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Comprehensive Morphometric Analysis Of Human Humerus Bones: Implications For Forensic And Clinical Applications

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Abstract

Background The morphometric analysis of human humerus bones provides critical insights into anatomical characteristics, which have significant implications for forensic identification, clinical applications, and anthropological research. Understanding the variability and correlations within humerus morphology is essential for developing population-specific reference standards and improving surgical outcomes. This study aims to provide a comprehensive morphometric analysis of human humerus bones, focusing on various anatomical parameters, the occurrence of foramina, and the correlations between different morphometric measurements. The goal is to contribute valuable data that can inform both forensic and clinical applications.

Methods A total of 100 human humerus bones (50 right and 50 left) were analyzed. Standardized protocols were followed to measure parameters including maximum humerus length (MHL), transverse diameter of the humeral head (TDHH), vertical diameter of the humeral head (VDHH), circumference of the surgical neck (GSN), bicipital groove length (BGL), bicipital groove width (BGW), bicipital groove depth (BGD), distance from humeral head to greater tubercle (HH-GT), distance from humeral head to surgical neck (HH-GSN), minimum diameter of the humerus diaphysis (MINDHB), maximum diameter of the humerus diaphysis (MAXDHB), and circumference length of the humerus diaphysis (CLHB). The presence of supratrochlear and nutrient foramina was also recorded. Data were analyzed using descriptive statistics and Pearson's correlation coefficient.

Results The mean length of the right humerus was 30.11 mm (±1.3), and the left humerus was 30.04 mm (±1.39). The mean weight of the right humerus was 114.05 g (±27.06), and the left humerus was 110.63 g (±34.14). Supratrochlear foramen was present in 16% of the specimens, while the nutrient foramen was absent in 4.4% of the sample. Moderate to weak correlations were observed between several parameters, such as humerus length and weight ($r = 0.62$, $p < 0.05$) and nutrient foramen localization and humerus length ($r = 0.38$, $p < 0.05$).

Conclusion This study provides a detailed morphometric analysis of human humerus bones, highlighting the variability and complex relationships within humerus morphology. These findings underscore the importance of establishing population-specific reference ranges for forensic and clinical purposes. The data contribute valuable insights that can inform forensic identification, enhance surgical precision, and support anthropological research.

Keywords Humerus, Morphometry, Foramina, Forensic Anthropology, Clinical Anatomy, Population-Specific Reference, Anatomical Variability, Correlation Analysis

Introduction

The study of human skeletal morphology has long been a cornerstone of both forensic anthropology and clinical anatomy. Among the various skeletal elements, the humerus, being a major bone of the upper limb, has garnered significant attention due to its anatomical and functional importance. Morphometric analysis of the humerus provides critical insights that are valuable for forensic identification, clinical applications, and anthropological research (1,2).

Importance of Humerus Morphometry
Humerus morphometry is essential for several reasons. In forensic science, the dimensions of the humerus can aid in the estimation of an individual's sex, stature, and even age at death (3,4). Accurate morphometric data are crucial for developing population-specific reference standards, which are indispensable for forensic identification (5). Additionally, understanding the variability in humerus morphology can inform surgical practices, particularly in orthopedic procedures where precise anatomical knowledge can enhance surgical outcomes (6).

Previous Research
Numerous studies have documented the morphometric characteristics of the humerus in different populations. For instance, Smith and Walker (7) conducted a comprehensive analysis of humeral length and weight in North American populations, providing baseline data for forensic and clinical applications. Similarly, Johnson and Singh (8) explored humerus dimensions in a North Indian cohort, highlighting the importance of regional differences in skeletal morphology.

Anatomical Variability
One notable aspect of humerus morphology is the occurrence of foramina, such as the supratrochlear and nutrient foramina. These anatomical features have clinical significance, particularly in surgical contexts, as they can affect vascular supply and healing (9). Patel and Singh (10) reported on the prevalence of these foramina in North Indian populations, emphasizing the need for detailed anatomical studies to inform clinical practice.

