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Original Research Article

Morphometric analysis of Humerus bone in Indian population

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Abstract:

Background: Morphometric analysis of the humerus is of significant importance in anatomy, orthopaedics, forensic medicine, and anthropology. Population-specific morphometric data are essential for accurate implant design, surgical planning, and forensic identification, as skeletal dimensions vary across different ethnic and geographical populations.

Objectives: To study the morphometric parameters of the humerus in the Indian population and to establish baseline reference data relevant to clinical and forensic applications.

Materials and Methods: This observational morphometric study was conducted over a period of 9 months April 2025 to Dec.2025 at Patna Medical College and Hospital (PMCH), Patna. A total of 30 adult humerus bones free from gross pathological changes were analyzed. Parameters measured included maximum length of the humerus, vertical and transverse diameters of the humeral head, mid-shaft circumference, and epicondylar breadth. Measurements were taken using standard osteometric instruments. Descriptive statistical analysis was performed, and results were expressed as mean, standard deviation, and range.

Results: The mean maximum length of the humerus was 304.6 ± 18.2 mm. The mean vertical and transverse diameters of the humeral head were 43.8 ± 3.6 mm and 41.9 ± 3.2 mm, respectively. The mid-shaft circumference had a mean value of 65.4 ± 4.9 mm, while the epicondylar breadth averaged 58.7 ± 4.1 mm. Right-sided humeri showed slightly higher mean values compared to left-sided bones; however, no statistically significant side-wise differences were observed.

Conclusion: The study provides normative morphometric data of the humerus in the Indian population. These findings may be useful for orthopaedic implant design, surgical procedures, and forensic identification.

Keywords: Humerus, Morphometry, Indian population, Orthopaedics, Forensic anatomy.

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Introduction

The humerus is the longest and one of the most functionally significant bones of the upper limb, playing a crucial role in mobility, load transmission, and articulation at both the shoulder and elbow joints. Morphometric analysis of the humerus has long been an area of interest in anatomy, orthopaedics, forensic medicine, and anthropology, as variations in its dimensions provide valuable information for clinical, surgical, and medico-legal applications [1]. Accurate morphometric data are particularly important in the Indian population, where skeletal characteristics may differ significantly from those of Western populations due to genetic, nutritional, and environmental factors [2].

In orthopaedic practice, detailed knowledge of humeral dimensions is essential for the design and selection of prostheses, intramedullary nails, plates, and screws used in the management of fractures, degenerative disorders, and reconstructive surgeries of the shoulder and arm [3]. Improper implant sizing due to reliance on non-population-specific data can lead to complications such as implant failure, joint instability, restricted range of motion, and early loosening [4]. Therefore, population-specific morphometric studies of the humerus are indispensable for improving surgical outcomes and advancing personalized orthopaedic care.

From an anthropological and forensic perspective, the humerus serves as a key bone for sex determination, stature estimation, and identification of skeletal remains, especially in cases involving incomplete or fragmentary bones [5]. Various parameters such as maximum length, head diameter, shaft circumference, and epicondylar breadth have been shown to exhibit sexual dimorphism and population-specific variability [6]. Establishing baseline morphometric data for the

Indian population enhances the accuracy of forensic assessments and contributes to the development of region-specific regression formulae.

Despite the clinical and forensic importance of humeral morphometry, there remains a paucity of comprehensive data pertaining to the Indian population, particularly from eastern regions of India. Most available studies are either limited by small sample sizes or derived from skeletal collections representing different ethnic backgrounds [7]. This lack of localized data underscores the need for systematic morphometric evaluation of the humerus in Indian subjects to bridge existing knowledge gaps.

The present study aims to perform a detailed morphometric analysis of the humerus in the Indian population using a sample of 30 subjects over a study duration of 9 months April 2025 to Dec.2025 at Patna Medical College and Hospital (PMCH), Patna. The findings of this study are expected to contribute valuable baseline data that may aid orthopaedic surgeons, anatomists, forensic experts, and biomedical engineers in clinical decision-making, implant design, and forensic identification. By providing population-specific morphometric parameters, this study seeks to enhance the applicability and relevance of anatomical data in the Indian context [8].

Materials and Methods

Study Design and Setting: This was a hospital-based, observational morphometric study conducted in the Department of Anatomy in collaboration with the Department of Orthopaedics at Patna Medical College and Hospital (PMCH), Patna. The study was carried out over a period of 9 months (April 2025 to Dec.2025).

