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A Study for Estimation of Human Height from the Length of Ulna

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ABSTRACT

Background: Stature estimation from skeletal remains bears immense importance in Forensic Sciences. Assessment of height from different parts of body by Anthropometric study of skeleton is of interest to Anatomist, Anthropologist and Forensic Experts.
Aims and objectives: The present study was undertaken to formulate a regression equation.
Methods: For estimation of stature of a population of 500 subjects collected from the General OPD of N.R.S. Medical College in correlation of a long bone Ulna in adult age group. The measurements were taken by standard anthropometric instruments in centimeters, according to the technique described by Vallois. Height of the subject was measured in standing position on a standard stadiometer. All data put in SPSS (Statistical Package for Social Science) Version 20 Software and analyzed where 'n' is the sample size for males and females.
Result: The observation were analyzed separately for both right and left ulna in each sex on all subjects and results are tabulated. The mean ages of the study subjects (male 33.98 ± 8.904) and female33.98±8.269) were not significantly different between genders. Gender differences in mean height and length of Ulna were found to be highly significant ($P < 0.05$). Mean Ulna lengths of the male were significantly larger than that of the females of all age groups.

Key words: Length of Ulna, stature of human

INTRODUCTION

Stature estimation from skeletal remains bears immense importance in Forensic Sciences. The humerus, femur, tibia, ulna have been used for the same purpose since long time back. Growth, the vital process, measured by measuring the height of a person, which itself is the sum of certain bones and appendages of the body and represents some relationship with form of proportion to total stature. Assessment of height from different parts of body by Anthropometric study of skeleton is of interest to Anatomist, Anthropologist and Forensic Experts.

Stature and body mass estimation from skeletal dimensions are therefore key to addressing biological and social questions about past populations. Anthropometry is a series of systemized measuring techniques that express quantitatively the dimensions of human body and skeleton. Relationships that exist between different parts of body and height have been of great interest to Anthropologists, Forensic and Medical Scientists for many years. This is because of the increase in the number of catastrophic events causing mass death from natural and man-made errors. The height as a measure of biological development of both an individual and a population is commonly used in Physical Anthropology. Stature evaluation based on the lengths of the limb bones, is one of the oldest problems in the history of Anthropology. The proportions of its particular components (extremities, trunk) also reveal great variability. For this reason, the application of the best formula to a particular population (or a group of individuals) is very difficult.

Many of previous workers have done this study on cadavers but cadavers cannot represent a population & they are largely of persons who are aged and might have suffered from chronic debilitating diseases, likely to have been dying in an abnormal posture and it may not be possible to straighten the body to get accurate stature measurement. All these short comings in cadaveric material obviate the present study to be undertaken on Living Persons. The forearm bone ulna is mostly subcutaneous throughout its length and easily approachable for measurement. Ulna is the medial bone of the two bones of forearm. It is a typical long bone. Upper end is the olecranon which is considered as the head of elbow, and the lower end has a medial projection, the styloid process. Both can be palpated subcutaneously. The posterior border is mostly subcutaneous along its length. So both the ends along the posterior border can be used to measure the ulnar length. So it is selected for present study. Ossification of the ulna starts at 8th fetal week and the proximal epiphysis fuses with the shaft in the14th year in Females and 16th year in Males. The distal epiphysis unites with the shaft in the 17th year in Females and 18th year in Males.

So Ossification of Upper Limb is usually completed within 20-25 years of age and after age of 50 years there occurs some degenerative changes in joints and cartilages. So the present study is done on persons belong to 20-50 years of age group. In the present study an attempt has been made to find out the correlation between bone length of Ulna and body height in West Bengal population. [5] Most researchers in this field of Anthropological and Forensic Osteology have chosen long bones for this purpose that is more beneficial than other method. [1]

People of eastern region of India have many things in common including stature of the average people of the society. One exhaustive work was done by Pan (1924) for estimation of age from long bones including tibia. [2] In the present investigation an attempt has been made to find out a valid formula for the estimation of the stature of person from the length of ulna.

