

A Morphometric Study of Distal Humeral Parameters of Telugu Population and Estimation of Humeral Length by Regression Analysis

Sinchal Datta

Associate Professor, Department of Anatomy, GITAM institute of medical sciences and Research.
Visakhapatnam, Andhra Pradesh

How to cite this article: Sinchal Datta. A Morphometric Study of Distal Humeral Parameters of Telugu Population and Estimation of Humeral Length by Regression Analysis. Indian Journal of Forensic Medicine and Toxicology/ Volume 19 No. 3, July - September 2025.

Abstract

Background: Long bones of human skeletal remains are useful for Forensic analysis, stature estimation and determination of sex. Aim of the study is to use morphometric data of distal Humerus for estimation humeral length by regression analysis and for aiding orthopaedic Surgeons in preparation of pre-contoured and locked anatomical plates for rehabilitation of distal Humerus fractures.

Material and Methods: Study was conducted on 211 unpaired dry humeri (107 right and 104 left) from the collection of Department of Anatomy of a Medical college in Andhra Pradesh, Using slide calliper and Osteometric board.

Results: The mean of maximum length of humeri of right/ left side were $307.83 + 20.74 / 305.58 + 22.93$. A strong positive correlation was observed between Humeral length and Distance between medial and lateral epicondyle (0.67 / 0.69), Distance between medial margin of Trochlea to Capitulum (0.68 / 0.65), Distance between Medial epicondyle to Capitulum (0.65 / 0.60) , length of medial flange of Trochlea (0.64 / 0.69) and length of the Lateral Flange of the Trochlea (0.52/0.63) of right and left Humeri.

Conclusion: The morphometric parameters of Distal end of right humeri were generally found to be greater than that of left humeri. There is a strong correlation between the Distal morphological parameters and the humeral length, except for anterior posterior diameter of Trochlea (D6). In absence of intact bones, the Distal Humeral landmark distances can also be used for Humeral length estimation and subsequent stature estimation.

Key word: Distal, Humerus, Regression, Correlations, Morphometric

Introduction

Genetic factors like race, environment and lifestyle influence the morphometric measurements

of Humeral parameters. Anthropometric techniques are used in Study of dry bones for Stature estimation, Determination of sex and racial traits of a person. Anthropometric measurements of Long bones have

Corresponding Author: Sinchal Datta, Associate Professor, Department of Anatomy, GITAM institute of medical sciences and Research. Visakhapatnam, Andhra Pradesh.

E-mail: sinchal37@gmail.com

Submission date: Apr 7, 2025

Acceptance date: May 27, 2025

Published date: July 10, 2025

This is an Open Access journal, and articles are distributed under a Creative Commons license- CC BY-NC 4.0 DEED. This license permits the use, distribution, and reproduction of the work in any medium, provided that proper citation is given to the original work and its source. It allows for attribution, non-commercial use, and the creation of derivative work.

provided reliable correlations with stature and exhibit sexual dimorphism but vary across various populations.

In archaeological studies stature estimated from human skeletal remains is an essential step in assessing health, sexual dimorphism, and general body size trends among past populations^[1]. Estimation of living stature and humeral length can be done from fragmented Humeral remains, in the absence of more appropriated long bones, as femur or tibia^[2,3]. Stature and general body size estimation from skeletal remains help in identification of unidentified war victims and missing persons in medico legal cases. So it has got enormous potential for use in Medical fields, Forensic science and state of Law.

Estimation of stature from a single extremity bone is a common forensic practice^[4] and many regression equations are given by various workers. Since 1996, the Trotter formulae, have been used almost without exception. In 2002 using bones from unidentified Bosnian and Croatian males victims of war, Ross and Konigsberg^[5] presented new formulae for stature estimation for Balkans. The same year, 2002, in his master thesis, Sarajlić also presented formulae for stature estimation of Bosnian population. The research was undertaken on male cadavers. The cadaver length was measured directly and the length of the long bones was obtained from radiographs.

The Femur is generally considered the best long bone for estimating stature. Pelvic bones and post cranial elements are used for determination of sex from archeological remains and are more accurate than Skull, but skull is frequently used as it is better preserved (Novotny et al,1993) but inter observer discordance affects the Reliability of assessment Sex from Cranial Traits^[6].

Humerus, Radius & Ulna are the bones used for stature estimation in absence of Femur and Tibia. Stature estimation can be done by measurement of the Humerus according to the study of Munoz et al^[7]. For this purpose Humerus can be used alone or collectively with other bones of upper limbs for the determination of sex and the estimation of stature

of an individual^[8]. In the absence of a complete Humerus, the Humeral fragments are used for determination of the full humeral length^[9].

