Original Article

Osteometric Morphometry of Dry Adult Tibiae in a South Indian (Andhra Pradesh) Population: A Cross-Sectional Study

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Abstract

Background: Population-specific osteometric data of the tibia are essential for forensic anthropology, orthopaedic implant design, and clinical anatomy. This study aimed to investigate the morphometric parameters of dry adult tibiae in a South Indian (Andhra Pradesh) population using simple, cost-effective instruments. **Material and Methods:** The study was conducted on 100 dry adult tibiae (50 right and 50 left) of unknown sex. Measurements were performed using an osteometric board, digital vernier calipers (accuracy 0.01 mm), flexible measuring tape, and thread. Seven linear parameters and two derived indices were recorded: maximum tibial length, antero-posterior and medio-lateral diameters at the nutrient foramen, circumference at the nutrient foramen, proximal and distal epiphyseal breadths, distance from proximal end to nutrient foramen, cnemic index, and foraminal index. Data were analysed using descriptive statistics and side-wise comparison. **Results:** The mean maximum tibial length was 369.5 ± 24.5 mm (range: 325–428 mm). The mean antero-posterior diameter, medio-lateral diameter, and circumference at the nutrient foramen were 28.4 ± 3.1 mm, 20.6 ± 2.9 mm, and 84.5 ± 8.2 mm respectively. Proximal epiphyseal breadth averaged 71.8 ± 5.6 mm and distal epiphyseal breadth 54.2 ± 4.8 mm. The nutrient foramen was located in the proximal third in 78% of bones. The mean cnemic index was 72.5 ± 10.8, indicating a predominantly mesocnemic tibial shaft morphology. No statistically significant bilateral differences were observed in any parameter ($p > 0.05$). **Conclusion:** This study provides baseline osteometric reference values for dry adult tibiae in the South Indian (Andhra Pradesh) population. The findings demonstrate bilateral symmetry, moderate size variation, mesocnemic shaft type, and consistent proximal-third location of the nutrient foramen. These population-specific data will be valuable for forensic identification, anthropological comparisons, and orthopaedic surgical planning in the region.

Keywords: Tibia, Osteometry, Morphometry, Nutrient foramen, Cnemic index, South Indian population, Andhra Pradesh, Forensic anthropology.

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Introduction

Tibia is the second longest and strongest bone in the human skeleton. It carries the majority of the body weight and it is responsible for the normal movement of the legs, stability of the knee and ankle joints as well as the transfer of loads from the femur to the foot. The tibia is often preserved well in cadavers and is large enough for measurements to be taken for estimation of stature, sexing, and identification of individuals from skeletal remains.[1]

In clinical practice, knowledge of the dimension of the tibia is equally important. Morphometric information is essential for surgeons to use for planning fracture fixation, intramedullary nailing, knee and ankle arthroplasty and for the design of population specific implants. Implant size can also not match the anatomy of the patient's jaw, causing issues like implant loosening, instability or sub-optimal implant function. Further, the position of the nutrient foramen is of clinical significance as damage to nutrient artery during surgery can impair blood supply, which in turn can delay healing.[2]

It is observed that the human skeleton has a high degree of variation in each geographic region, ethnic group and even from country to country. Research made in various regions of India has shown that, there is difference in the tibial length, shaft diameters, breadths of epiphyses and other indices like cnemic (platycnemic) index when compared with the western or North Indian population. South Indian bones are relatively smaller in comparison to other bones, especially Andhra Pradesh, and so need bone reference values for the respective geographical area, rather than using data from other populations.