MATERIALS AND METHOD

The present study was undertaken to formulate a regression equation for estimation of stature of a population of 500 subjects collected from the General OPD of N.R.S. Medical College in correlation of a long bone Ulna in adult age group.

All method and procedures applied within this study are approved by Ethical committee of Nilratan Sircar Medical College, Kolkata –14.

Study design: Cross sectional study.

Selection criteria: Random sample of 500 subjects (250 males and 250females) were taken from the General Out Patient Department (OPD) of N. R. S. Medical College.

Exclusion criteria:-

1. Cases having old fractures.
2. Cases with any significant long term disease e.g. Osteoporosis etc
3. Persons with orthopaedic deformity involving any fore arm bones or total height.
4. Persons with metabolic or developmental disorders e.g. Achondroplasia, Hypochondroplasia, any congenital heart disease which could have affected the general or bony growth were excluded from study.

Sample size: In the present study 500 subjects were taken, 250males and 250 females, belonging to the age group of 20 - 50 years, from N.R.S Medical College, General OPD. The subjects gave their written consent for this study in the appropriate informed consent form (written in three languages – Bengali, Hindi and English, together).

The following parameters have been noted:

Name, age, sex, height in cms, Length of right and left ulna in cms, only after taking the consent of the subject for measurement in appropriate format (copy attached behind).

Measurement technique: The measurements were taken by standard anthropometric instruments in centimetres, according to the technique described by Vallois. [3] All the measurements were taken by same observer and with the same instruments, to avoid any technical and or inter-observer error and to maintain reproducibility. To eliminate discrepancy due to diurnal variations, the measurements were taken between 10am to 2pm.Each measurements were taken three times and their mean value was noted for estimation of height.

Height [1] : (Standing Height): Height of the subject was measured in standing position on a standard stadiometer ,from vertex to floor with standing barefooted, erect on an even floor, both feet close in contact with each other, the trunk braced along the vertical board, and head adjusted in Frankfurt plane, and then head was tilted slightly upwards by applying gentle force to the mastoid process and zygomatic bone. The measurement was taken in centimetres by bringing horizontal slide bar to the vertex. Height of the subject is measured in cm in standing erect vertex to heel with barefoot.

Ulnar length [1]: For measuring the ulnar length in centimeters (Figure-1):- Subjects were asked to sit and to hold their fore arm, both right and left, one by one in full flexion with wrist in full flexion close to their chest, thus to make both tip of olecranon and tip of ulnar styloid process prominent. Then two points are marked with skin marking pencil and the ulnar length noted with a measuring tape in centimetres.

First point: Tip of olecranon process (Point-A).

Second point: Tip of ulnar styloid process (Point-B).

Distance between the two points on right and left side was measured with the help of measuring tape along the subcutaneous posterior border of Ulna.

In order to eliminate the influence of the epiphyseal growth factor in formulation of the regression equations, adults belonging to the age group of 20 – 50 years were selected. The study was undertaken at the General OPD of N.R.S. Medical College, Kolkata.

Out of a total of 572 subjects, data from 72 were rejected due to apparent & definite skeletal deformities in the limbs and pelvis. Hence 500 subjects (250 males and 250 females) of the age group, mentioned above, were finally included in the present study.

Figure 1 : Ulnar length measurement

STATISTICAL METHOD

All data put in SPSS (Statistical Package for Social Science) VERSION 20 SOFTWARE and analysed where 'n' is the sample size for males and females.

The intercept / constant or additive factor (a) was obtained as follows: [4]

a=y- bx, where y and x are the sample means of y and x respectively.

To determine how reliable these regression equations are likely to be the confidence limits for 'a' and 'b' and the equations were calculated using the following formulae.

a ± t (0.05) X Sa and b ± t (0.05) X S, where Sa is the estimated standard error associated with the constant.

(a) S, is the estimated standard error of regression coefficient.

(b) In t (0.05) is the 't' value at 0.05% level of significance.

The equation which has been formulated should be statistically significant in the sense that it should depend upon the regression coefficient (b) and thus 'b' should not be zero. The null hypothesis b=O and new hypothesis that b>O was set up to ascertain the dependence of the regression equations on the regression co-efficient (b). 5% significance level was chosen for testing the hypothesis.

