Anatomy Section

Original Article

# Regression Equation for Estimation of Length of Humerus from its Segments: A South Indian Population Study

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## ABSTRACT

**Introduction:** The aim of the present study was to estimate the length of the humerus from the measurements of proximal and distal segments of humerus in South Indian population using regression equation. This becomes essential for archaeologists, anthropologists and forensic investigators, even when a fragment of bone is available. The current study was therefore focussed on proximal and distal segments of humerus and using their measurements, the length of the humerus was estimated.

**Methods:** A total of 170 humeri, 82 right and 88 left were used for our analysis. Maximum length of humerus, vertical and transverse diameter of proximal segment, transverse diameter and biepicondylar width of distal segment were measured using anthropometric techniques.

**Results:** With the measurements obtained descriptive statistics, linear regressions and regression equations for both sides were derived to estimate the length of the humerus in South Indian population. In the right humeri, multiple linear regression of vertical diameter of superior articular surface alone showed significant changes in maximum humeral length contributing up to 78%. In the left humeri, multiple linear regressions of vertical diameter of superior articular surface as well as transverse diameter of inferior articular surface showed significant changes in maximum humeral length ( P<0.01).

**Conclusion:** The result of our study concludes that the length of the humerus can be estimated from the measures of proximal and distal segments of humerus of both sides.


**Key Words:** Proximal and distal segments of humerus, Length, Regression equation, South Indian population

## KEY MESSAGE

- Estimation of length of humerus from measurement of its proximal and distal segments are possible.
- Guidelines for Forensic, Archaeological and Anthropometric study.

## INTRODUCTION

Estimation of stature from bones plays an important role in identifying unknown bodies, parts of bodies or skeletal remains. Anthropometric techniques have been commonly used to estimate stature and bone length from skeletal remains and unknown body parts by anthropologists, medical scientists and anatomists for over a hundred years [1-3]. Knowing the mean values of the humerus segments is very important for anatomical and forensic sciences and it helps the investigator to define the identity of a skeleton. Also, these data provide evidences to indicate the characteristic features of a population for archaeological materials [4, 5]. The estimation of bone length from incomplete long bones was first identified by Muller. She defined 5 segments for the humerus by using the margins of articular surfaces and the key points of muscle attachments [6]. The knowledge of the segment measurements which are defined is very helpful in determining the humerus length [7]. From these, it is possible to estimate the stature, which becomes essential to assess sexual dimorphism. Studies on this topic in the Indian population are sparse. Moreover, no such study has been reported in the South Indian population so far. Therefore, the present study was attempted to estimate the length of the humerus from the dimensions of the proximal and the distal segments of the humerus in the south Indian population by using regression equations.

## MATERIALS AND METHODS

This study was carried out on 170 adult dry South Indian humeri (right side 82; left side 88) of both sexes,aged 30–60 years at the Vinayaka Mission Kirupananda Variyar Medical College, Salem. The maximum length of the humerus was measured by using an osteometric board. The vertical diameter and the transverse diameter of the superior articular surface of the proximal segment, transverse diameter of the inferior articular surface and the biepicondylar width of the distal segment were measured by using a vernier caliper [Table/Fig-6]. Broken, diseased and damaged bones were excluded from the study. The measurements were taken as under:

1. The vertical diameter of the superior articular surface was measured as the maximum distance between two points on the head of the humerus, in the plane of the tip of greater tuberosity.
2. The transverse diameter of the superior articular surface was measured as the maximum width between two points on the head of the humerus.

3. The transverse diameter of the inferior articular surface was measured as the maximum combined width of the trochlea and the capitulum at the anterior surface.
4. The biepicondylar width was measured as the maximum distance between the medial and the lateral epicondyles.
5. The maximum length of the humerus was measured as the straight distance between the highest point on the head of the humerus and the deepest point on the trochlea.

All the measurements were expressed in centimeters. By using these measurements, minimum, maximum, mean and standard deviation were calculated. For doing the statistical analysis, the SPSS 12.0 version was used.

## RESULTS

Statistical analysis was carried out in a total of 170 adult dry South Indian humeri. The descriptive statistics, linear regressions and regression equations were derived. The results were tabulated.

**1. Descriptive analysis:** [Table/Fig-1, 2, 3] show the mean values of the maximum length of the humerus (MHL) and the proximal and the distal segments of the humeri of both sides. No statistical test was carried out to analyze the differences between the right and left sides because the right and left humeri did not belong to the same individuals.

**2. Simple linear regression:** [Table/Fig-4] shows the regression Co-Efficient (COE) and the significance (P value) for the dimensions of the proximal and the distal segments of both the humeri separately. On analyzing the proximal segment of the right side, the best results were seen with P1 than P2, while on the distal segment, the best results were seen with D1 than D2. On the proximal segment of the left humerus, the best results were obtained with P1 than P2 and on the distal segment with D1 than D2.