The anthropometric parameters of the Humerus e.g. its head diameter and epicondyle width can be used to determine sex^[10]. Some studies show that maximum length of Humerus and the vertical diameter of the head of the Humerus are useful to determine the gender of skeletal remains^[11]

Fractures of the humeral shaft in individuals over 65 years of age are becoming increasingly common, correlating with the rise in life expectancy and the prevalence of osteoporosis^[12] Correlations between different measurements between the anatomical landmarks of the Distal Humerus will help the orthopedic surgeon in reconstructive surgery.

This study will provide morphometric data of the Distal humerus of Telugu population, which can be used in reconstructive surgeries by Orthopaedic surgeons for complex fractures involving damage to the distal end of arm bone. This study will provide data for improved prosthesis and precontoured implants development, as Total elbow arthroplasty (TEA) is increasingly becoming a popular option for non-reconstructable Distal Humeral fractures in osteoporotic patients. Limited study has been done in India and abroad towards collection of Distal Humeral Morphometric data, they show variances across race & sex and they can vary due to change in the mode of living. Thus the Prosthetic design will be population and sex specific and studies are needed to provide such data for appropriate prosthetic manufacture.

Material and methods

Materials:

211 dry unpaired adult Humerus bone of unknown age and sex, from the bone banks of Department of Anatomy of private medical college in Andhra Pradesh were considered for the current study. They were segregated to determine whether they belonged to the right or the left side 107 bones were right sided Humerus & 104 were left sided Humerus. Ethical committee clearance was obtained.

Whole bones without any deformities or fracture lines and broken ends were included. Bones with

deformities due to malignant lesions were excluded from the study. Every measurement was taken three times by different persons to eliminate bias.

Methods:

Sample size selection: The sample size depends on the Population size, Confidence level which corresponds to a Z-score, Margin of error (E) and Standard deviation. Cochran's Formula can be used for sample size (N) s shown below

$$N = Z^2 * p(1-p)/E^2$$

p = Population proportion

The Z-score for 95% confidence level is 1.96 and assuming a margin for error of 5% (0.05) the maximum sample size is ~384. As we have a sample size of 211 data the margin of error comes to around ~7%.

Sampling Technique: There are two type of sampling techniques, Probability Sampling & Non-Probability Sampling. As the bone samples used for this study are from the bone bank of a medical college, which were segregated based on some inclusion and exclusion criteria, the sampling method qualifies for Non-Probability Sampling type namely Purposive Sampling and Convenience Sampling without bias.

The maximum length of Humerus was measured using a Osteometric board and morphological Parameters of the Humerus was measured using Vernier calipers. The standard Morphological parameters listed below measurements were recorded **Ref Fig:1**

D1 : The length of Humerus bone measured from the tip of the head of the Humerus to the transverse line passing at the apex of the Trochlea.

D2 : transverse distance between the medial and lateral Epicondyles.

D3 : transverse distance from the Medial Margin of Trochlea to Capitulum.

D4 : horizontal distance from the medial Epicondyle to the Capitulum,

D5 : the maximal Transverse diameter of the Trochlea.

D6 : Anteroposterior diameter of the Trochlea at the mid part of the Trochlea.

D7 : Maximal length of the Medial Flange of the Trochlea.

D8 : Maximal length of the Lateral Flange of the Trochlea.

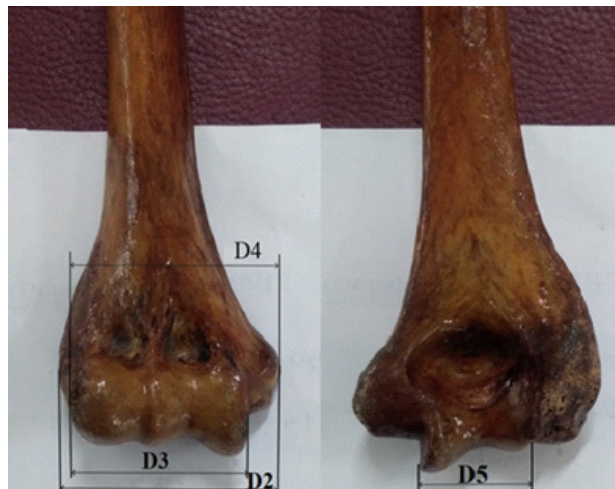


FIG 1: Distal humeral parameters

Results

Data was collected separately for Right and left humeri and was captured into MS Excel sheets Data was checked for outlier data. Thereafter, Microsoft Excel Data analysis package was used to obtain descriptive statistics separately for Right and left humeri samples for computing Mean, minimum & maximum length and Standard deviations ref **Table-1**