Testing whether 'b' was significantly greater than zero or not involved the following steps: [5]

At first 't' value was calculated using the formulae

$$t = \frac{b}{s/\sum X^2 - \left(\sum x\right)^2/n}$$

Where x, = some value of x [here minimum, maximum and mean values were taken] T = Critical t score for ‘a’ = 0.025

Whether the regression coefficient of males and females were significantly

This calculated 't' value was then compared with the critical 't' scores at 5% level.

Also 95% confidence intervals of prediction of y values were calculated using the formula (Rees 1991): [6]

$$(a + b_x) + tS_t \sqrt{[1/n + (x_o - \bar{x})^2/\sum x^2 - (\sum x)^2/n]}$$

different or not and hence the justification for the formulation of separate equations was tested by calculation of F values by the following method(Williams 1984): [7]

The square of standard error of estimation of male sample and female samples were calculated and the squared standard error was compared using an ‘F’ test.

The F value was calculated with 40 degrees of freedom (n-2 for males) in numerator and 30 degrees of freedom (n-2 for females) in the denominator as follows:

F = larger squared standard error smaller squared standard error

The F value was then compared with the critical F values from the statistical table.

RESULTS

The sample of the present study included 500 subjects (Males = 250, Females = 250) from the southern part of West Bengal.

The age distribution of the sample is shown in Table 4. Age of Males varied between 20 years to 50 years and that of Females between 20 years to 50 years. The Mean age of the male sample was 33.98 years and that of the female subjects was 33.98 years. The mean age of the whole sample (n=500) was 33.98 years. It can be seen from the findings that the modal height of both male and female subjects was at age group 30-40 years.

Thus the regression equations, those have been obtained, are from data contributed mostly by this younger age group.

The observation were analyzed separately for both right and left ulna in each sex on all subjects and results are tabulated. The mean ages of the study subjects (male 33.98 ± 8.904) and female33.98 ±8.269) were not significantly different between genders. Gender differences in mean height and length of Ulna were found to be highly significant ($P < 0.05$). Mean Ulna lengths of the male were significantly larger than that of the females of all age groups.

The prediction of a significant relationship amongst the pair of variables was determined by the “Correlation coefficient" i.e., Pearson's 'r'. The relationship between the changes of a dependent variable (say, y) and an independent variable (say, x) was ascertained by simple linear regression, with the "Regression coefficient (b)"; where the model of the regression equation was y = a + bx [where a = y intercept, when x = 0]. As in every equation; a 95% confidence interval (which was equivalent to 1.96 standard deviation) was accepted and the standard error of regression (STE) was calculated. The final equation model was y = (a + bx) ± (1.96 x STE).

The parameters were tabulated and statistically analyzed. The correlation coefficient (r) was found to be 0.968 (p=0.000) for the left ulna with stature and it was 0.974 (p=0.000) for the right ulna with stature. Supportive regression equations and scatter-plot diagrams could successfully interpret the height from the ulnar length in females.

Correlations

		HEIGHT	RT ULNA	LT ULNA
HEIGHT	Pearson Correlation	1	.974**	.968**
	Sig. (2-tailed)		.000	.000
	N	500	500	500
RTULNA	Pearson Correlation	.974**	1	.996**
	Sig. (2-tailed)	.000		.000
	N	500	500	500
LTULNA	Pearson Correlation	.968**	.996**	1
	Sig. (2-tailed)	.000	.000	
	N	500	500	500
**. Correlation is significant at the 0.01 level (2-tailed).				

(RT:Right,LT:Left)

TABLE:-1

Parameters(cm)	Mean	SD	Range
Height	156.92	11.250	135-183
Length of right ulna	25.60	2.090	21-30.10
Length of left ulna	25.54	2.076	21-30

Mean, SD, Range for all parameters:- (Both sexes together)

Table no. 1 shows that, the mean height of total subjects is 156.92 ±11.25. Mean of length of right and left ulna are 25.60 ±2.09 and 25.54 ± 2.08 respectively with range of 20 to 30.1 cm.