Inferences on the morphometry of tibia have been made by several researchers in south India, which include the position of nutrient foramen and cnemic index and the proximal end of tibia.[3] Gupta et al. documented detailed measurements of the proximal tibia and its clinical implications in a South Indian sample.[2] Murlimanju and colleagues studied the anatomical morphometry of the tibial plateau in South Indian dry bones.[4]

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Banu et al. recently reappraised overall tibial osteometry in a South Indian medical college setting and reported a mean tibial length of approximately 36.8 cm with predominant proximal-third location of the nutrient foramen.[3]

Despite these contributions, comprehensive osteometric data on the entire dry adult tibia—covering maximum length, shaft parameters at the nutrient foramen, epiphyseal breadths, and derived indices—remain limited for the Andhra Pradesh region. Most earlier studies used advanced tools or focused on only selected parameters. Simple, reproducible instruments such as an osteometric board, vernier calipers, measuring tape, and thread are still widely available in teaching institutions and can generate reliable baseline data when applied with standard techniques.[6,7]

The present study was therefore undertaken to provide detailed morphometric reference values of dry adult tibiae in a South Indian (Andhra Pradesh) population using basic osteometric tools. It was intended to record the linear measurements, bilateral symmetry, indices of the cnemic and foraminal indices and the distribution of nutrient foramena. Population-specific data will be beneficial for forensic specialists, anatomists and orthopaedic surgeons in this area and will provide a reference for future comparative and applied studies.

Materials and Methods

The present study was an osteometric cross sectional research on 100 dry adult human tibiae of unknown sex (50 right tibia and 50 left tibia). All the bones were collected from the bone banks of GMC, Anantapur, KMC, Kurnool and GMC, Kadapa in Andhra Pradesh, South India. Only tibiae that were completely ossified, had no deformities, fractures, pathological changes, or post mortem damage were included. Gross destruction, osteophytes, and incomplete ossification of bones were excluded.

All measurements were made with simple easily obtainable and inexpensive equipment, in order to guarantee replications in resource-poor settings: an osteometric board for maximum length, a digital vernier caliper (accuracy 0.01 mm) for linear diameters and breadths, a flexible non-stretchable measuring tape to measure circumference and a thin thread to verify difficult or curved distances. [8,9] The following standard osteometric parameters were recorded for each tibia:

1. Maximum tibial length (MTL): Measured as the straight distance from the highest point on the medial condyle to the tip of the medial malleolus using the osteometric board.
2. Antero-posterior diameter at nutrient foramen (APDNF): Taken at the level of the nutrient foramen on the posterior surface of the shaft using vernier calipers.
3. Medio-lateral diameter at nutrient foramen (MLDNF): Measured perpendicular to the APDNF at the same level.
4. Circumference at nutrient foramen (CNF): Recorded by placing the measuring tape around the shaft at the nutrient foramen level; thread was used to mark and confirm the exact girth where needed.
5. Proximal epiphyseal breadth (PEB): Maximum transverse distance between the most medial and lateral points of the proximal articular surface (medial and lateral condyles).
6. Distal epiphyseal breadth (DEB): Maximum transverse distance across the distal end, including the medial malleolus and fibular notch.
7. Distance from proximal end to nutrient foramen (DPNF): Straight distance from the uppermost point of the intercondylar eminence (proximal reference) to the centre of the nutrient foramen.

The nutrient foramen was identified macroscopically on the posterior surface of the shaft (usually near the soleal line). Its position was classified using the foraminal index calculated as: (DPNF / MTL) × 100

Two derived indices were also computed: Cnemic (Platycnemic) index = (MLDNF / APDNF) × 100 (Classified as: < 63.0 – platycnemic; 63.0–69.9 – mesocnemic; ≥ 70.0 – euricnemic, with slight adjustments based on common Indian population references).[10,11]

All measurements were taken by a single observer to minimise inter-observer error, and each parameter was recorded three times; the average value was used for analysis. Data were entered into a Microsoft Excel sheet and analysed using descriptive statistics (mean, standard deviation, range). Side-wise comparison (right vs left) was performed, and differences were considered statistically non-significant when $p > 0.05$ (as per earlier similar studies). No sex determination was attempted due to unknown sex of the bones.Ethical clearance was obtained from the Institutional Ethics Committee of GMC, Kadapa. The study adhered to standard guidelines for handling human skeletal remains in anatomical research.

Figure 1: Showing the measuring the Tibia parameters

Results

The present osteometric study was conducted on 100 dry adult tibiae (50 right-sided and 50 left-sided) of unknown sex belonging to the South Indian (Andhra Pradesh) population. All measurements were taken using standard osteometric techniques: maximum length with an osteometric board, linear diameters and breadths with vernier calipers (accuracy 0.01 mm), circumference with a flexible measuring tape, and thread-assisted confirmation of curved distances where required. The nutrient foramen was identified macroscopically and its position verified. Seven linear parameters and two derived indices were recorded. Data are presented in millimetres (mm) unless otherwise specified.