Regression analyses were subsequently performed. Firstly humeral length was regressed on various morphometric parameters of the distal end. Pearson's Correlations coeff (r), Coefficient of Determination (r^2) and SEE (Standard error of Estimate) was computed. The linear regression equations were derived for the estimation of Humeral length using individual distal humeral parameters. Humeral length was noted to be having a strong correlation with the distal morphometric parameters a shown in **Table: 2**. All the correlations have highly significant F values ($p < 0.001$).

The SEE for all the equations ranged between 16.57 to 18.65mm / 15.49 to 19.29 mm for Left / Right Humeri.

Table 1: Statistical analysis of the humeral dimensions for left & right Humerus (mm)

| Parameters | Mean + SD (mm) | | Minimum(mm) | | Maximum(mm) | |
|------------|----------------|----------------|-------------|--------|-------------|--------|
| | Right Humerus | Left Humerus | right | Left | right | Left |
| D1 | 307.83 ± 20.74 | 305.58 ± 22.93 | 265.00 | 255.00 | 381.00 | 376.00 |
| D2 | 57.44 ± 4.68 | 56.50 ± 5.0 | 47.80 | 45.50 | 72.00 | 69.40 |
| D3 | 39.69 ± 3.51 | 39.87 ± 4.41 | 32.00 | 31.90 | 49.00 | 57.80 |
| D4 | 54.53 ± 4.78 | 53.24 ± 5.03 | 42.00 | 42.80 | 70.50 | 65.50 |
| D5 | 24.23 ± 2.7 | 23.63 ± 2.53 | 18.80 | 18.50 | 29.60 | 34.00 |
| D6 | 15.24 ± 2.39 | 14.92 ± 2.10 | 10.50 | 10.00 | 22.50 | 21.00 |
| D7 | 23.48 ± 2.54 | 23.34 ± 2.44 | 17.50 | 17.20 | 32.00 | 31.00 |
| D8 | 17.66 ± 2.24 | 17.56 ± 2.10 | 13.00 | 11.20 | 25.00 | 26.00 |

Table 2: Regression equations, Pearson's Correlation, Coeff of Determination and Standard error of Estimate.

| Parameter (X) | Regression equations (Humeral length= A * X + B) | | Pearson's Correlation coeff | | R2 (Index of determination) | | SEE(mm) | |
|---------------|---|----------------------|--------------------------------|------|--------------------------------|--------|---------|-------|
| | Right Humerus | Left Humerus | Right | Left | left | Rights | left | Right |
| D2 | y = 2.9657x + 137.49 | y = 3.1647x + 126.76 | 0.67 | 0.69 | 0.48 | 0.45 | 16.69 | 15.49 |
| D3 | y = 4.0319x + 147.82 | y = 3.3757x + 170.97 | 0.68 | 0.65 | 0.42 | 0.46 | 17.59 | 15.52 |
| D4 | y = 2.8098x + 154.62 | y = 2.7264x + 160.43 | 0.65 | 0.60 | 0.36 | 0.42 | 18.46 | 15.87 |
| D5 | y = 4.1796x + 206.58 | y = 5.3594x + 178.94 | 0.54 | 0.59 | 0.35 | 0.30 | 18.59 | 17.48 |
| D6 | y = 3.2807x + 257.84 | y = 6.4146x + 209.84 | 0.38 | 0.59 | 0.34 | 0.14 | 18.65 | 19.29 |
| D7 | y = 5.2157x + 185.38 | y = 6.522x + 153.36 | 0.64 | 0.69 | 0.48 | 0.41 | 16.57 | 16.02 |
| D8 | y = 4.8483x + 222.22 | y = 6.9295x + 183.88 | 0.52 | 0.63 | 0.40 | 0.28 | 17.81 | 17.74 |

Discussion

It is a common practice to estimate Humeral length and Human stature from Regression equations developed using human long bone and their fragments^[13]. The statistical method of regression analysis has been used in the estimation of stature from intact long bones of the upper and lower limbs for different populations like Americans whites and negroes by Trotter and Gleser, 1952^[14], data from Americans after Korean war was used to re-evaluate the previous regression equations by Trotter and Gleser in 1958^[15], for South Africans by Bidmos et al^[16] and Turkish by Celbis and Agritmis, 2006^[8]. Whole length of Humerus can be estimated from measurement of proximal or distal fragments.

