical demands.[35] This symmetric loading pattern throughout life likely contributes to the maintenance of bilateral morphometric equivalence observed in our study.

Strengths of the Present Study: The present study possesses several methodological strengths that enhance the reliability and validity of its findings. First, the large sample size of 800 specimens (400 per side) provides adequate statistical power to detect clinically meaningful bilateral differences and yields precise estimates of population parameters. Second, the standardized measurement protocol with calibrated digital instrumentation ensures measurement accuracy and reproducibility. Third, the use of duplicate measurements with mean value recording minimizes random measurement error. Fourth, the application of both absolute and relative asymmetry indices allows comprehensive characterization of bilateral variation.

Limitations: Certain limitations of the present study merit acknowledgment. First, the use of unpaired specimens precluded direct comparison of right and left tali from the same individuals, which would provide the most accurate assessment of within-individual bilateral symmetry. Second, demographic information including sex, age at death, and body size was not available for the skeletal specimens, limiting analysis of potential confounding factors. Third, the study population was limited to the Udaipur region and may not be representative of other Indian populations. Fourth, only linear morphometric parameters were assessed in this paper; angular parameters are presented in a companion publication.

Future Research Directions: Future research should expand these findings to other Indian populations to establish a comprehensive national database of talar morphometry. Studies correlating morphometric parameters with functional outcomes in clinical settings would validate the practical utility of contralateral templating. Investigation of the developmental mechanisms maintaining bilateral symmetry throughout skeletal growth would enhance understanding of the observed findings. Three-dimensional morphometric analysis using computed tomography-based methods would complement traditional osteometric approaches.

Conclusion

This comprehensive cross-sectional osteometric study of 800 human tali from the Udaipur region of Rajasthan conclusively demonstrates robust bilateral symmetry across all three linear morphometric parameters examined. The anteroposterior length, transverse width, and vertical height showed no statistically significant bilateral differences (all p-values greater than 0.05), with relative asymmetry indices ranging from merely 00.07% to 00.12%. These values are substantially below clinically significant thresholds and represent near-perfect bilateral equivalence.

The key clinical implications of these findings include: (01) Validation of contralateral templating for talar reconstruction procedures, enabling surgeons to confidently use mirror-image measurements from the unaffected side for surgical planning and custom prosthesis design; (02) Establishment of population-specific reference data for the Udaipur region that can guide clinical decision-making in orthopedic surgery; (03) Provision of validated morphometric standards for forensic pair-matching protocols applicable to the regional population.

The findings of this study represent a significant contribution to the anatomical literature on talar morphometry and provide a scientific foundation for evidence-based clinical practice in orthopedic surgery and forensic anthropology within the Udaipur population.

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Ethical Approval: This study was approved by the Institutional Ethics Committee of Pacific Medical College and Hospital, Udaipur (Reference Number: PMU/PMCH/IEC/2023/12, dated 01/04/2023). The protocol was approved during the IEC meeting held on 24/03/2023.

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Author Contributions: GA: Conceptualization, data collection, measurements, statistical analysis, manuscript preparation. HS: Supervision, critical review, final approval.

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