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ORIGINAL RESEARCH

MORPHOMETRIC EVALUATION OF DRY HUMAN TALUS: A COMPARATIVE STUDY OF RIGHT AND LEFT SIDED SPECIMENS

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ABSTRACT

Background: The talus is central to load transmission between the leg and foot, and its morphology has direct relevance to ankle and hindfoot biomechanics, fracture reconstruction, and implant design. **Objective:** To quantify selected morphometric parameters of dry human tali and compare right- and left-sided specimens. **Methods:** This cross-sectional morphometric study included 100 fully ossified dry tali of undetermined sex (51 right, 49 left) from the Department of Anatomy, Government Medical College, Kota, Rajasthan, India. Maximum anteroposterior length (MAPL), maximum transverse width (MTW), trochlear length (TL), circumference of the posterior calcaneal articular facet (CFACP), length and width of the sulcus tali (LST and WST), neck-body angle (NBA), and bone weight were recorded using a digital Vernier caliper, thread-based perimeter measurement, digital goniometer, and digital weighing scale, as appropriate. Right-left comparisons were performed using an independent-samples t-test, with nominal statistical significance set at $p < 0.05$. **Results:** Most measurements were closely comparable between sides. Mean weight was 13.54 ± 0.87 g on the right and 13.54 ± 0.92 g on the left ($p = 0.97$). MAPL, MTW, TL, CFACP, LST, and WST also showed no statistically significant side-related differences. NBA was 150.60 ± 4.20° on the right and 152.40 ± 4.40° on the left (unadjusted $p = 0.04$). **Conclusion:** The linear dimensions and weight of right- and left-sided tali were similar in this sample. A small nominal difference was observed in NBA; however, because the specimens were unpaired and eight comparisons were performed, this finding should be interpreted as exploratory rather than evidence of true within-individual bilateral asymmetry. The data add regional osteometric reference values that may be useful for anatomical research and may inform future work on talar reconstruction and implant design.

Keywords: Talus; Morphometry; Neck-body angle; Sulcus tali; Osteometry; Side-related variation

INTRODUCTION

The talus occupies a mechanically important position between the leg and foot. It articulates superiorly with the tibia and fibula, inferiorly with the calcaneus, and anteriorly with the navicular, thereby transmitting substantial loads across the ankle and hindfoot during standing and locomotion [1]. Unlike most long and short bones of the lower limb, the talus has no direct muscular attachment; its position and motion are therefore governed predominantly by articular geometry, ligamentous constraints, and externally transmitted forces [1,2].

The bone consists of a head, neck, and body. The angular relationship between the neck and body influences the orientation of the talar head and the spatial configuration of the talonavicular and subtalar regions. The inferior aspect of the neck contains the sulcus tali, which contributes to the sinus tarsi together with the corresponding sulcus of the calcaneus [1,2]. Three-dimensional studies further demonstrate that talar shape varies with sex, age, and population, underscoring the importance of population-specific morphometric data [3].

Side-related talar variation has attracted clinical interest because contralateral anatomy is often used as a reference during reconstructive planning. Matched-pair cadaveric analyses have demonstrated that some talar dimensions may differ

between sides, whereas other studies have reported substantial side-wise similarity [4,5]. Accurate morphometric information is also relevant to fracture fixation, screw trajectory planning, ankle arthroplasty, and the design of patient- or population-specific talar components [5,6]. Measurements of the sulcus tali may additionally contribute to understanding the morphology of the sinus tarsi and subtalar region [7].

The present study therefore measured selected linear, angular, circumferential, and weight parameters in a collection of dry human tali from Rajasthan, India, and compared right- and left-sided specimens. The primary aim was to provide regional reference data and to determine whether any measured parameter showed evidence of a side-associated difference in this unpaired skeletal sample.

MATERIALS AND METHODS

Study design and specimens

A cross-sectional morphometric study was conducted on 100 dry, fully ossified human tali of undetermined sex obtained from the Department of Anatomy, Government Medical College, Kota, Rajasthan, India. The collection comprised 51 right-sided and 49 left-sided bones. Grossly intact tali with normal morphology were included. Specimens showing congenital abnormalities, acquired deformity, fracture-related distortion, or other gross structural alteration were excluded. The authors reported compliance with applicable local and international ethical principles governing the use of human skeletal material in anatomical research.