But from the data analysis result we found that all the parameters of lower end of Humerus are having statistically significant correlation with the whole length of the Humerus. This information may

be useful for the cosmetic surgery in fracture of lower end of Humerus as well as for preparing prosthesis. But for a growing bone this may not be useful.

With advances in osteosynthesis, anatomically pre-molded locked plates, reinforced Y-plates, and Lecestre plates are used for stabilization & rehabilitation of complex distal humeral fractures^[17]. Cobb and Morrey's 1997 study on 20 elderly patients (21 elbows) of mean age of 72 years, who had underwent TEA for acute distal Humerus fractures, reported excellent results

An Anthropometric study of paired humeri by Colin P. McDonald et al concluded that the anthropometric features of the distal Humerus of both sides that are used during elbow surgery are similar. Hence Preoperative imaging of the contralateral normal elbow should be considered in patients with periarticular bone loss where referencing anatomical landmarks of the injured side is not possible. This

information can be used as part of a preoperative plan to determine the ideal position of the implant, for ligament reconstruction or external fixator during surgery in combination with computer-assisted elbow surgery^[18].

Table 3: Comparison with other studies

| Parameters | Group | Siva Narayana and Himabindu ^[19] (100 humerus) | Salles et. al ^l (40 humerus) | Ashiyani et al ^[20] (100 humerus) | Shivani Azhagiri ^[21] et al (100 humerus) | Present study 211 humerus |
|------------|-------|---|---|--|--|---------------------------|
| D1 | Right | - | 313±23 | 303.9±16.6 | 309.98±26.58 | 307.83 + 20.74 |
| | Left | - | 305±16 | 303.2±15.8 | 303.40±18.41 | 305.58 + 22.93 |
| D2 | Right | 58.0±4.0 | 58.0±6 | 56.6±3.6 | 57.55±4.39 | 57.44 ± 4.68 |
| | Left | 57.0±4.6 | 57.0±4 | 55.8±4.2 | 56.91±4.07 | 56.50 ± 5.0 |
| D3 | Right | 40.7±6.3 | 40.0±4 | 38.7±2.5 | - | 39.69 ± 3.51 |
| | Left | 41.0±6.8 | 39.0±4 | 39.0±3.0 | - | 39.87 ± 4.41 |
| D4 | Right | 56.3±3.7 | 58.0±5 | 54.2±3.3 | 55.18±4.19 | 54.53 ± 4.78 |
| | Left | 56.0±4.5 | 56.0±4 | 53.9±4.1 | 54.07±3.92 | 53.24 ± 5.03 |
| D5 | Right | 22.4±2.2 | 24.0±3 | 22.6±1.8 | 24.76±2.34 | 24.23 ± 2.7 |
| | Left | 22.4±2.2 | 24.0±2 | 22.4±2.0 | 24.76±2.46 | 23.63 ± 2.53 |
| D6 | Right | 15.6±1.8 | 16.0±2 | 14.5±1.5 | 17.16±1.89 | 15.24 ± 2.39 |
| | Left | 15.6±1.8 | 16.0±1 | 14.5±1.7 | 16.13±2.05 | 14.92 ± 2.10 |

Conclusion

Knowledge of the morphometric parameters of Humerus segments are important in forensic studies and in archeological investigations for determining the racial traits like stature. It can be used by Surgeons for treatment of the distal humeral fractures towards early rehabilitation of the patients.

Attempt was made to in the present study, to use Morphometric parameters of Telegu population for estimating Humeral Length by regression analysis, as no such study was found available. Estimation of Humeral length from Distal humeral parameters using Regression analysis can be done for other Indian Population with different genetic and racial traits for comparison. As Regression analysis is an accepted method for estimation of length of long bones and living height of individuals, from measurements of long bones fragments and their maximum length. Regression equations were generated to estimate Humeral length (for both left and right) using morphometric parameters D2, D3,

D4, D5, D7 and D8 are shown in **Table-2**. They have a Pearson's correlation ranging from 0.52 to 0.68 and SEE ranging from 16.57 to 18.65mm / 15.49 to 19.29 mm (Right/ Left Humerus) indicating a moderately strong positive correlation between Humeral length and the mentioned morphometric parameters.

Any regression analysis is based on a representative quality data. Limitation of this study lies in the fact that the data obtained were not segregated based on Sex and age. Future research using CT based methods can provide segregated Distal humeral data. The equations and correlations would have been better if the data available had been paired and could have been segregated based on sex & age.