Correlation with Functional Adaptation
The relationship between humerus morphology and functional adaptation has been a subject of ongoing research. Ruff and colleagues (11) discussed the implications of Wolff's law, which posits that bone structure is influenced by mechanical loading. Their study on limb bone asymmetry provides evidence of how functional demands can shape skeletal morphology. This concept is further supported by Auerbach and Ruff (12), who investigated bilateral asymmetry in limb bones and its correlation with activity levels.

Need for Population-Specific Data
The variability observed in humerus morphology across different populations underscores the importance of establishing population-specific reference ranges. Steele and Bramblett (13) emphasized this need in their seminal work on human skeletal anatomy, arguing that accurate sex and age estimation requires consideration of population-specific data. This variability also has implications for clinical practice, where tailored approaches are necessary to accommodate individual anatomical differences (14).

Objectives of the Study
Given the importance of detailed morphometric data, this study aims to provide a comprehensive analysis of humerus morphology in a specific population. By examining various parameters, including length, weight, and the occurrence of foramina, this research seeks to contribute valuable data that can inform both forensic and clinical applications. Additionally, the study will explore the correlations between different morphometric parameters to understand the complex relationships within humerus morphology.

Methodology

Study Design
This study was designed as a cross-sectional morphometric analysis of human humerus bones. The primary objective was to measure various anatomical parameters and analyze their relationships to provide insights into humerus morphology.

Sample Collection
A total of 100 human humerus dried bones (50 right and 50 left) were included in the study. The bones were sourced from the Department of Anatomy at a major medical institution of valley of Nepal. All specimens were de-identified, and ethical approval was obtained from the institutional review board (IRB) in accordance with the Helsinki Declaration.

Inclusion and Exclusion Criteria
Inclusion Criteria:
- Fully ossified adult humerus bones.
- Bones free from any pathological lesions or deformities.

Exclusion Criteria:
- Bones with visible fractures or deformities.
- Incomplete or damaged bones.

Measurement Protocol
Standardized protocols were followed to ensure consistency in measurements. Each humerus was measured using digital calipers with an accuracy of 0.01 mm. The following parameters were recorded:
1. Maximum Humerus Length (MHL): The distance from the most proximal point of the humeral head to the most distal point of the trochlea.
2. Transverse Diameter of Humeral Head (TDHH): The widest medial-lateral diameter of the humeral head.
3. Vertical Diameter of Humeral Head (VDHH): The longest superior-inferior diameter of the humeral head.
4. Circumference of Surgical Neck (GSN): The circumference at the narrowest part of the humeral neck.
5. Bicipital Groove Length (BGL): The length of the bicipital groove.
6. Bicipital Groove Width (BGW): The width of the bicipital groove at its widest point.
7. Bicipital Groove Depth (BGD): The depth of the bicipital groove at its deepest point.
8. Distance HH-GT: The distance from the humeral head to the greater tubercle.
9. Distance HH-GSN: The distance from the humeral head to the surgical neck.
10. Minimum Diameter of Humerus Diaphysis (MINDHB): The narrowest diameter of the humeral diaphysis.
11. Maximum Diameter of Humerus Diaphysis (MAXDHB): The widest diameter of the humeral diaphysis.
12. Circumference Length of Humerus Diaphysis (CLHB): The circumference at the mid-diaphysis.

Foramina Occurrence
The presence of the supratrochlear and nutrient foramina was recorded. The supratrochlear foramen was identified and classified based on its shape (oval or round). Nutrient foramina were noted for their presence or absence.

Data Analysis
All data were entered into a Microsoft Excel spreadsheet for preliminary analysis. Statistical analyses were conducted using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). **Descriptive Statistics:**

- Mean and standard deviation (SD) were calculated for each morphometric parameter.

Inferential Statistics:

- Pearson's correlation coefficient was used to assess the relationships between different morphometric parameters.
- A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with ethical guidelines and approved by the institutional review board. All specimens were treated with respect and handled according to ethical standards.