Table 1: Descriptive statistics of linear osteometric parameters of dry adult tibiae (N = 100)

Parameter	Mean ± SD	Range (Min–Max)
Maximum tibial length (MTL)	369.5 ± 24.5	325–428
Antero-posterior diameter at nutrient foramen (APDNF)	28.4 ± 3.1	22.1–35.8
Medio-lateral diameter at nutrient foramen (MLDNF)	20.6 ± 2.9	15.4–27.3
Circumference at nutrient foramen (CNF)	84.5 ± 8.2	68–102
Proximal epiphyseal breadth (PEB)	71.8 ± 5.6	60.2–84.5
Distal epiphyseal breadth (DEB)	54.2 ± 4.8	44.5–65.1
Distance from proximal end to nutrient foramen (DPNF)	118.5 ± 11.5	91–147

The maximum length of the tibia showed the highest absolute variability, reflecting natural population differences in stature. Shaft parameters at the nutrient foramen level (APDNF, MLDNF and CNF) exhibited moderate variation, consistent with the triangular cross-section of the tibial shaft in South Indian bones. Epiphyseal breadths (PEB and DEB) were relatively less variable, indicating more conserved articular dimensions. The mean DPNF placed the nutrient foramen predominantly in the proximal third of the bone.

Table 2: Side-wise comparison of osteometric parameters (Right n = 50; Left n = 50)

Parameter	Right (Mean ± SD)	Left (Mean ± SD)	Observation
MTL (mm)	371.0 ± 25.0	368.0 ± 24.0	No significant difference
APDNF (mm)	28.5 ± 3.2	28.3 ± 3.0	No significant difference
MLDNF (mm)	20.7 ± 3.0	20.5 ± 2.8	No significant difference
CNF (mm)	84.8 ± 8.5	84.2 ± 7.9	No significant difference
PEB (mm)	72.0 ± 5.7	71.6 ± 5.5	No significant difference
DEB (mm)	54.5 ± 4.9	53.9 ± 4.7	No significant difference
DPNF (mm)	118.8 ± 11.8	118.2 ± 11.2	No significant difference

Bilateral symmetry was evident across all measured parameters. The minor numerical differences between right and left sides were statistically non-significant ($p > 0.05$), suggesting that tibial morphometry in the Andhra Pradesh population does not exhibit meaningful lateralization. This symmetry is clinically relevant for forensic identification and implant design when only one side is available.

Table 3: Descriptive statistics of derived tibial indices (N = 100)

Index	Formula	Mean ± SD	Range	Interpretation
Cnemic (Platycnemic) index	(MLDNF / APDNF) × 100	72.5 ± 10.8	55.2–89.4	Mesocnemic type (majority)
Foraminal index	(DPNF / MTL) × 100	32.1 ± 3.2	23.8–41.5	Proximal-third dominance

The cnemic index classifies the tibial shaft cross-section at the nutrient foramen level; a mean of 72.5 indicates a predominantly mesocnemic (moderately flattened) morphology typical of South Indian populations. The foraminal index confirms that the nutrient artery entry point is located in the proximal third in the overwhelming majority of bones, which has direct implications for surgical planning (e.g., avoidance of vascular injury during proximal tibial procedures).

Table 4: Distribution of nutrient foramen location according to foraminal index (N = 100)

Type	Foramen Location	Foraminal Index Range	Number of Bones	Percentage (%)
I	Proximal third	< 33.33	78	78
II	Middle third	33.33–66.66	22	22
III	Distal third	> 66.66	0	0

The nutrient foramen was never observed in the distal third. Type-I (proximal-third) location predominated (78 %), followed by Type-II (22 %). This distribution is of surgical and radiological importance, as it predicts the most common site of nutrient artery entry and helps in planning intramedullary nailing or vascularised bone grafts.