**3. Simple Linear regression equations:** In the earlier days, the multiplication factor method was used for the estimation of stature from the anthropometric measurements of the body but now-adays, the most widely used method is the regression formulae. Worldwide, the regression formulae have been accepted as of utmost importance in the determination of stature from various anthropometric dimensions [8, 9]. In the present study, the formula which was related to the dimensions of the proximal and the distal segments of the humerus was derived as under:

**Right Humerus:**

$MHL = 11.81 + 4.57 \times PS\ VD\ SAS$
$MHL = 13.20 + 4.55 \times PS\ TD\ SAS$
$MHL = 12.99 + 4.45 \times DS\ TD\ IAS$
$MHL = 16.89 + 2.44 \times DS\ BECW$

**Left Humerus:**

$MHL = 11.53 + 4.49 \times PS\ VD\ SAS$
$MHL = 13.83 + 4.27 \times PS\ TD\ SAS$
$MHL = 11.91 + 4.60 \times DS\ TD\ IAS$
$MHL = 23.56 + 1.18 \times DS\ BECW$

### Multiple Linear Regression:

**Right Humerus:** In the proximal segment, the vertical diameter of the superior articular surface showed that $R = 0.77$, $r^2 = 5.73$, $p<0.01$. Beta (OR): .76 (the other three variables were excluded in this model (non predictors) which meant that out of the 4 variables which were studied, the vertical diameter of the superior articular surface in the proximal segment alone gave a significant maximum humerus length of up to 78% of contribution).

| | N | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| PS - VD of SAS | 170 | 3.20 | 5.00 | 4.0718 | .37278 |
| PS - TD of SAS | 170 | 3.10 | 4.70 | 3.7635 | .33472 |
| DS - TD of IAS | 170 | 3.20 | 4.80 | 3.9012 | .33494 |
| DS - Biepicondylar Width | 170 | 3.20 | 6.60 | 5.4453 | .53372 |
| Maximum Humeral Length | 170 | 24.60 | 37.40 | 30.1065 | 2.23419 |
| Valid N (list wise) | 170 | | | | |

**[Table/Fig-1]**

| | N | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| PS - VD of SAS | 82 | 3.20 | 5.00 | 4.0378 | .40449 |
| PS - TD of SAS | 82 | 3.10 | 4.70 | 3.7524 | .34219 |
| DS - TD of IAS | 82 | 3.30 | 4.80 | 3.8793 | .36776 |
| DS - Biepicondylar Width | 82 | 4.40 | 6.60 | 5.4963 | .52339 |
| Maximum Humeral Length | 82 | 24.60 | 37.40 | 30.2805 | 2.44447 |
| Valid N (list wise) | 82 | | | | |

**[Table/Fig-2]:** Right Humerus

| | N | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| PS - VD of SAS | 88 | 3.40 | 4.80 | 4.1034 | .33986 |
| PS - TD of SAS | 88 | 3.10 | 4.60 | 3.7739 | .32923 |
| DS - TD of IAS | 88 | 3.20 | 4.70 | 3.9216 | .30189 |
| DS - Biepicondylar Width | 88 | 3.20 | 6.40 | 5.3977 | .54181 |
| Maximum Humeral Length | 88 | 26.10 | 34.00 | 29.9443 | 2.01938 |
| Valid N (list wise) | 88 | | | | |

**[Table/Fig-3]:** Left Humerus

| S.No | Variables | COE | P |
|---|---|---|---|
| P1 | PS - VD SAS | 0.75 | <.001 |
| P2 | PS - TD SAS | 0.63 | <.001 |
| D1 | DS - TD IAS | 0.67 | <.001 |
| D2 | DS - BECW | 0.52 | <.001 |

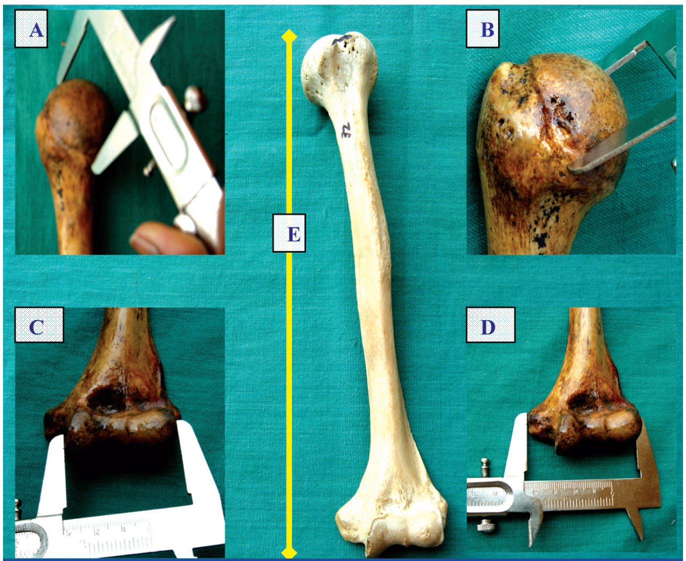
**[Table/Fig-4]:** Right Humerus

| S.No | Variables | COE | P |
|---|---|---|---|
| P1 | PS - VD SAS | 0.75 | <.001 |
| P2 | PS - TD SAS | 0.69 | <.001 |
| D1 | DS TD - IAS | 0.68 | <.001 |
| D2 | DS - BECW | 0.31 | <0.05 |