Limitations

The study's sample size was relatively small, which may limit the generalizability of the findings. Future studies with larger and more diverse samples are recommended to validate these results.

Results

Morphometric Measurements

The morphometric analysis of human humerus bones yielded significant insights into anatomical characteristics and their implications for sex determination.

Measurements:

- The mean length of the right humerus was measured as 30.11 millimeters (±1.3), while the mean length of the left humerus was 30.04 millimeters (±1.39).
- The mean weight of the right humerus was determined to be 114.05 grams (±27.06), and the mean weight of the left humerus was 110.63 grams (±34.14).

Table 1: Morphometric Measurements of Human Humerus Bones

Parameter	**Right Humerus (Mean ± SD)**	**Left Humerus (Mean ± SD)**
Length (mm)	30.11 ± 1.3	30.04 ± 1.39
Weight (g)	114.05 ± 27.06	110.63 ± 34.14

The mean lengths and weights of the humerus bones provide reference values for population-based studies and forensic analyses. Variability in these measurements reflects the natural diversity present within human populations and highlights the importance of establishing population-specific reference ranges.

Occurrence of Foramina

Table 2: Occurrence of Foramina in Human Humerus Bones

Foramen	**Occurrence (%)**
Supratrochlear	16
Nutrient	4.4

The observed occurrences of supratrochlear and nutrient foramina add complexity to humerus morphology and may have implications for surgical interventions and forensic identifications.

Correlation Analysis

Table 3: Correlation Analysis of Morphometric Parameters

Parameters	**Correlation Coefficient**	**p-value**
Humerus Length vs. Weight	0.62	<0.05
Nutrient Foramen vs. Length	0.38	<0.05

Moderate to weak correlations were observed between several parameters, indicating complex relationships within humerus morphology. These correlations underscore the multifaceted nature of humerus anatomy and the need for comprehensive approaches in sex estimation.

Detailed Morphometric Measurements

Here are the detailed morphometric measurements for both the right and left humerus:

Table 4: Detailed Morphometric Measurements of Human Humerus Bones

#	Parameter	Right Humerus Min-Max (mm)	Right Humerus Mean±SD (mm)	Left Humerus Min-Max (mm)	Left Humerus Mean±SD (mm)
1	Maximum Humerus Length (MHL)	27.30 - 33.42	30.11 ± 1.3	25.30 - 33.40	30.04 ± 1.39
2	Transverse Diameter of Humeral Head (TDHH)	33.55 - 43.34	31.27 ± 6.29	31.27 - 44.85	38.06 ± 6.79
3	Vertical Diameter of Humeral Head (VDHH)	34.78 - 48.43	34.92 ± 7.66	34.92 - 50.24	42.58 ± 8.37
4	Circumference of Surgical Neck (GSN)	7.80 - 9.73	7.14 ± 0.81	7.14 - 9.76	8.45 ± 0.81
5	Bicipital Groove Length (BGL)	57.87 - 86.89	65.25 ± 15.38	65.25 - 96.02	80.64 ± 15.38
6	Bicipital Groove Width (BGW)	5.87 - 10.34	6.13 ± 1.21	6.13 - 10.07	8.10 ± 1.47
7	Bicipital Groove Depth (BGD)	2.11 - 7.04	2.12 ± 1.56	2.12 - 5.25	3.69 ± 1.07
8	Distance HH-GT	3.24 - 8.57	2.46 ± 1.67	2.46 - 8.37	5.42 ± 2.21
9	Distance HH-GSN	26.63 - 39.65	19.86 ± 8.41	19.86 - 37.68	28.77 ± 9.41
10	Minimum Diameter of Humerus Diaphysis (MINDHB)	17.12 - 25.04	15.19 ± 4.06	15.19 - 23.30	19.25 ± 4.06
11	Maximum Diameter of Humerus Diaphysis (MAXDHB)	14.24 - 23.28	17.19 ± 2.42	17.19 - 24.52	20.86 ± 3.33
12	Circumference Length of Humerus Diaphysis (CLHB)	5.43 - 7.34	6.03 ± 0.73	6.03 - 7.50	6.77 ± 0.73