Morphometric assessment

Linear measurements were obtained using a digital Vernier caliper with a reported resolution of 0.01 mm. The neck-body angle was measured with a digital goniometer, bone weight was recorded on a digital weighing scale, and the circumference of the posterior calcaneal articular facet was determined using a thread-based perimeter method. The measurement approach was consistent with techniques used in previous talar morphometric studies [4,6,7]. The recorded variables were maximum anteroposterior length (MAPL), maximum transverse width (MTW), trochlear length (TL), circumference of the posterior calcaneal articular facet (CFACP), length of the sulcus tali (LST), width of the sulcus tali (WST), neck-body angle (NBA), and bone weight.

MAPL was defined as the greatest anteroposterior distance between the most anterior point of the talar head and the most posterior point of the body. MTW was the greatest mediolateral distance between the most medial and lateral points of the talus. TL represented the anteroposterior length of the trochlear surface. CFACP represented the perimeter of the posterior calcaneal articular facet. LST was the maximum longitudinal extent of the sulcus tali, and WST was the greatest distance between the sulcus margins at its widest point. NBA was the angle between the longitudinal axes of the talar neck and body. Weight was recorded in grams.

Figure 1. *Representative measurement technique for dry human tali using a digital Vernier caliper*
(a) maximum transverse width (MTW), (b) maximum anteroposterior length (MAPL), and (c) width of the sulcus tali (WST).

Statistical analysis

Data were entered in Microsoft Excel and analysed in SPSS (version not specified in the source manuscript). Continuous variables were summarized as mean and standard deviation (SD); standard error of the mean (SEM) was also calculated in the original analysis. Because matched right-left donor pairs were not documented, side comparisons were treated as

independent and assessed using an independent-samples t-test. Nominal statistical significance was defined as $p < 0.05$. Eight separate right-left comparisons were performed and the reported p values were not adjusted for multiplicity; accordingly, isolated marginal p values were interpreted cautiously.

RESULTS

Morphometric data from 100 dry human tali are summarized in Table 1. Most parameters showed close agreement between right- and left-sided specimens. Mean talar weight was 13.54 ± 0.87 g on the right and 13.54 ± 0.92 g on the left ($p = 0.97$). MAPL measured 52.54 ± 4.78 mm on the right and 52.50 ± 4.25 mm on the left ($p = 0.97$), while MTW measured 38.98 ± 8.78 mm and 38.33 ± 3.52 mm, respectively ($p = 0.63$).

Trochlear length was 29.71 ± 3.25 mm on the right and 30.00 ± 2.83 mm on the left ($p = 0.64$). CFACP was 88.47 ± 7.69 mm and 88.22 ± 7.77 mm, respectively ($p = 0.87$). LST measured 20.58 ± 3.29 mm on the right and 21.15 ± 3.50 mm on the left ($p = 0.40$), whereas WST was 6.33 ± 4.58 mm and 6.32 ± 2.39 mm, respectively ($p = 0.99$).

NBA was the only parameter with a nominal side-related difference: 150.60 ± 4.20° on the right versus 152.40 ± 4.40° on the left (unadjusted $p = 0.04$). The absolute mean difference was 1.8°. Because eight parameters were tested, this marginal result does not meet a conservative Bonferroni-adjusted threshold of 0.00625 and should therefore be considered exploratory.

Table 1. Comparison of morphometric parameters between right- and left-sided tali

Parameter	Right n	Right mean ± SD	Left n	Left mean ± SD	p value*
Weight (g)	51	13.54 ± 0.87	49	13.54 ± 0.92	0.97
MAPL (mm)	51	52.54 ± 4.78	49	52.50 ± 4.25	0.97
MTW (mm)	51	38.98 ± 8.78	49	38.33 ± 3.52	0.63
TL (mm)	51	29.71 ± 3.25	49	30.00 ± 2.83	0.64
LST (mm)	51	20.58 ± 3.29	49	21.15 ± 3.50	0.40
WST (mm)	51	6.33 ± 4.58	49	6.32 ± 2.39	0.99
NBA (°)	51	150.60 ± 4.20	49	152.40 ± 4.40	0.04
CFACP (mm)	51	88.47 ± 7.69	49	88.22 ± 7.77	0.87

MAPL, maximum anteroposterior length; MTW, maximum transverse width; TL, trochlear length; LST, length of sulcus tali; WST, width of sulcus tali; NBA, neck-body angle; CFACP, circumference of posterior calcaneal articular facet; SD, standard deviation. *Unadjusted p values from independent-samples t-tests.