**[Table/Fig-5]:** Left Humerus
PS – Proximal Segment; DS – Distal Segment;
VD of SAS – Vertical Diameter of Superior Articular Surface;
TD of SAS – Transverse Diameter of Superior Articular Surface;
TD of IAS – Transverse Diameter of Inferior Articular Surface.
BECW – Bi EpiCondylar Width.
MHL – Maximum Humeral Length.

**Left Humerus:** The vertical diameter of the superior articular surface in the proximal segment and the transverse diameter of the inferior articular surface showed that $R = 0.788$, $r^2 = 6.20$.

Both the measures showed significant changes in the maximum humerus length with $P<0.01$ and Beta (OR) for the vertical diameter




**[Table/Fig-6]:** Showing the measurements of proximal & distal segments of humerus
A - Vertical diameter of the superior articular surface;
B - Transverse diameter of the superior articular surface;
C - Transverse diameter of the inferior articular surface;
D - Biepicondylar width;
E - Maximum length of the humerus.

of the superior articular surface in the proximal segment was 0.54 Beta (OR) the transverse diameter of the inferior articular surface was 0.32 (the other two variables were excluded in this model (non-predictors), which meant that these two variables gave a significant maximum humerus length.

## DISCUSSION

The measurements of the length of the long bones play a vital role in the estimation of stature of an individual. In the archaeological approach, statures which are estimated from human skeletal remains is an essential step in assessing health, sexual dimorphism and the general body size that trends among the past populations [22]. The estimation of living stature can be done from the humeral length in the absence of more appropriate long bones as the femur or the tibia [11].

The humerus is the longest and the largest bone of the upper limb and it is very important to identify the humeral length from the segmental measurements [10]. Steele and Mckern [11] defined a method based on the proportionality between the determined distances among the fixed points of the bones and their total length. In forensic investigations and anthropometric studies, the mean value of the total humerus length gives important evidence to indicate the characteristic features of a population [2-6]. The height of individuals is also vital for medico-legal investigations. Thus, in forensic anthropology, the projection of stature from the bones plays an important role in the identification of missing persons [24].

Bioanthropologists have pointed out that one of the largest difficulties in developing a stature estimation formula, is the unavailability of skeletal series with information about the body height data, thus making it possible to test the accuracy of the estimates of the living stature from the fragments of the bones [25, 26]. Because of the unavailability of information about the individuals in the present study, it was not possible to establish correlations between the measurements of the fragments of the humerus and the height of each person.

Regression analysis is a more appropriate method for defining the relationship between the length of the long bones and the living height of individuals and between the length of the measurements of the long bone fragments and their maximum length [23]. The systematic use of regression formulae derived in a specific population can under or overestimate stature, when applied in another population. Thus, authors have recommended that regression equations which are obtained in a certain population should not be applied to other populations [12, 13] . In our study, the data was sex aggregated, though the greatest accuracy in estimating stature would be obtained when the sex was available [9, 14]. But still, Petersen [15] noted that the differences of the femur length were independent of sex and thus, this analysis was considered with both sexes being aggregated. For the estimation of the length of the long bone from its fragments, the use of accurately recognizable landmarks is mandatory. Because of these reasons, the measures used to derive a regression equation to estimate the length of the long bones become limited. Usually, the transverse dimensions along the diaphysis are not appropriate for estimating the length because of their inability in defining the precise landmarks. Therefore, the only leftover location opts for measurements on the fragments of the proximal or distal diaphysis. Hence, for our present study, the dimensions of the proximal and the distal segments of the humeri alone were selected. Several authors have derived linear regressions to estimate the maximum length of long bones from the measurement of its fragments in different populations [16-21]. In our present study, we also derived regression equations to measure the length of the humerus, the right and left sides separately in a South Indian population, which have not yet reported.

Considering the proximal measures, the vertical diameter of the superior articular surface alone showed significance in estimating the maximum length of the humerus on the right side. However, on the left side, both the vertical diameter of the superior articular surface as well as the transverse diameter of the inferior articular surface exhibited significant correlation.

## CONCLUSION

The results of our study concluded that it is possible to estimate the maximum length of the humerus from the measures of its proximal and distal fragments with relative accuracy. Our study may help in this perspective in forensic, anthropometric and also archaeological investigations for the identification of the remains of unknown bodies by using regression equations in a South Indian population.

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