Metrical parameters for approximation of height from superior extremity long bones in humans

Shaikh Sanobar Ismatulla[1], Abdur Rafe Abdul Waheed[2,*], Asim Badaam[3]

[1]Professor and Head, [2,3]Assistant Professor, Dept. of Anatomy, [1]Shri Vasantrao Naik Government Medical College, Yavatmal, Maharashtra, [2]Government Medical College, Aurangabad, Maharashtra, [3]JIIUIIMS, Aurangabad, Maharashtra, India

***Corresponding Author: Abdur Rafe Abdul Waheed**
Email: abdurrafe@ymail.com

Received: 12th July, 2018 **Accepted:** 16th August, 2018

Abstract
This study entitled "Metrical parameters for approximation of height from superior extremity long bones in humans" was worked out in the Anatomy Department, GMC, Aurangabad. Students belonging to second year of M.B.B.S, B.D.S, and B.sc Nursing with other non-medico members of the department were included in the study. The age range of the study subjects was between 20 to 50 years including both males and females totaling 500 in number. The study focused on devising a linear regression equivalence to estimate height from the length of arm and forearm bones (viz. humerus, radius and ulna). The stature or height was measured with the help of an anthropometer from crown to heel, length of humerus from humeral head to the farthest point on trochlea, length of ulna from the tip of olecranon process to the distal point of its styloid process, length of radius from the most proximal margin of the head to the distal point of its styloid process. All these measurements were taken with the help of spreading calipers. Correlation coefficient (r) for length of long bones with stature was 0.565 for male humerus, 0.4699 for female humerus, 0.5434 for male radius, 0.4987 for female radius, 0.6398 for male ulna and 0.5637 for female ulna. 't' test applied for testing the statistical significance of the obtained values was found to be significant. The regression equations for approximation of stature were formulated using length of humerus, radius and ulna.

Keywords: Stature estimation, Humerus, Radius, Ulna.

Introduction

Anthropometry is of immense help in the field of medical science to establish identity of a person from unknown human remains. For this reason Anthropology is drawing increased interest from workers belonging to Anatomy and Forensic Medicine streams of medical science. With the help of anthropometry, different measurements on a living person and also on skeletal remains can be estimated. It's a well known scientific and observational fact that stature or height can be used efficiently to establish proper identity of an individual. As is the case with other physical characters of an individual, height or stature can also be influenced by his or her sex, age, climate, and racial background.

Pearson K., et al (1898-99)[1] was first to introduce the co-relational calculus for height estimation from the measurements of different long bones. Telekka et al (1950)[2] were of the view that each racial group needed a different formula for the approximation of stature.

In the past many researchers worked on cadavers and or on skeletal remains. But the cadavers represent just a small subset of any given population, since they usually belong to persons of older age, and or to those who have suffered from chronic, morbid incapacitating diseases. Furthermore, according to Trotting M. et al (1952)3 there is an increase in the height of 2.5 cm after death, when the measurement is taken in the recumbent position.

The very purpose of involving living persons as subjects in this study was to overcome the various shortcomings in height estimation from cadavers or skeletal remains. By measuring the lengths of superior extremity long bones (humerus, radius and ulna) an attempt was made for correct estimation of height of an individual.

Stature is normally estimated by making use of the mathematical or the anatomical methods. While employing the anatomical method for calculating the living stature of an individual, it is necessary to add correction factors that can compensate for soft tissue.[4-6] However, the main disadvantage of anatomical method is its requirement of a nearly complete skeleton for stature estimation. The mathematical method, in comparison, makes use of one or more bone lengths to estimate the stature of a person. This method incorporates use of stature tables, bone lengths and regression formulae to estimate stature of a living person from long bone lengths.[4-6]

In (1898-1899) Karl Pearson devised the formal stature regression formulae, for the first time, for quantitating the stature by making use of long bone measurements. In employing the mathematical method, the bone length measurement is substituted into a regression equation. The apparent advantage of this method is that a single bone can be used to estimate the stature of an individual. However, the main disadvantage is in using different regression formulae for different populations and each different for different bone. The obvious reason is due to variation in body proportions, making each formula population and sex specific.[3,6,7] Regression formulae derived from long bones are generally more accurate than those utilizing other bones such as the skull[8] or hand and foot bones.[9,10]

Bony union with shafts of all the ossification centres of upper limb bones is usually completed by 20-25 years of age while degenerative changes in joints and cartilages starts occuring after the age of 50 years.[11] Hence, this study focused on persons (both male and female living adults) belonging to 20-50 years age group.