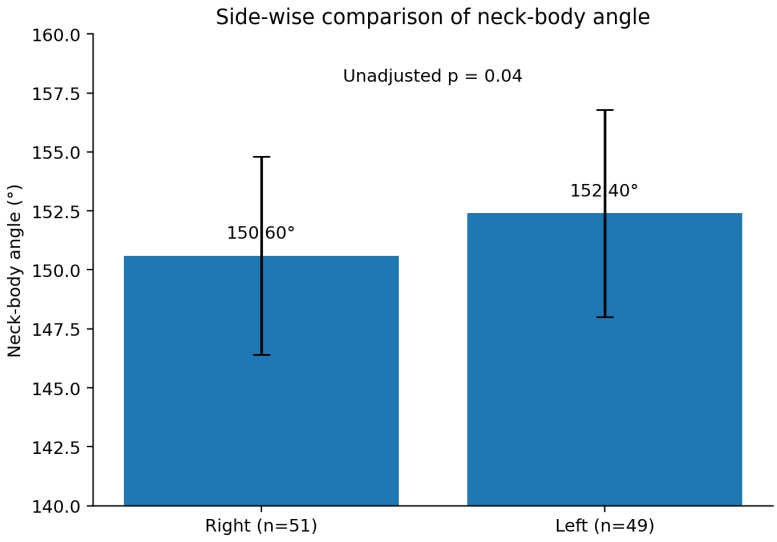

Figure 2. *Side-wise comparison of neck-body angle.*

Bars show mean values and error bars show standard deviation. The reported p value is unadjusted for multiple comparisons.

DISCUSSION

This study evaluated eight morphometric characteristics in 100 dry human tali and found broad similarity between right- and left-sided specimens. The linear measurements, posterior calcaneal facet circumference, and bone weight did not differ significantly by side. NBA showed a small nominal difference, with a larger mean angle on the left. The interpretation of this finding requires caution because the specimens were not matched pairs and the p value was marginal in the context of multiple testing.

The MAPL values in the present series (52.54 mm right; 52.50 mm left) are similar to measurements reported in several Indian and Anatolian osteometric studies. Ari and Kafa [8] reported slightly larger values in a late Byzantine sample, Otag and Cimen [9] reported means of 55.94 and 56.54 mm in an Anatolian collection, and Gautham et al. [10] reported 52.3 and 52.9 mm in an Indian sample. Boyan et al. [11] described values of 53.05 and 50.51 mm, while Vedapriya et al. [12], Singh and Singh [6], and Kolap et al. [7] reported broadly comparable overall talar lengths. These differences are consistent with variation in sample composition, population, sex distribution, and measurement definitions across studies.

The present MTW values (38.98 mm right; 38.33 mm left) are close to those reported by Gautham et al. [10], Boyan et al. [11], and Kolap et al. [7], but exceed the values reported by Singh and Singh [6]. LST and WST were also within the broad range described in earlier literature, although Kolap et al. [7] reported substantially larger sulcus measurements. Standardization of landmark definitions is important when comparing these parameters because relatively small changes in caliper placement can alter sulcus measurements. Table 2 summarizes the principal linear comparisons after conversion to millimetres for consistency.

Table 2. Comparison of selected linear talar measurements with previous studies

Study	Location	MAPL R/L (mm)	MTW R/L (mm)	LST R/L (mm)	WST R/L (mm)
Ari & Kafa [8]	Bursa, Turkey	57.2 / 56.4	49.1 / 46.9	17.6 / 21.0	3.8 / 4.8
Mahato & Murthy [2]	Tamil Nadu, India	55.7 / 55.8	29.0 / 30.3	24.6 / 26.2	15.0 / 14.4
Otag & Cimen [9]	Anatolia, Turkey	55.94 / 56.54	40.79 / 43.39	—	6.83 / 6.05
Gautham et al. [10]	India	52.3 / 52.9	37.9 / 36.8	20.1 / 20.4	6.9 / 6.8
Boyan et al. [11]	Adana, Turkey	53.05 / 50.51	39.33 / 39.50	21.06 / 21.66	6.08 / 5.22
Vedapriya et al. [12]	Hyderabad, India	53.4 / 53.3	38.3 / 38.5	—	—
Singh & Singh [6]	Uttar Pradesh, India	52.81 / 52.67	31.19 / 31.70	21.97 / 21.78	5.87 / 5.98
Kolap et al. [7]	Goa, India	50.85 / 51.87	36.92 / 38.51	31.44 / 32.01	10.08 / 10.90
Present study	Rajasthan, India	52.54 / 52.50	38.98 / 38.33	20.58 / 21.15	6.33 / 6.32

R/L = right/left. Values originally reported in centimetres were converted to millimetres. Dashes indicate data not reported in the source comparison.