TABLE:-2 B. Male cases

Parameters(cm)	Mean	SD	Range
Height	164.20	9.627	142-183
Length of right ulna	27.02	1.441	22.2-30.10
Length of left ulna	26.95	1.416	22.3-30

Table no. 2 shows that mean height of male subjects is 164.20 ± 9.66. Mean of length of right and left ulna in male subjects are 27.02 ± 1.44 and 26.95 ± 1.42respectively, with range of 22.2 to30.1 cm.

TABLE:-3 Female cases

Parameters(cm)	Mean	SD**	Range
Height	149.63	7.377	135-167.70
Length of right ulna	24.18	1.620	21-29.80
Length of left ulna	24.12	1.618	21-29.70

Table no.3 shows that mean height of female subjects is 149.63 ± 7.38. Mean of length of right and left ulna in female subjects are 24.18 ± 1.62 and 24.12 ± 1.62 respectively, with range of 21 – 29.80 cm.

TABLE:-4

Subject distribution	Age groups			Total
	1. 20-30 yrs	2. 31-40 yrs	3. 41-50 yrs	
Male	103	75	72	250
Female	97	90	63	250
Total	200	165	135	500

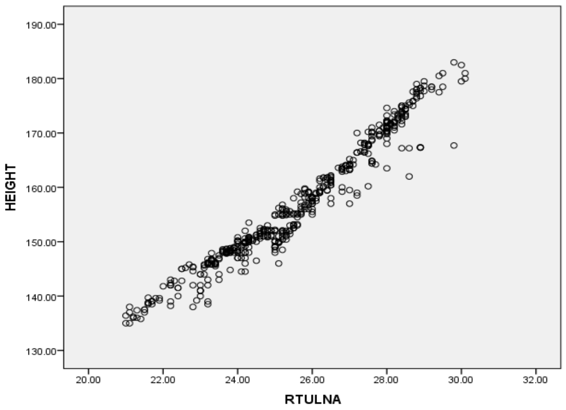
Table No. 4 shows distribution of different age groups (1. 20-30 yrs, 2. 31-40 yrs, 3. 41-50 yrs) of subjects, both male and female and both sexes together by their numbers.

Now to calculate the regression formulae for estimation of height from the length of right and left ulna and both ulnar length together in both sexes and in whole study population are ;

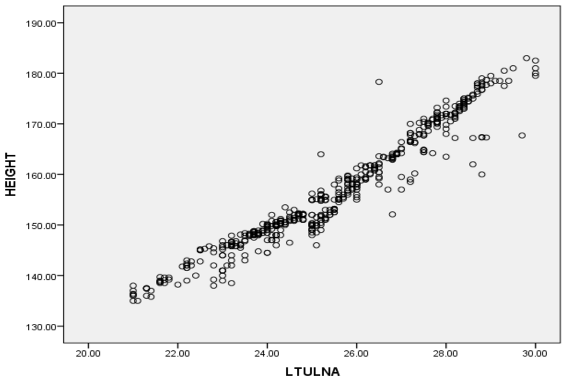
Regression equations

Using right ulna in total population height (H) is H = 22.69 ± 5.244 x length of right ulna.

Using left ulna in total population height (H) is H = 22.96 ± 5.245 x length of left ulna.
Using both ulna in total population height (H) is H =2 3.001 ± 6.562 x length of right ulna +1.334 x length of left ulna.