Materials and Methods

The present research activity was performed in the Anatomy Department, Government Medical College, Aurangabad, Maharashtra. The subjects enrolled in study were asymptomatic 500 healthy students (adult males and females) of 2nd MBBS, 2nd BDS, B.Sc Nursing and non-teaching staff of the department of Anatomy in between 20 to 50 years of age.

Before the beginning of this research work, approval from the IEC (Institutional Ethics Committee) and Dean, GMC, Aurangabad were obtained. Informed consent of each study subject was obtained before enrolling them in the study. Data collection was done more or less twice a week, spread over a period of 2 years. The study was analytical type of an observational study.

For height measurement "anthropometer" was utilized and for measuring lengths of humerus, radius and ulna "spreading calipers". The various measurements were obtained as per the table given below:

Table 1: Measurements of different bones

S. No	Bone/Parameter	Measuring points
1	Humerus	Head----------------------- Distal point of trochlea
2	Ulna	Olecranon tip------------- Tip of styloid process
3	Radius	Radial head----------------Tip of styloid process
4	Height	Crown --------------------- Heel (erect position)

The lengths of all the bones were quantified on the right and the left sides consecutively. Data obtained was tabulated, average, standard deviation and co-efficient of variation was found out. Furthermore, co-relation co-efficient, simple linear regression, and other related statistical calculations were made out. 't' test was applied to test the statistical significance. All calculations were done using Microsoft Excel.

Observations and Results

The statistical data, extracted from the calculations and analysis was tabulated as shown below. A look at the following tables will give the values of different parameters at a glance.

Table 2: Measurements of different parameters in males (210 subjects)

S. No.	Variable in (cm)	Average of Males (210)	Standard Deviation (SD)	Summation	Summation of Square	Summation of Product XY	Co-efficient of variation (r in %)
1.	Height Y(cm)	169.48	5.732	35590.8	6038731		
2.	Average length of Rt.& Lt Humerus in (cm) X1	31.07	2.25	6526.4	203893	1102680	7.26
3.	Average length of Rt.& Lt Radius in (cm) X2	25.49	1.90078	5353.1	137210.7	908475.1	7.45
4.	Average length of Rt.& Lt Ulna in (cm) X3	27.62	1.81553	5829.9	162535.3	989436.5	6.53

Table 3: Measurements of different parameters in females (290 subjects)

S. No.	Variable in (cm)	Average of Females (290)	Standard deviation (SD)	Summation	Summation of square	Summation of product XY	Co-efficient of variation (r in %)
1.	Height Y(cm)	156.07	2.66	45422	7122822		
2.	Average length of Rt.& Lt Humerus in (cm) X1	31.24	2.2634	9060	284372.5	1420623	6.85
3.	Average length of Rt.& Lt Radius in (cm) X2	23.96	2.2634	6950.9	167246.3	1089868	6.22
4.	Average length of Rt.& Lt Ulna in (cm) X3	26.15	11.7567	7583.5	198809.87	1188949.46	5.03

Table 4: Statistical measurements in males (210 subjects)

Independent variable	Average length of Right & Left Male Humerus X_1 (in cm)	Average length of Right& Left Male Radius X2 (in cm)	Average length of Right & Left Male Ulna X_3(in cm)
Intercept (a)	120.70	127.9	113.66
Regression coefficient (b)	1.57083	1.63122	2.010
Correlation coefficient (r)	0.565	0.5434	0.6398
Coefficient of determination (r^2)	0.32	0.2952	0.4093
Standard Error of Estimate	19.02	15.88	14.65
t	11.46	11.622	11.6469

