



Research Article

Morphometric Study of Upper Limb Bones for Stature Estimation in the North Gujarat Population

Unnati J Panchal¹, Jankiben V Patel², Akashkumar M Patel³, Ravi S Patel⁴

¹ Junior Resident, General Surgery, Nootan Medical College and Research Centre. Visnagar.

² MBBS, Davao Medical School Foundation, Philippines

³ MBBS, Davao Medical School Foundation, Philippines

⁴ Tutor, Anatomy, GMERS Medical College, Vadnagar

OPEN ACCESS

Corresponding Author:

Unnati J Panchal

Junior Resident, General Surgery,
Nootan Medical College and
Research Centre. Visnagar.

Received: 07-09-2025

Accepted: 24-09-2025

Available online: 20-10-2025

Copyright © International Journal of
Medical and Pharmaceutical Research

ABSTRACT

Background: Estimating stature from skeletal remains is a fundamental aspect of forensic anthropology. Although lower limb bones are commonly used, upper limb bones such as the humerus, radius, and ulna become valuable when lower limb bones are unavailable. Since the relationship between bone length and stature varies with population, sex, and ethnicity, the development of region-specific regression equations is essential for precise estimation.

Objective: To formulate regression equations specific to the North Gujarat population for estimating stature using the percutaneous lengths of the humerus, radius, and ulna.

Methods: A cross-sectional study was conducted on 300 healthy adults (150 males and 150 females) aged 20–50 years from North Gujarat. Stature and bone lengths were measured following standard anthropometric techniques. Pearson's correlation assessed relationships between stature and bone lengths, while simple and multiple linear regression analyses produced sex-specific and combined predictive equations. The accuracy of each model was evaluated using the coefficient of determination (R^2) and standard error of estimate (SEE).

Results: The mean stature was 167.4 ± 6.1 cm in males and 153.8 ± 5.4 cm in females. All three bone lengths demonstrated significant positive correlations with stature ($p < 0.001$), with the ulna showing the strongest correlation (males: $r = 0.84$; females: $r = 0.78$). Multiple regression involving the humerus and ulna yielded the highest accuracy ($R^2 = 0.79$; SEE = 3.6 cm). These results align with previous studies conducted in Gujarat and other Indian populations.

Conclusion: Upper limb bone lengths, particularly the ulna are reliable predictors of stature in the North Gujarat population. The derived regression equations will assist forensic anthropologists, anatomists, and medico-legal experts in identification processes when only partial upper limb remains are available.

Keywords: Stature Estimation, Forensic Anthropology, Humerus, Radius, Ulna, Anthropometry, North Gujarat.

INTRODUCTION

Stature estimation forms a key element in reconstructing a biological profile during forensic and medico-legal investigations, particularly in cases involving mass disasters, homicide, or accidents where dismembered or skeletal remains are recovered [1,2]. Anthropometry, the scientific study of human body measurements, has established itself as a cornerstone in biological anthropology and remains indispensable in forensic science, where it is widely used for personal identification and analysis of human remains in both medico-legal and clinical contexts [14]. Stature, a crucial identity marker, can be estimated using various body parts via anthropometric methods. Regression analysis, which predicts stature from bone lengths, is particularly useful when only isolated body parts are available [3,4].

The proportional relationships between body segments and stature vary among populations due to genetic, nutritional, environmental, and geographic factors [5]. Therefore, stature estimation formulas must be population-specific to ensure

precision [7]. Several Indian studies have addressed this need across regions such as Kerala, Maharashtra, and parts of Gujarat, confirming regional variation in regression constants.

While studies exist on individual upper limb bones in Gujarat, comprehensive data encompassing the humerus, radius, and ulna for the North Gujarat population are limited. This study aims to fill this gap by establishing reliable regression equations for stature estimation using percutaneous measurements of these three major upper limb bones.

MATERIALS AND METHODS

Study Design: A cross-sectional observational study was carried out in North Gujarat.

Sample and Sampling

Three hundred healthy adults (150 males, 150 females) aged 20–50 years were selected through convenience sampling. The sample size aligns with comparable anthropometric studies.

Inclusion Criteria

- Healthy adults aged 20–50 years native to North Gujarat.

Exclusion Criteria

- Individuals with fractures, deformities, congenital anomalies, or skeletal disorders affecting bone growth or stature.