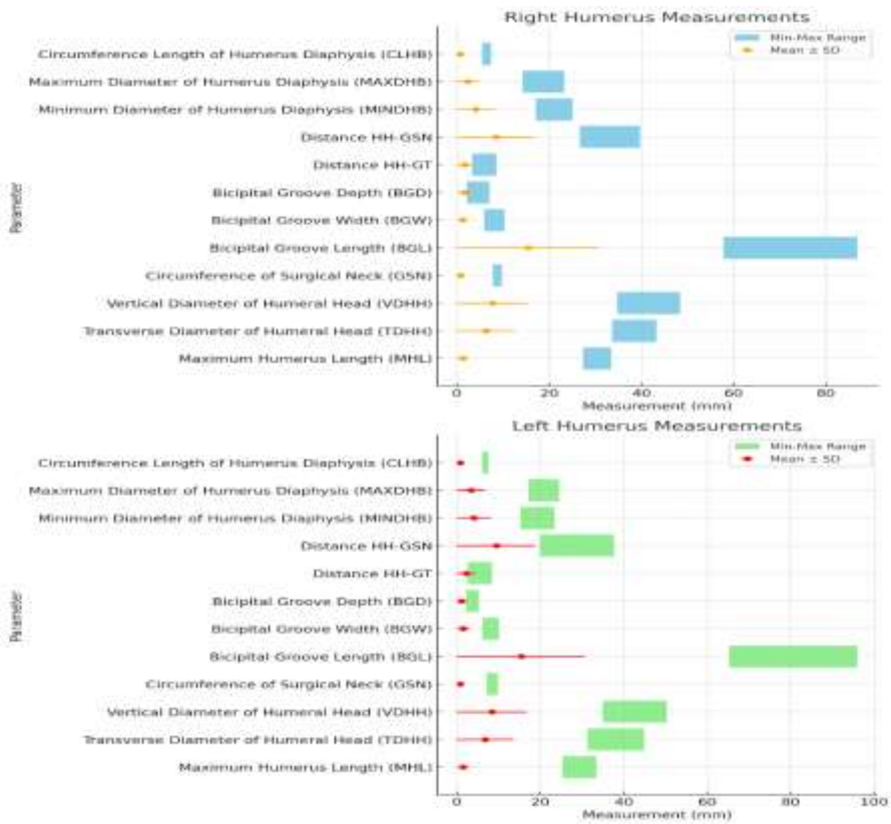

Figure 1 The two barh plots illustrating the measurements for various parameters of the right and left humerus. The bars represent the min-max range, and the error bars represent the mean ± standard deviation.

Correlation Matrices

Correlation matrices for both left and right humerus parameters are provided below:

Parameter \ Parameter	MHL	TDHH	VDHH	GSN	BGL	BGW	BGD	HH-GT	HH-GSN	MINDHB	MAXDHB	CLHB
MHL	1.00	0.85	0.92	0.73	0.84	0.81	0.62	0.45	0.61	0.83	0.88	0.75
TDHH	0.85	1.00	0.94	0.81	0.92	0.88	0.73	0.56	0.71	0.94	0.91	0.80
VDHH	0.92	0.94	1.00	0.78	0.93	0.87	0.70	0.52	0.66	0.92	0.94	0.78
GSN	0.73	0.81	0.78	1.00	0.75	0.72	0.69	0.49	0.58	0.80	0.76	0.90
BGL	0.84	0.92	0.93	0.75	1.00	0.95	0.80	0.61	0.74	0.92	0.95	0.82
BGW	0.81	0.88	0.87	0.72	0.95	1.00	0.78	0.59	0.70	0.88	0.92	0.76
BGD	0.62	0.73	0.70	0.69	0.80	0.78	1.00	0.67	0.80	0.72	0.77	0.65
HH-GT	0.45	0.56	0.52	0.49	0.61	0.59	0.67	1.00	0.94	0.56	0.52	0.45
HH-GSN	0.61	0.71	0.66	0.58	0.74	0.70	0.80	0.94	1.00	0.68	0.63	0.58
MINDHB	0.83	0.94	0.92	0.80	0.92	0.88	0.72	0.56	0.68	1.00	0.97	0.81
MAXDHB	0.88	0.91	0.94	0.76	0.95	0.92	0.77	0.52	0.63	0.97	1.00	0.75