Study Sample: The study included 30 humerus bones obtained from adult Indian subjects. The bones were either derived from patients undergoing relevant orthopaedic procedures or from dry bone collections available in the anatomy department, ensuring that all specimens belonged to the Indian population. Only fully ossified and structurally intact humeri were included in the study.

Inclusion and Exclusion Criteria: Only adult humerus bones without any gross pathological changes were included. Bones showing evidence of fractures, deformities, congenital anomalies, severe osteoarthritic changes, or erosion due to prolonged preservation were excluded to avoid measurement bias.

Morphometric Parameters Studied: Each humerus was subjected to detailed morphometric analysis. The parameters measured included the maximum length of the humerus, vertical and transverse diameter of the humeral head, mid-shaft circumference, and epicondylar breadth. All measurements were taken using a standard osteometric board, digital vernier caliper, and measuring tape, as appropriate for the parameter being assessed. Measurements were recorded in millimeters.

Measurement Technique: All measurements were taken following standard osteometric techniques to ensure accuracy and reproducibility. Each parameter was measured twice by the same observer, and the average of the two readings was considered for final analysis to minimize intra-observer error.

Data Recording and Statistical Analysis: The collected data were systematically recorded in a pre-designed proforma and later entered into a Microsoft Excel spreadsheet. Statistical analysis was performed using appropriate statistical software. Descriptive statistics such as mean, standard deviation, minimum, and maximum values were calculated for each morphometric parameter. The results were analyzed to establish baseline morphometric values for the humerus in the Indian population.

Results

A total of 30 humerus bones were analyzed in the present study. All specimens were complete, fully ossified, and free from visible deformities or pathological changes, ensuring reliability of the morphometric measurements. Various parameters of the humerus were measured to establish baseline morphometric data for the Indian population.

Overall Morphometric Characteristics of the Humerus: The descriptive statistics of the measured morphometric parameters are presented in Table 1. The maximum length of the humerus ranged from 268 mm to 338 mm, with a mean value of 304.6 ± 18.2 mm. The vertical diameter of the humeral head varied between 38 mm and 51 mm, showing a mean of 43.8 ± 3.6 mm. The transverse diameter of the humeral head ranged from 36 mm to 48 mm, with a mean value of 41.9 ± 3.2 mm.

The mid-shaft circumference demonstrated values between 57 mm and 76 mm, with a mean of 65.4 ± 4.9 mm. The epicondylar breadth, an important parameter for prosthetic sizing and forensic identification, showed a minimum value of 51 mm, a maximum of 67 mm, and a mean of 58.7 ± 4.1 mm.

Table 1: Descriptive Statistics of Morphometric Parameters of the Humerus (n = 30)

Parameter	Minimum (mm)	Maximum (mm)	Mean ± SD (mm)
Maximum length of humerus	268	338	304.6 ± 18.2
Vertical diameter of humeral head	38	51	43.8 ± 3.6
Transverse diameter of humeral head	36	48	41.9 ± 3.2
Mid-shaft circumference	57	76	65.4 ± 4.9
Epicondylar breadth	51	67	58.7 ± 4.1

Side-wise Distribution of Humerus: Out of the 30 humerus bones studied, 16 bones (53.3%) were right-sided and 14 bones (46.7%) were left-sided. The side-wise distribution is shown in Table 2.

Table 2: Side-wise Distribution of Humerus Bones

Side	Number (n)	Percentage (%)
Right	16	53.3
Left	14	46.7
Total	**30**	**100**

Comparison of Morphometric Parameters Between Right and Left Sides: A comparison of morphometric measurements between right and left humerus bones is presented in Table 3. The mean maximum length of the right humerus (306.8 ± 17.6 mm) was slightly higher than that of the left humerus (302.1 ± 18.9 mm). Similarly, the mean values of humeral head diameters, mid-shaft circumference, and epicondylar breadth were marginally higher on the right side. However, these differences were not statistically significant.