In summary, the morphometric profile of dry adult tibiae in the Andhra Pradesh population reveals moderate size variation, bilateral symmetry, mesocnemic shaft morphology, and consistent proximal-third placement of the nutrient foramen. These population-specific baseline values obtained with basic osteometric tools provide a reliable reference for forensic anthropology, orthopaedic implant sizing, and future comparative studies across Indian ethnic groups. No anomalies (double foramina or absent foramina) were encountered in the present series.

Discussion

The current osteometric study on 100 dry adult tibiae from the population of South India (Andhra) offers significant baseline data of simple and reproducible instrumentation. The mean value of maximum tibial length (369.5 ± 24.5 mm, 36.95 cm) in the present study is within the range reported by the South Indian population. It is quite comparable with the mean length of 36.79 cm ± 2.24 cm reported by Banu et al. in an ongoing study in South India from a medical college. Other series in South India have been found with similar values with means ranging from about 35.2 cm to 37.2 cm, which suggests that the general body stature of South Indian ethnic groups is stunted when compared to North Indian or western populations.[3]

There were no statistically significant differences between the right and left sides for any of the measured parameters, as there was bilateral symmetry. The present finding was in agreement with most of the previous osteometric studies relating to the tibia performed by Banu et al. who compared the dimensions of tibia sidewise and found that there were no significant differences ($p > 0.05$). This symmetry becomes useful for a clinical approach for either implant templating or forensic reconstruction of a contralateral bone when the other side is damaged or missing.[3]

APDNF = 28.4 ± 3.1 mm; MLDNF = 20.6 ± 2.9 mm; CNF = 84.5 ± 8.2 mm: all these parameters suggest a moderately robust tibial diaphysis. The tibia is moderately flattened medio-laterally, and most of the tibiae are classified as mesocnemic with a cnemicindex of 72.5 ± 10.8. This value is in close agreement with the values reported earlier in the above mentioned study (Banu et al. 2001) of South Indian sample whose cnemic index was 72.57 ± 11.0. The earlier studies conducted in South Indian region have reported cnemic index ranging from approximately 66.98 to 78.40, showing that mesocnemic morphology is common in this region.

The nutrient foramen is of importance in surgery. The mean foraminal index in the present series was 32.1 ± 3.2 with 78% occurring in the proximal third and 22% in the middle third, and none in the distal third. From all of these results, it can be seen that the results of this study are fairly comparable with those of Banu et al. who reported as mean foraminal index of 32.1, 75 percent proximal-third and 25 percent middle-third. This is similar to the findings in other studies from South India, though with a few nuances, such as 80.95% proximal in some studies,[3] which underscores the need for careful manipulation of the proximal tibia when doing intramedullary nailing, bone grafting or fracture fixation so as not to injure the nutrient artery, which can compromise the medullary blood supply and delay union.

Proximal epiphyseal breadth (71.8 ± 5.6 mm) and distal epiphyseal breadth (54.2 ± 4.8 mm) offer a valuable guide for knee and ankle arthroplasty planning. Generally these dimensions are also smaller than in North Indian or Western populations, making it even more important to design an implant with dimensions appropriate to the individual population so that it fits properly and will not produce complications like implant loosening or overhang.

These minor differences compared to the other study of South Indian region conducted by Gupta et al,[2] could be due to the difference in sample size, precise measurement landmarks used, variation in bones sampled from different sub-regions of South India or to subtle environmental and genetic variations between the districts. In the present investigation the use of simple instruments (osteometric board, vernier calipers, tape and thread) proves that reliable morphometric data can be obtained even in resource-poor environments without sacrificing accuracy.

In general, the morphometric profile developed during the present investigation from a study in Andhra Pradesh area find good agreement with the recent literature from South India mainly with Banu et al,[2] and emphasizes the need for further study in the region.

Limitation: Bones of unknown sex and age and a relatively small sample size are limitations of the study. Further, including sex determination in the future with larger multi-centric samples from various regions of both Andhra Pradesh and Telangana would help augment the database.

Conclusion

These results will help forensic anthropologists in stature and identity estimation, anatomists in teaching and orthopaedic surgeons in pre-operative planning and development of custom implants for the local population.

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Conflicts of interest

There are no conflicts of interest.

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