Conflict of Interest: None

Source of Funding: None

Ethical Clearance: Approval date: 01/05/2024

Reference approval no: GIMSR/Admin/Ethics/ approval/IEC-293/204

Permission for the study was taken from the Institutional Ethics Committee of GITAM institute

of medical sciences and Research, Visakhapatnam, Andhra Pradesh. The bones used in the study are from the collection of the Department of Anatomy, GITAM institute of medical sciences and Research.

References

- Salles, Carvalho, Silva, Santana. Reconstruction of humeral length from measurements of its proximal and distal fragments. *Brazilian Journal of Morphological Sciences*. 2009.; 26((2)): p. 55-61.
- Hoppa RD, Gruspier KL. Estimating diaphyseal length from fragmentary subadult skeletal remains: implications for palaeodemographic reconstructions of a southern Ontario ossuary. *American Journal of Physical Anthropology*. 1996 July; 100(3): p. 341-354.
- Steele DG, McKern TW. A method for assessment of maximum long bone length and living stature from fragmentary long bones. *American Journal of Physical Anthropology*. 1969 September; 31(2): p. 215-227.
- B R, Mujumdar RD. Stature estimation from femur and humerus by regression and autometry. *Acta Anatomica*. 1976 July; 94(2): p. 311-20.
- Ross AH, Konigsberg LW. New formulae for estimating stature in the Balkans. *Journal of Forensic Sciences*. 2002;(47(1)): p. 165-7.
- Walrath DE, Turner P, Bruzek J. Reliability test of the visual assessment of cranial traits for sex determination. *AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY* 125. 2004 October; 125(2): p. 132-137.
- Munoz JI, Linares-Iglesias M, Suarez-Penaranda JM, Mayo M, Miguens X, Rodriguez-Calvo MS, et al. Stature estimation from radiographically determined long bone length in a Spanish population sample. *Journal of Forensic Sciences*. 2001 March; Volume: 46(Issue: 2): p. 363-366.
- Celbis O, Agritmis. Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. *Forensic Science International*. 2006 May 10; Volume 158(Issues 2-3).
- Wright LE, Vásquez A. Estimating the length of incomplete long bones: Forensic standards from Guatemala. *AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY*. 2003; 120(3): p. 233-251.
- Albanese, F.V. Cardoso, R Saunders. Universal methodology for developing univariate sample-specific sex determination methods: an example using the epicondylar breadth of the humerus. *Journal of Archaeological Science*. 2005 January; Volume 32(Issue 1): p. 143-152.
- Khan MA, Humara G, Mansor Nizami S. Determination of Gender from Various Measurements of the Humerus. *Cureus*. 2020 Jan; 12(1).
- Abaydi, Bouziani T, Tbatou A, Radi. Distal humerus fractures in subjects over 65 years old: about 62 cases in Moroccan population. *Pan African Medical Journal*. 2024 June; 48(1).
- Yasar İscan M, Steyn M. *Human Skeleton in Forensic Medicine: CHARLES C THOMAS, Springfield,;* 2013.
- Trotter M, C. Gleser G. Estimation of stature from long bones of American Whites and Negroes. *American Journal of Biological Anthropology*. 1952 December; 10(4): p. 463-514.
- Trotter, C. Gleser. A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. *American Journal of Biological Anthropology*. 1958 March; Vol 16(1): p. 79-123.
- A. Bidmos, Brits. Updated lower limb stature estimation equations for a South African population group. *South African Journal Science*. 2020 May; Vol 116(5/6).
- Lecestre, Dupont, Lortat Jacob A, Ramadier. Severe fractures of the lower end of the humerus in adults. *Rev Chir Orthop Reparatrice Appar Mot*. 1979 Jan-Feb; 17(5): p. 11-23.
- McDonald C, King, Peters T, Johnson. An anthropometric study of the distal humerus with implications towards contralateral registration. In *Orthopaedic Proceedings*; 1 March 2010. p. 14.
- Himabindu DA, Amudalapalli Siva N. The Morphometric Study of Distal end of Humerus. *PARIPEX - INDIAN JOURNAL OF RESEARCH*. 2018 April; Volume-7(4): p. 136-137.
- A. Ashiyani Z, Solanki S, Mehta CD. The Morphometric Measurement of Segments of Humerus. *Journal of Research in Medical and Dental Science*. 2016 January - March; 4(1): p. 38-40.
- Azhagiri, Venkatesh, Ramasamy, Ramachandran K. Study on morphometry of distal humerus and its clinical correlations. *BIOINFORMATION*. 2024 August; 20(8): p. 859-861.