Table 3: Side-wise Comparison of Morphometric Parameters (Mean ± SD)

Parameter	Right (n = 16)	Left (n = 14)
Maximum length of humerus (mm)	306.8 ± 17.6	302.1 ± 18.9
Vertical head diameter (mm)	44.1 ± 3.4	43.4 ± 3.8
Transverse head diameter (mm)	42.3 ± 3.1	41.4 ± 3.3
Mid-shaft circumference (mm)	66.1 ± 4.7	64.6 ± 5.1
Epicondylar breadth (mm)	59.2 ± 4.0	58.1 ± 4.2

The present study provides comprehensive morphometric data of the humerus in an Indian population. Considerable variation was observed in all parameters studied, reflecting population-specific skeletal diversity. The values obtained serve as baseline reference data and may be useful in orthopaedic implant design, fracture management, anthropological research, and forensic identification.

Discussion

Morphometric analysis of the humerus provides valuable insights into population-specific skeletal characteristics that have important clinical, forensic, and anthropological implications. The present study evaluated various morphometric parameters of the humerus in an Indian population and generated baseline data that may assist in implant design, fracture fixation, and skeletal identification.

In the present study, the mean maximum length of the humerus was found to be 304.6 ± 18.2 mm, which is comparable to values reported in other Indian studies but differs from those observed in Western populations. Previous studies have demonstrated that humeral length varies significantly among different ethnic groups, emphasizing the need for region-specific morphometric databases [9,10]. Such variations are attributed to genetic factors, nutritional status, lifestyle, and physical activity patterns unique to each population.

The dimensions of the humeral head are of particular importance in shoulder arthroplasty. In the current study, the mean vertical and transverse diameters of the humeral head were 43.8 ± 3.6 mm and 41.9 ± 3.2 mm, respectively. These findings align with studies conducted on Asian populations, which have consistently reported smaller humeral head dimensions compared to Western counterparts [11]. Reliance on non-population-specific implant designs may therefore result in improper prosthesis fitting, leading to complications such as limited range of motion, joint instability, and early prosthetic failure [12].

Mid-shaft circumference and epicondylar breadth are key parameters used in both orthopaedic fixation techniques and forensic identification. The mean mid-shaft circumference observed in this study (65.4 ± 4.9 mm) reflects the structural robustness of the humerus and has direct relevance in intramedullary nailing and plate fixation

procedures. Similar findings have been reported by other Indian authors, who emphasized the utility of shaft dimensions in determining appropriate implant size and strength [13].

The epicondylar breadth, with a mean value of 58.7 ± 4.1 mm, is particularly useful in sex determination and skeletal reconstruction. Several authors have demonstrated that epicondylar breadth exhibits significant sexual dimorphism and population specificity, making it a reliable parameter in forensic investigations [14]. Although sex-wise analysis was not performed in the present study due to limited sample size, the baseline values obtained may serve as reference data for future studies involving larger and sex-differentiated samples.

A slight predominance of right-sided humeri was observed in the present study, with marginally higher mean values for most parameters on the right side. Similar observations have been reported in earlier studies and are often attributed to hand dominance and differential mechanical loading [15]. However, the side-wise differences were not statistically significant, suggesting symmetrical growth patterns of the humerus in the studied population.

The findings of the present study contribute to the growing body of Indian morphometric data and highlight the importance of developing population-specific anatomical standards. The limitations of the study include a relatively small sample size and the absence of sex-wise analysis, which should be addressed in future research involving larger cohorts and advanced imaging modalities.

Conclusion

The present study provides comprehensive morphometric data of the humerus in an Indian population based on the analysis of 30 adult humerus bones. Significant variability was observed in all measured parameters, reflecting population-specific anatomical characteristics. The morphometric values obtained in this study serve as important baseline reference data for the Indian population.

These findings have direct clinical relevance, particularly in orthopaedic practice, where accurate knowledge of humeral dimensions is essential for proper implant selection, fracture fixation, and shoulder arthroplasty. Population-specific morphometric data help reduce implant mismatch and improve surgical outcomes. Additionally, the parameters studied are valuable in forensic and anthropological contexts, especially for sex determination, stature estimation, and identification of skeletal remains.

Although minor side-wise differences were observed, they were not statistically significant, indicating symmetrical growth patterns of the humerus. The main limitations of the study include a relatively small sample size and the absence of sex-wise analysis. Future studies involving larger samples, sex differentiation, and radiological assessment are recommended to further validate and expand upon these findings.

Overall, this study contributes meaningful morphometric data to the existing literature and underscores the importance of population-specific anatomical research in enhancing clinical and forensic applications.

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