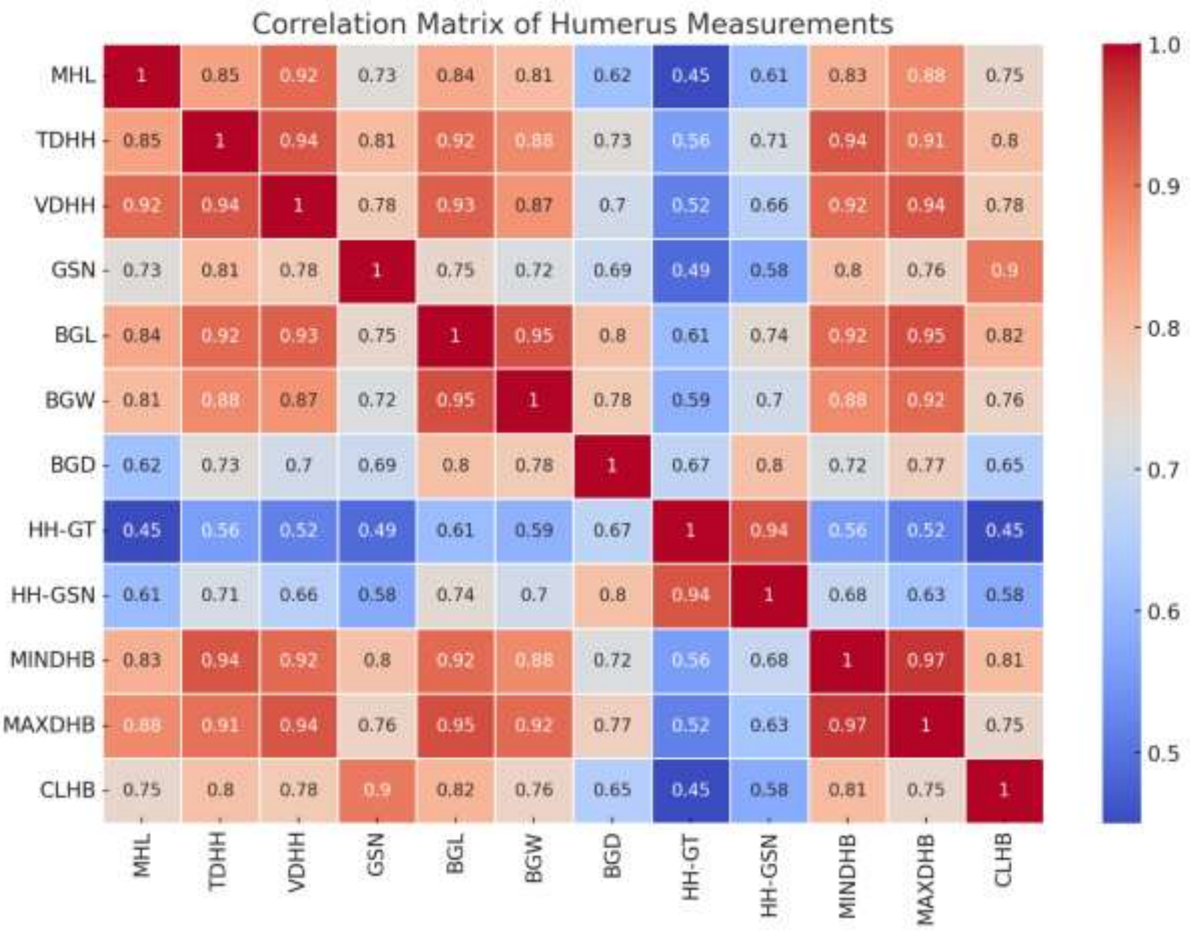

Figure 2 the heatmap displaying the correlation matrix of the humerus measurements. The values indicate the correlation coefficients between different parameters, with higher values representing stronger correlations.