Table 5: Statistical measurements in females (290 subjects)

Independent variable	Average length of Right & Left Female Humerus X_1 (in cm)	Average length of Right & Left Female Radius X2 (in cm)	Average length of Right & Left Female Ulna X_3 (in cm)
Intercept (a)	119.69	113.44	96.31
Regression coefficient (b)	1.18969	1.801	2.3062
Correlation coefficient (r)	0.4699	0.4987	0.5637
Coefficient of determination (r^2)	0.22080	0.2487	0.3177
Standard Error of Estimate	9.48	8.46	6.59
t	8.87	9.6692	11.4721

't' test to test the statistical significance is given by the formula,

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-\mathrm{r}2}}$$

As evident from Table 3 and Table 4 the 't' value is statistically significant for humerus, and radius.

Simple linear regression formula is Y=a+b X where Y = height of the subject, a = Intercept, b = Regression coefficient and X = average lengths, for humerus X_1, radius X_2 and ulna X_3 (cm).

Table 6: Regression analysis for total height prediction in males and females

	Regression Formula(Simple Linear)	Males (210 subjects) Height (in cms)	Females(290 subjects) Height (in cms)
Average length of Right & Left. Humerus X_1 (in cms)	Y_1=a+b X_1	Y_{1a}=120.70+1.57083 x31.07	Y_{1b}=119.69+1.18969 x 31.24
Average length of Right & Left Radius X_2 (in cms)	Y_2=a+b X_2	Y_{2a}=127.9+1.63122 x 25.49	Y_{2b}=113.44+1.801 x 23.96
Average length of Right & Left Ulna X_3 (in cms)	Y_3= a+b X_3	Y_{3a}=113.66+2.010 x27.62	Y_{3b}= 96.31+2.3062 x 26.15

The Standard Error of Estimate works out to be 19.02 for male humerus and 9.48 for females humerus, 15.88 for male radius and 8.46 for female radius, 14.65 for male ulna and 6.59 for female ulna.

Table 7: Comparison of actual height & estimated height from the regression equation

S. No.		Mean Length of Right & Left Humerus (in cms)	Actual Height (in cms)	Estimated Height (in cms)	Difference (in cms)
1	Males Females	31.07 31.24	169.48 156.07	169.47 156.55	-0.01 +0.48
		Mean length of Right & Left Radius (in cms)	Actual Height (in cms)	Estimated Height (in cms)	Difference(in cms)
2	Males Females	25.49 23.96	169.48 156.07	169.44 156.59	-0.04 +0.52
		Mean length of Right & Left Ulna (in cms)	Actual Height (in cms)	Estimated Height (in cms)	Difference(in cms)
3	Males Females	27.62 26.15	169.49 156.07	169.17 156.61	-0.48 +0.54

Thus from the above table, males show greater correlation with stature than the females

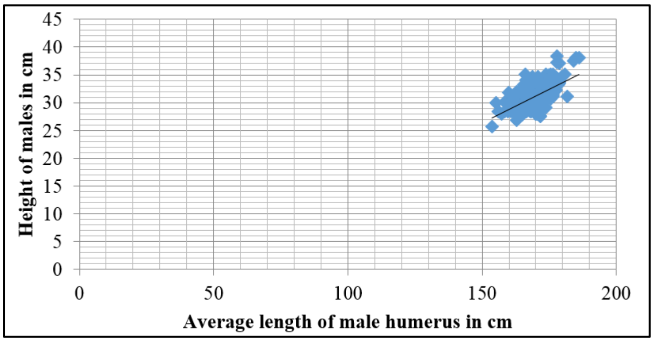

Fig. 1: Correlation of length of male humerus and height in cms: (Scatter Diagram)

Fig. 2: Correlation of length of female humerus and height in cms: (Scatter Diagram)

