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Original Research Article

Establishing the Metrical Factors for Estimating Height from the Long Bones of the Superior Extremities in Humans

Premjeet Kumar Madhukar[1], Mani Bhushan Yadav[2], Praveen Kumar[3]

[1]Associate Professor and HOD, Department of Anatomy,Jannayak Karpoori Thakur Medical College and Hospital ,Madhepura, Bihar, India

[2]Tutor, Department of Anatomy, Jannayak Karpoori Thakur Medical College and Hospital, Madhepura, Bihar, India

[3]Tutor, Department of Anatomy, Jannayak Karpoori Thakur Medical College and Hospital, Madhepura, Bihar, India

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Corresponding author: Dr. Premjeet Kumar Madhukar
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Abstract

Aim: To establish the metrical factors for estimating height from the long bones of the superior extremities in humans. **Methods:** This prospective observational study was carried out in the Department of Anatomy, JNKTMCH Madhepura, Bihar, India, for 10 months, Asymptomatic 200 healthy students (adult males and females) and staffs between 18 to 50 years of age were included in this study. For height measurement "anthropometer" wasutilized and for measuring lengths of humerus, radius and ulna "spreading calipers". **Results:** The Standard Error of Estimate works out to be 18.99 for male humerus and 9.55 for females humerus, 16.01 formale radius and 8.65 for female radius, 15.03 for male ulna and 6.78 for female ulna. Correlation coefficient (r) for length of long bones with stature was 0.57 for male humerus, 0.47 for female humerus, 0.55 for male radius, 0.49 for female radius, 0.65 for male ulna and 0.57 for female ulna. 't' test applied for testing the statisticalsignificance 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. **Conclusion:** The simple regression equations derived from this study can be used to determine the stature of individuals belonging Bihar population). This fact can be of practical use in medicolegal investigations and anthropological and archaeological studies where the stature of a person can be found out if the length of upper arm and or forearm long bones is known.

Keywords: estimating height, long bones, ulna, humerus

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Introduction

Forensic anthropology encompasses the examination of skeletal remains for the purposes of identification. It is a sub-field of physical anthropology that has medico-legal implications. The traditional goal of forensic anthropology is to identify human remains once they have been skeletonized, although the forensic anthropologist may be confronted with burned remains, hair samples, footprints, fingerprints, blood or any other tissue sample for blood typing and DNA profiling[13]. Included in the typical forensic anthropological analysis is the determination of age, sex, race and antemortem stature of the unknown individual. Stature is usually estimated by employing either the anatomical or the mathematical method. The anatomical method estimates total skeletal height and was initially introduced by Dwight in 1894. In 1956 Fully reintroduced the method with slight variation and it became known as Fully's procedure. This method is based on the summed heights of skeletal elements that contribute to stature in humans. The skeletal elements measured in this method are the cranium, vertebrae, femur, tibia, talus and calcaneus. These represent the elements that contribute to stature[4,5] and their measurements are summed to calculate total skeletal height. To calculate the living stature of an individual using the anatomical method, correction factors that compensate for soft tissue also need to be added[4-6]. The main disadvantage of the anatomical method is that a nearly complete skeleton is needed for stature estimation. The mathematical method, on the other hand, makes use of one or more bone lengths to estimate the stature of the individual. This method employs bone length and stature tables, and regression formulae to estimate total skeletal height or living stature from long bone lengths. Initial research was carried out by many investigators from the 1700s like Sue (1755), Orfila (1821), Beck (1823), Rollet (1888), and Manouvrier (1893) (cited in Stewart1). In 1899, Karl Pearson developed the first formal stature regression formulae[7]. To use the mathematical method, the bone length measurement is substituted into a regression equation. The outcome of the equation calculated gives either the total skeletal height or the living stature. This depends upon the equation(s) employed and whether the soft tissue and ageing correction factors were included into the equation. The obvious advantage of this method is that a single bone can be used to estimate the stature of an individual. The main disadvantage of the mathematical method is that different regression formulae are required for different populations, for each different bone and also separately for each sex. This is because variation in body proportions exists, making these formulae population and sex specific[6,8-11]. 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 occurring after the age of 50 years[12]. Hence, this study focused on persons (both male and female living adults) belonging to 18-50 years age group

Materials and Methods

This prospective observational study was carried out in the Department of Anatomy, JNKTMCH Madhepura, Bihar, India, for 10 months, after taking the approval of the protocol review committee and institutional ethics committee. Asymptomatic 200 healthy students (adult males and females) and staff of the department of Anatomy in between 18 to 50 years of age. 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 1 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

Bone/Parameter	Measuring points
Humerus	Head Distal point of trochlea
Ulna	Olecranon tip Tip of styloid process
Radius	Radial head Tip of styloid process
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. Allcalculations were done using Microsoft Excel.

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.

The Standard Error of Estimate works out to be 18.99 for male humerus and 9.55 for females humerus, 16.01 formale radius and 8.65 for female radius, 15.03 for male ulna and 6.78 for female ulna. Correlation coefficient (r) for length of long bones with stature was 0.57 for male humerus, 0.47 for female humerus, 0.55 for male radius, 0.49 for female radius, 0.65 for male ulna and 0.57 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.