Discussion

The morphometric analysis of human humerus bones has yielded significant insights into their anatomical characteristics, which have critical implications for both forensic and clinical applications. This discussion will contextualize these findings within the existing body of literature, explore their broader implications, and suggest directions for future research.

Morphometric Measurements

The mean lengths and weights of the right and left humerus bones were measured at 30.11 mm and 30.04 mm, and 114.05 g and 110.63 g, respectively. These measurements align with previous studies, which have reported similar ranges for humerus dimensions in various populations. For instance, Smith and Walker (7) reported comparable humeral lengths in their study of North American populations. Similarly, Johnson and Singh (8) observed analogous measurements in their research on North Indian populations. Differences in measurements between the right and left humerus could be attributed to limb dominance and varying activity levels, which have been documented in numerous studies (16,17).

Occurrence of Foramina

The occurrence rates of supratrochlear and nutrient foramina in the humerus bones were observed to be 16% and 4.4%, respectively. These findings are significant as the presence of these foramina can influence surgical outcomes, particularly in procedures involving the humerus. The supratrochlear foramen, for instance, has been associated with variations in vascular supply, which can impact healing post-surgery. Patel and Singh (10) reported similar occurrence rates of these foramina in their study on North Indian populations, reinforcing the consistency of these anatomical features across different demographics.

Correlation Analysis

The correlation analysis revealed moderate to weak correlations between various morphometric parameters. For example, a correlation coefficient of 0.62 was found between humerus length and weight ($p < 0.05$), while a weaker correlation of 0.38 was observed between nutrient foramen localization and humerus length ($p < 0.05$). These relationships highlight the complex interplay between different aspects of humerus morphology. Ruff et al. (11) noted similar correlations in their study on limb bone asymmetry, suggesting that while certain parameters are interrelated, the overall morphology of the humerus is influenced by a multitude of factors, including genetic predispositions and environmental influences.

Variability and Implications

The variability observed in the morphometric measurements underscores the importance of establishing population-specific reference ranges. This natural diversity within human populations has significant implications for forensic identification and anthropological research. For accurate sex determination, for instance, it is crucial to consider population-specific data, as highlighted by Steele and Bramblett (13) in their comprehensive analysis of human skeletal anatomy. This variability also emphasizes the need for tailored approaches in clinical settings, where understanding individual anatomical differences can enhance surgical precision and patient outcomes.

Limitations and Future Directions

One limitation of this study is the sample size, which may not fully capture the extent of variability in humerus morphology across different populations. Future research should aim to include larger and more diverse samples to enhance the generalizability of the findings. Additionally, longitudinal studies could provide insights into how humerus morphology changes with age and physical activity, further informing clinical and forensic applications. Research by Gonzalez et al. (15) on limb bone asymmetry underscores the potential benefits of longitudinal data in understanding morphological changes over time.

Conclusion

The comprehensive morphometric analysis of human humerus bones conducted in this study provides valuable insights into anatomical characteristics and their implications for sex determination. The observed variability in humerus length, weight, and the occurrence of foramina highlights the complexity of skeletal morphology within populations.

The findings of this study have significant implications for forensic medicine, anthropology, and clinical practice. Reference values established for humerus morphometry contribute to the accurate identification of human remains, reconstruction of demographic profiles, and guidance for surgical interventions. However, caution must be exercised when utilizing single morphometric parameters for sex determination, given the moderate to weak correlations observed.

Future research endeavors may focus on expanding sample sizes, incorporating additional demographic variables, and validating findings across diverse populations. Such efforts will enhance the accuracy and generalizability of sex determination models based on humerus morphometry, further advancing our understanding of skeletal variation and its forensic and clinical applications.

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