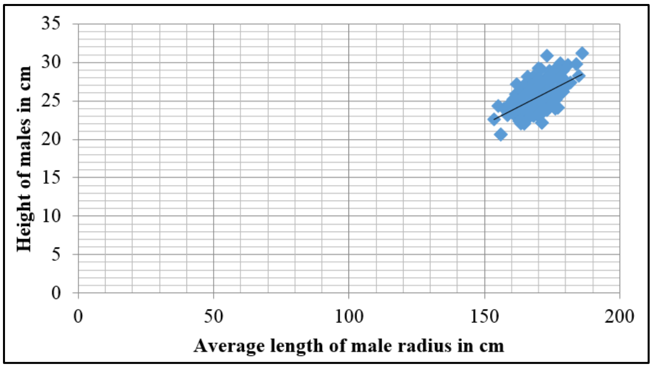

Fig. 3. Correlation of length of male radius and height in cms (Scatter Diagram)

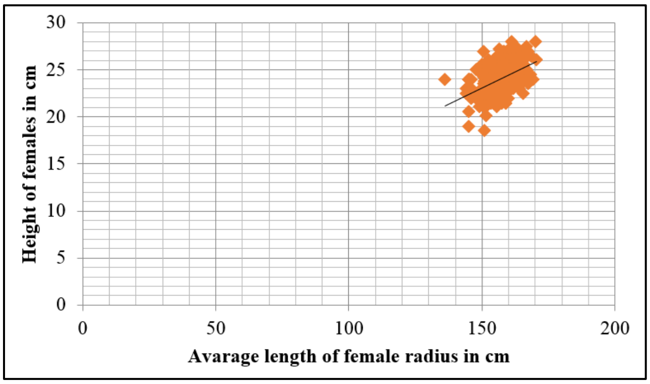

Fig. 4: Correlation of length of female radius and height in cms (Scatter Diagram)

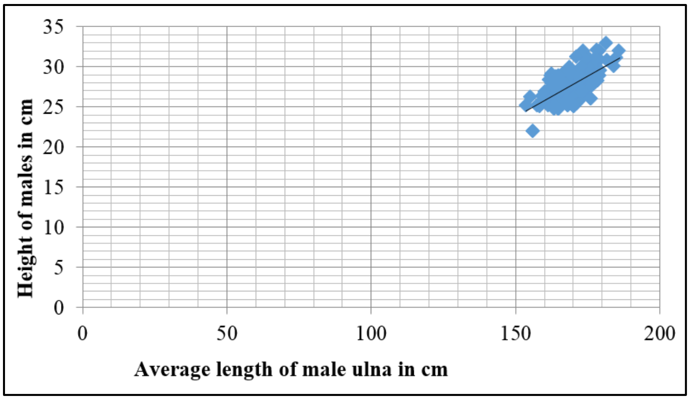

Fig. 5: Correlation of length of male ulna and height in cms (Scatter Diagram)

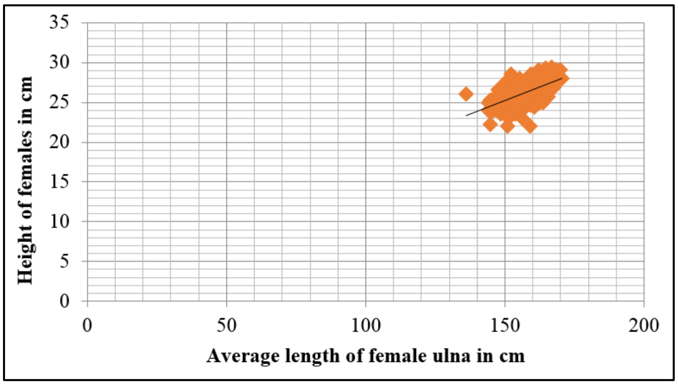

Fig. 6: Correlation of length of female ulna and height in cms (Scatter Diagram)

Discussion

This research activity was performed in the Anatomy Department, Government Medical College, Aurangabad, Maharashtra. The subjects enrolled in study were asymptomatic 500 healthy students (adult males and females) of 2nd MBBS, 2nd BDS, B.Sc Nursing and non-teaching staff of the Department of Anatomy in between age range of 20 to 50 years. In the present work, correlation if any, between the lengths of superior extremity long bones and height of a person was found out.