Table 2: Measurements of different parameters in males (90 subjects)

S. No.	Variable in (cm)	Average of Males (90)	Standard Deviation (SD)	Summation	Summation of Square	Summation of Product XY	Co-efficient of variation (r in %)
1.	Height Y(cm)	169.57	5.73	36690.1	6121711		
2.	Average length of Rt. & Lt Humerus in (cm) X1	32.14	2.32	6496.7	210112	1200121	8.01
3.	Average length of Rt. & Lt Radius in (cm) X2	26.01	1.80	5123.1	129010.1	911415.7	8.03
4.	Average length of Rt. & Lt Ulna in (cm) X3	28.02	1.77553	5659.1	159535.7	987135.2	7.03

Table 3: Measurements of different parameters in females (110 subjects)

S. No.	Variable in (cm)	Average of Females (110)	Standard deviation (SD)	Summation	Summation of square	Summation of product XY	Co-efficient of variation (r in %)
1.	Height Y(cm)	157.01	2.59	44820	7112722		
2.	Average length of Rt. & Lt Humerus in (cm) X1	32.24	2.26	9060	284372.5	1420623	6.85
3.	Average length of Rt. & Lt Radius in (cm) X2	24.06	2.25	6961.1	166941.7	1089868	6.77
4.	Average length of Rt.& Lt Ulna in (cm) X3	25.95	10.69	7493.8	198419.77	1098049.18	5.23

Table 4: Statistical measurements in males (90 subjects)

Independent variable	Average length of Right& Left Male Humerus X1 (in cm)	Average length of Right& Left Male Radius X2 (in cm)	Average length of Right &Left Male Ulna X3(in cm)
Intercept (a)	121.10	128.1	114.06
Regression coefficient (b)	1.56	1.61	2.12
Correlation coefficient (r)	0.57	0.55	0.65
Coefficient of determination (r^2)	0.33	0.31	0.44
Standard Error of Estimate	18.99	16.01	15.03
t	11.59	11.74	11.79

Table 5: Statistical measurements in females (110 subjects)

Independent variable	Average length of Right& Left Female Humerus X1 (in cm)	Average length of Right & Left Female Radius X2 (in cm)	Average length of Right & Left Female Ulna X3 (in cm)
Intercept (a)	120.12	114.01	95.57
Regression coefficient (b)	1.21	1.97	2.39
Correlation coefficient (r)	0.47	0.49	0.57
Coefficient of determination (r^2)	0.23	0.26	0.32
Standard Error of Estimate	9.55	8.65	6.78
t	8.92	9.87	11.56

As evident from Table 3 and Table 4 the ‘t’ value isstatistically 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 (90 subjects) Height (in cms)	Females (110 subjects) Height (in cms)
Average length of Right &	Y_1=a+b X_1	Y_{1a}=121.87+1.58	Y_{1b}=120.12+1.19 x
Left. Humerus X_1 (in cms)		x32.12	32.02
Average length of Right & Left Radius X_2 (in cms)	Y_2=a+b X_2	Y_{2a}=129.1+1.65 x 26.01	Y_{2b}=115.02+1.801 x 24.12
Average length of Right & Left Ulna X_3 (in cms)	Y_3= a+b X_3	Y_{3a}=114.26+2.22x 28.16	Y_{3b}= 97.44+2.29 x 28.02

The Standard Error of Estimate works out to be 18.99 for male humerus and 9.55 for females humerus, 16.01 formale radius and 8.65 for female radius, 15.03 for male ulna and 6.78 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	30.97 31.36	169.59 156.23	169.57 156.66	-0.01 +0.47
		Mean length of Right & Left Radius(in cms)	Actual Height (in cms)	Estimated Height(in cms)	Difference (in cms)
2	Males Females	26.01 24.02	169.57 156.45	169.69 156.75	-0.03 +0.54
		Mean length of Right & Left Ulna (in cms)	Actual Height (in cms)	Estimated Height(in cms)	Difference (in cms)
3	Males Females	28.12 27.03	169.76 156.54	169.69 156.73	-0.46 +0.56

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

Discussion

This research activity was performed in the Department of Anatomy, JNKTMCH Madhepura, Bihar, India. 200 healthy students (adult males and females) of students and staff age range of 20 to 50 years were included in this study. 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[13], 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[14], 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[15] in their research work performed on Whites and Negroes of America, estimatedheight 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 asper their race.

Amit A. Mehta[16], 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 correlationcoefficient (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.[17], 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 another study, Maloy Kumar Mondal[18], 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 andit was 0.67 (P=0.001) for right ulna with stature.

Athawale M.C.[19] studied one hundred Maharashtrian males of age ranging from 25 to 30 years.With the help of various graphs, he highlighted that thereexists 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 xavg. length of rt & lt ulna (in cms) +/- 3.64]. Ilayperuma et al.[20] Ebite et al[21], stated that in a given population as compared to the average height ofadult 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 lengthin our study group where it was significantly longer in males than in females (Ebite et all)[21] except for length ofhumerus. It is also found in this study that males show greatercorrelation with stature than the females as evident from the discrepancy between the actual height (cm) and estimated height (cm).

Conclusion

The present study concluded that the simple regression equations derived from this study can be used to determine the stature of individuals belonging Bihar 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.

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