Mean talar weight in the present sample was 13.54 g on both sides. Earlier forensic studies using known-sex collections reported greater mean weights in male than in female tali and showed substantial population variation [13-16]. Direct numerical comparison with the present series is limited because sex and age were not available for these specimens. Trochlear length in the current study (29.71 mm right; 30.00 mm left) was close to values reported by Ari and Kafa [8] and Gautham et al. [10], and slightly lower than those reported by Otag and Cimen [9]. CFACP was similar to the values reported by Gautham et al. [10] but lower than those reported by Ari and Kafa [8].

The mean NBA values of 150.60° on the right and 152.40° on the left are consistent with the general adult anatomical range described in standard texts [1] and with values reported in previous morphometric studies [6,10]. Singh and Singh [6] likewise reported a statistically significant side-related difference in NBA. However, the present study differs from matched-pair investigations because the right and left bones were not documented as belonging to the same donors. Consequently, the observed difference represents a comparison between two side-defined groups and should not be interpreted as direct evidence of within-individual asymmetry. Matched-pair three-dimensional studies are more appropriate for that question [4].

Table 3. Comparison of weight, trochlear length, posterior calcaneal facet circumference, and neck-body angle

Study	Location	Weight R/L (g)	TL R/L (mm)	CFACP R/L (mm)	NBA R/L (°)
Singh & Singh [13]	Varanasi, India	M: 24.06/23.09; F: 15.66/15.03	—	—	—
Ahmad et al. [14]	Bahawalpur, Pakistan	M: 29.23/28.76; F: 22.25/22.15	—	—	—
Ari & Kafa [8]	Bursa, Turkey	—	31.5 / 30.8	101.0 / 98.5	—
Patel et al. [15]	Jamnagar, India	M: 20.53/20.42; F: 15.53/14.74	—	—	—
Otag & Cimen [9]	Anatolia, Turkey	—	33.45 / 34.12	—	—
Gautham et al. [10]	India	—	30.6 / 30.4	86.7 / 86.7	155.56 / 155.20
Dagar et al. [16]	India	M: 27.18/27.18; F: 18.28/18.28	—	—	—
Present study	Rajasthan, India	13.54 / 13.54	29.71 / 30.00	88.47 / 88.22	150.60 / 152.40

R/L = right/left; M = male; F = female; TL = trochlear length; CFACP = circumference of posterior calcaneal articular facet; NBA = neck-body angle. Published centimetre values were converted to millimetres where applicable.

Clinical and anatomical implications

Population-specific talar measurements can provide useful background information for anatomical teaching, forensic assessment, and orthopaedic reconstruction. Contemporary CT- and three-dimensional model-based studies demonstrate that talar geometry can vary by sex and population and that implant design may benefit from anatomically representative datasets [3,5,17,18]. The present measurements therefore contribute regional reference data. Nevertheless, clinical application to screw placement, total talar replacement, or patient-specific prosthetic design would require larger datasets, known demographic characteristics, and three-dimensional assessment of articular geometry.

Limitations

Donor age and sex were unknown, preventing sex-specific or age-specific analysis. Second, the specimens were not documented as matched right-left pairs; therefore, true bilateral asymmetry within individuals could not be assessed. Third, the study relied on manual osteometric techniques, and intra-observer or inter-observer reliability was not reported. Fourth, CFACP was obtained using a thread-based method, which may introduce additional measurement variability. Finally, eight independent comparisons were performed without multiplicity adjustment; the isolated p value of 0.04 for NBA should therefore be interpreted cautiously and warrants confirmation in a prespecified, adequately powered matched-pair study.

CONCLUSION

In this sample of 100 dry human tali from Rajasthan, most linear dimensions, posterior calcaneal facet circumference, and bone weight were similar between right- and left-sided specimens. NBA was modestly greater on the left, with an unadjusted p value of 0.04; however, the unpaired specimen design and multiple comparisons limit the strength of this inference. The study provides regional osteometric reference data and supports further morphometric research using known-sex, known-age, matched-pair specimens and reproducibility testing before direct clinical or prosthetic application.

Conflict of Interest: The authors declare no conflict of interest.

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