Sarojini Devi H,[12] Das B.K., Purnabati S, Singh D and Jayshree Devi made use of upper arm length to evaluate correlation coefficient and regression equation formula for height estimation among living population of Maring tribes of Chandel District, Manipur, India.

Dr. Balkrishna Thummar,[13] Dr. Zarana K. Patel, Dr. Shailesh Patel, Dr. S.P. Rathod, formulated regression equation by working on 310 subjects (males and females) between 20-40 years of age belonging to the state of Gujarat for estimation of height from the length of ulna.

Trotter M. and Glesser G.C.[3] in their research work performed on Whites and Negroes of America, estimated height from long bone lengths. They tried to find out association between long bone lengths and height. They were of the view of having different regression equations for different races. Furthermore, for height estimation using different parameters, subjects of a particular age group and sex should have their own regression tables as per their race.

Amit A. Mehta,[14] Anjulika A. Mehta, V.M. Gajbhiye, Sarthak Verma in their study performed on adult males and females (50 each) in the age range of 18-30 years belonging to Central India, estimated stature from length of ulna. They found the correlation coefficient (r) for right ulna to be 0.754 and for left ulna 0.70. Based on their study they concluded that there exists a positive correlation between ulnar length and estimated height.

Anitha M. R.,[15] Chaitra B.R., V. Rajitha, Bharathi D, studied 300 adult males, and measured heights of study subjects and bilateral ulnar lengths to find out the correlation coefficient (r) between them. They also derived the simple regression formula to show correlation between ulnar length and height of an individual.

In an another study, Maloy Kumar Mondal,[16] Tapan Kumar Jana, Susmita Giri (Jana), Hironmoy Roy studied 300 Bengali female subjects and estimated their stature from the lengths of their ulna and formulated a linear regression equation. The Correlation coefficient (r) was found to be 0.82 (P=0.002) for left ulna with stature and it was 0.67 (P=0.001) for right ulna with stature.

Athawale M.C.[17] studied one hundred Maharashtrian males of age ranging from 25 to 30 years. With the help of various graphs, he highlighted that there exists a correlation between the height of a person, lengths of radius and ulna, and upper limb length. They put forth the following regression formula for height estimation from the lengths of long bones [Stature (in cms) = 59.2923 + 4.1442 x avg. length of rt & lt radius (in cms) +/- 3.66. Stature (in cms) = 56.9709 + 3.9613 x avg. length of rt & lt ulna (in cms) +/- 3.64]. Ilayperuma et al, 2008,[18] Ebite et al,[19] Williams et al[20] stated that in a given population as compared to the average height of adult females the average height of adult males was significantly higher. The results of the present study too, corroborates the above mentioned finding. There was distinct sexual dimorphism in the radial and ulnar length in our study group where it was significantly longer in males than in females (Ebite et all)[19] except for length of humerus.

It is also found in this study that males show greater correlation with stature than the females as evident from the discrepancy between the actual height (cm) and estimated height (cm).

Conclusions

Although as widely believed, the co-relationship between height and length of bones of lower limb is more practically significant in contrast to the bones of upper limb for both sexes, the bones of upper limb, nonetheless, can also be utilized to estimate height in conditions where necessary, for example, in a case with deformities of lower extremity. Of the three long bones of the upper extremity, stature estimation from the length of ulna is far more superior and of high significance as compared to stature estimation from the lengths of other two long bones, i.e humerus and radius. The possible reason is due to subcutaneous nature of ulna, making its approachment for taking measurements simple, easy and nearly flawless. Many studies conducted in the past has highlighted the significance of ulna in estimation of stature of an individual from its length.

To conclude, simple regression equations derived from this study can be used to determine the stature of individuals belonging to Aurangabad District (Maharashtrian population). This fact can be of practical use in medicolegal investigations and anthropological and archeological studies where the stature of a person can be found out if the lengths of upper arm and or forearm long bones is known.