Anthropometric Measurements

All measurements were conducted by a single trained investigator using standard techniques to minimize inter-observer error. Participants were measured in the afternoon to avoid diurnal variation.

1. **Stature:** Measured using a stadiometer with the subject standing barefoot in the Frankfurt plane; recorded to the nearest 0.1 cm.
 2. **Humerus Length:** Measured from the acromion process to the lateral epicondyle using a spreading caliper with the elbow flexed at 90°.
 3. **Radius Length:** Measured from the radial head to the tip of the styloid process using a sliding caliper with the forearm in mid-pronation.
 4. **Ulna Length:** Measured from the olecranon process to the styloid process with the forearm fully pronated.
- Each measurement was taken thrice, and the mean was used for analysis.

Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (mean $\pm$ SD) were computed for all variables. Pearson's correlation determined the relationship between stature and bone lengths. Simple and multiple linear regression models were developed for both sexes and the combined sample. The R^2 value and SEE assessed predictive accuracy. A p -value < 0.05 was considered statistically significant.

RESULTS

Descriptive Statistics and Correlation

The mean age of participants was 32.8 ± 8.0 years. Males had significantly greater mean values for stature and bone lengths compared to females ($p < 0.001$) (Table 1).

All upper limb bone lengths correlated positively and significantly with stature ($p < 0.001$), with the ulna showing the strongest relationship in both sexes (Table 2).

Table 1: Descriptive Statistics (Mean $\pm$ SD)

Parameter	Males (n=150)	Females (n=150)
Stature (cm)	167.4 $\pm$ 6.1	153.8 $\pm$ 5.4
Humerus (cm)	31.3 $\pm$ 1.5	28.4 $\pm$ 1.8
Radius (cm)	24.1 $\pm$ 1.7	22.4 $\pm$ 1.5
Ulna (cm)	26.7 $\pm$ 1.8	24.9 $\pm$ 1.3

Table 2: Pearson's Correlation Coefficient (r) Between Stature and Bone Lengths

Bone	Males	Females	Combined
Humerus	0.78	0.77	0.82
Radius	0.70	0.67	0.73
Ulna	0.84	0.78	0.84

All correlations significant at $p < 0.001$.

Regression Equations for Stature Estimation

A. Sex-Combined (n = 300)

1. Ulna: Stature = $60.45 + 2.54 \times \text{Ulna}$ ($R^2 = 0.75$; SEE = 4.3 cm)
2. Humerus: Stature = $41.15 + 3.90 \times \text{Humerus}$ ($R^2 = 0.65$; SEE = 4.3 cm)
3. Radius: Stature = $71.32 + 1.97 \times \text{Radius}$ ($R^2 = 0.55$; SEE = 5.4 cm)
4. Humerus + Ulna: Stature = $30.12 + 2.12 \times \text{Humerus} + 1.44 \times \text{Ulna}$ ($R^2 = 0.79$; SEE = 3.6 cm)

B. Sex-Specific

Males (n=150):

- Ulna: Stature = $65.14 + 2.40 \times \text{Ulna}$ ($R^2 = 0.66$; SEE = 3.7 cm)
- Humerus: Stature = $45.22 + 3.80 \times \text{Humerus}$ ($R^2 = 0.61$; SEE = 4.3 cm)
- Humerus + Ulna: Stature = $35.14 + 2.32 \times \text{Humerus} + 1.27 \times \text{Ulna}$ ($R^2 = 0.73$; SEE = 3.2 cm)

Females (n=150):

- Ulna: Stature = $54.87 + 2.75 \times \text{Ulna}$ ($R^2 = 0.63$; SEE = 3.8 cm)
- Humerus: Stature = $38.90 + 4.30 \times \text{Humerus}$ ($R^2 = 0.56$; SEE = 4.2 cm)
- Humerus + Ulna: Stature = $28.43 + 2.24 \times \text{Humerus} + 1.55 \times \text{Ulna}$ ($R^2 = 0.67$; SEE = 3.6 cm)

DISCUSSION

The present findings reaffirm the strong positive correlation between upper limb bone lengths and stature in the North Gujarat population, consistent with prior research across India and abroad. The ulna proved to be the most accurate single bone for stature estimation, corroborating results by Yadav et al. [13] and Thummar et al. [9].