Conflicts of Interest: None.

References

1. Pearson K. Mathematical contribution to the theory of evolution. On the reconstruction of the stature of prehistoric races. *Philos Trans R Soc London.* 1898;192:169-244.
2. Telekka A. On the prediction of human stature from the long bones. *Acta Anatomica.* 1950;9:103-111.
3. Trotter M. and Glesser G.C. Estimation of stature from long bones of American Whites and Negroes. *American Journal of Physical Anthropology.* 1952;10:463-514.
4. Lundy J.K. The mathematical versus anatomical methods of stature estimate from long bones. *Am J Forensic Med Pathol.* 1985;6(1):73-76.
5. Fully G. New method of determination of the height. Ann. Med. Leg: *Criminol Police Sci Toxicol.* 1956;36:266-273.
6. Lundy J.K. Regression equations for estimating living stature from long limb bones in the South African Negro. *S.Afr J Sci.* 1983;79:337-338.
7. Dupertuis C.W. and Hadden J. On the reconstruction of stature from long bones. *Am J Phys Anthropol.* 1951;9:15-54.
8. Chiba M. and Terazawa K. Estimation of stature from somatometry of skull. *Forensic Sci Int.* 1998;97:87-92.
9. Musgrave J.H. and Harneja N.K. The estimation of adult stature from metacarpal bone length. *Am J Phys Anthropol.* 1978;48:113-119.
10. Manisha R. Dayal, Maryna Steyn and Kevin L. Kuykendall. Stature estimation from bones of South African whites. *South African Journal of Science.* 2008;104:124-128.
11. Maloy Kumar Mondal, Tapan Kumar Jana, Jonaki Das, Sumohan Biswas. Use of length of ulna for Estimation of Stature in Living Adult Male in Burdwan District and Adjacent areas of West Bengal. *J Anat Soc India.* 2009;58(1):16-18.
12. Sarojini Devi H., Das B.K., Purnabati S., Singh D. and Jayshree Devi. Estimation of stature from upper arm length among the Marings of Manipur. *Indian Medical Journal August.* 2006;100(8):271-273.
13. Balkrishna Thummar, Zarana K. Patel, Shailesh Patel, S.P. Rathod. Measurement of Ulnar Length for estimation of Stature in Gujarat. *NJIRM.* 2011;2(2):36-40.
14. Amit A. Mehta, Anjulika A. Mehta, V.M. Gajbhiye, Sarthak Verma. Estimation of stature from Ulna. *Int J Anat Res.* 2015;3(2):1156-1158.
15. Anitha M.R., Chaitra B.R., V. Rajitha, Bharathi D. Estimation of stature using ulnar length in living adult individuals in South Indian Population. *Int J Anat Res.* 2016;4(1):2139-2141.
16. Maloy Kumar Mondal, Tapan Kumar Jana, Susmita Giri (Jana), Hironmoy Roy. Height Prediction from Ulnar length in Females: A study in Burdwan District of West Bengal (Regression Analysis). *Journal of Clinical and Diagnostic Research*. 2012;6(8):1401-1404.
17. Athawale M.C. Estimation of height from length of forearm bones, a study of one hundred Maharashtrian male adults of age between twenty five and thirty years. *American Journal of Physical Anthropology.* 1963;21:105-112.
18. Ilayperuma I., Nanayakkara B.G. & Palahepitiya K.N. A Model for reconstruction of personal stature based on the measurements of foot length. *Galle Med J*. 2008;13:6-9.
19. Ebite L.E., Ozoko T.C., Eweka A.O., Otuaga P.O., Oni A. O. and Om Iniabohs. F.A.E. Height: Ulna Ratio: A Method of Stature Estimation In a Rural Community in Endo State Nigeria. *The Internet Journal of Forensic Science*. 2008;3:(1).

How to cite this article: Ismatulla S. S, Waheed A.R.A, Badaam A. Metrical parameters for approximation of height from superior extremity long bones in humans. Indian J Clin Anat Physiol. 2018;5(4):443-448.