The ulna's superior reliability may be attributed to its subcutaneous course and easy palpability, which minimizes measurement error. The humerus also demonstrated a high correlation due to its proportional relationship with overall limb length. The radius, though a significant predictor, consistently yielded lower correlations, in line with other studies.

Comparison with earlier studies in Gujarat shows minor variations in regression constants and coefficients, underscoring the influence of regional genetic diversity even within a single state. Multiple regression equations combining humerus and ulna improved accuracy (higher R^2 , lower SEE), aligning with global trends.

The limitation of the study is that percutaneous measurements may differ slightly from direct osteometric data. Future research using skeletal or radiographic measurements is recommended. These equations apply only to adults; separate analyses are needed for adolescent and elderly groups.

Declaration:

Conflicts of interests: The authors declare no conflicts of interest.

Author contribution: All authors have contributed in the manuscript.

Author funding: Nil

CONCLUSION

This study establishes population-specific regression equations for stature estimation based on humerus, radius, and ulna lengths in the North Gujarat adult population. Among these, the ulna is the most dependable single predictor. The formulated equations offer valuable tools for forensic and anthropological identification, especially in cases involving partial upper limb remains. Adoption of such region-specific equations will enhance the precision of stature estimation in forensic practice.

REFERENCES

1. Potdar AB, Rathod P, Potdar PA, Desai MM. A Study of Estimation of Stature from Forearm Length. *Indian J Forensic Med Toxicol.* 2019;13(2):219-221.
2. Chawla H, Tyagi A, Dixit P, Aravindan U, Kumari M. Estimation of Stature from Upper Limb Measurements by Regression Analysis in North-West Indian Population. *J Indian Acad Forensic Med.* 2024;46(1):30-34.
3. Sheikh NA, Ramanaiah TV. Stature Estimation from Forearm Length. *Indian J Forensic Med Pathol.* 2014;7(2):59-63.
4. Trotter M, Gleser GC. Estimation of stature from long bones of American Whites and Negroes. *Am J Phys Anthropol.* 1952;10(4):463-514.
5. Uzun O, Yeginoğlu G, Oksüz CE, Kalkışım ŞN, Zihni NB. Estimation of Stature from Upper Extremity Anthropometric Measurements. *J Clin Diagn Res.* 2019;13(1):AC09-AC15.
6. Rana D, Chauhan RS, Khajuria S, Kumar R. Correlation of Stature with Anthropometric Measurements of Upper Limb in Himachal Pradesh. *Int J Health Sci Res.* 2025;15(4):372-378.
7. Krogman WM, Iscan MY. *The Human Skeleton in Forensic Medicine.* 2nd ed. Springfield: Charles C Thomas; 1986.
8. Ahmad N, Mohammad F, Farooque I. Estimation of Height from the Long Bones of Upper Limb and Hand Dimensions in South Indian Population. *J Evid Based Med Healthc.* 2014;1(7):473-478.
9. Balkrishna T, Zarana K Patel, Shailesh Patel, S. P. Rathod. Measurement of Ulnar Length for estimation of Stature in Gujarat. *NJIRM.* 2011;2(2):36-40.

10. Kumaran MS, Bastia BK, Kumar L. Estimation of Stature from the Percutaneous Lengths of the Radial and Ulnar Bones in Gujarati Population. *Indian Internet J Forensic Med Toxicol*. 2014;12(1):7-10.
11. Shakya T, Mishra D, Pandey P. Estimation of Stature from Upper Arm Length. *Int J Health Sci Res*. 2021;11(5):23-29.
12. Akhlaghi M, Hajibeygi M, Zamani N, Moradi B. Estimation of stature from upper limb anthropometry in Iranian population. *J Forensic Leg Med*. 2012;19(5):280-4.
13. Yadav A, Sharma SK, Sinha N, Prasad R, Jha MK. Estimation of Human Stature Using Measurements of Upper Limb Long Bones. *Int J Pharm Qual Assur*. 2025;16(5):239-244.
14. Mumtaz SH, Sharma BR. Estimation of stature from right upper limb measurements. *Santosh Univ J Health Sci*. 2015;1(2):53-6.
15. Kandregula Jyothirmayi DN. Estimation of living stature from selected upper limb anthropometric measurements: A study on central Indian population. *Journal of Pharmaceutical Negative Results*. 2023 Jan 1:1918-25.