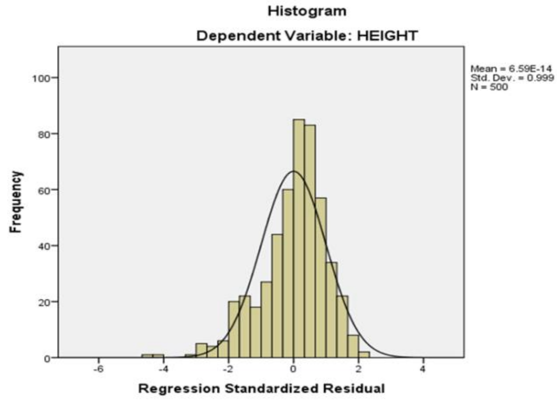


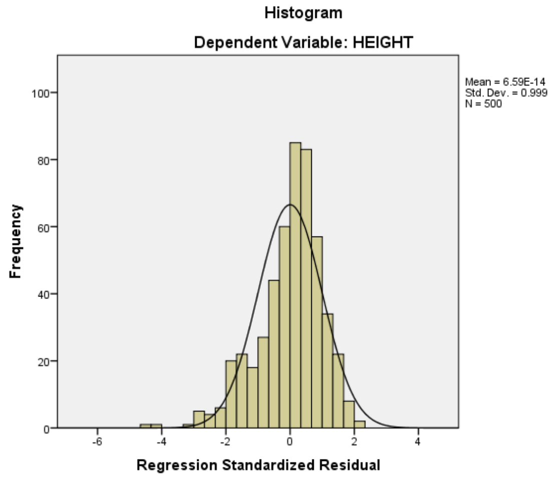
Scatered diagram showing length of right ulna to height taken in centimetres in whole population.

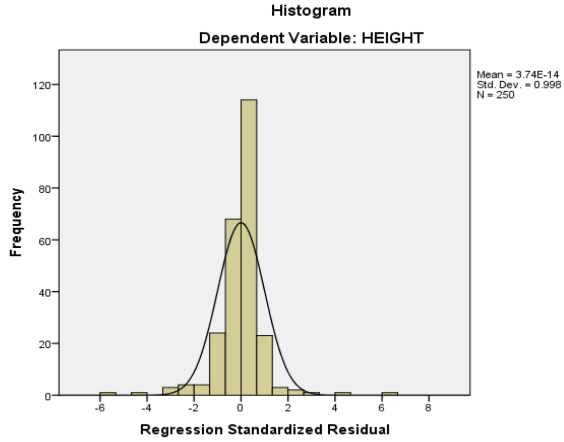


Scatered diagram showing length of left ulna with height taken in centimetres in whole population.

Regression equations
Using right ulna in male height (H) is H = -12.339 ± 6.534 x length of right ulna.
Using left ulna in male height (H) is H = -11.519 ±6.519 x length of left ulna.
Using both ulna in male height (H) is H = -12.039 ± 6.876 x length of right ulna +0.335 x length of left ulna.



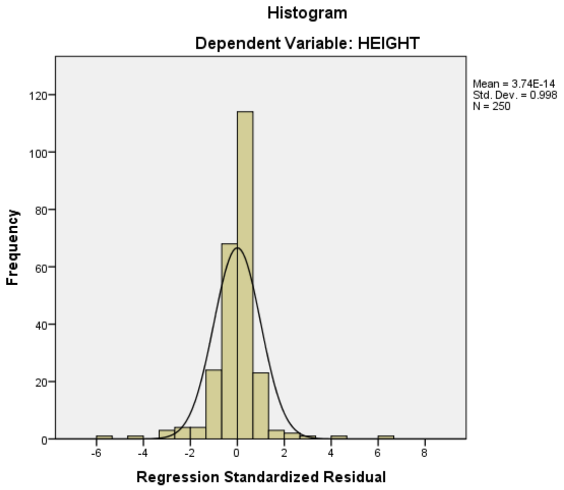


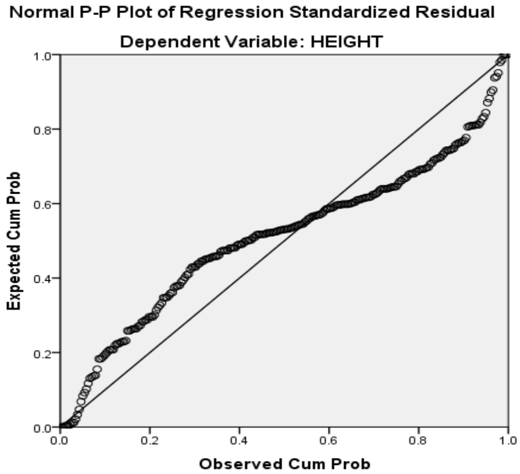


Regression equations
Using right ulna in male height (H) is H = -12.339 ± 6.534 x length of right ulna.
Using left ulna in male height (H) is H = -11.519 ±6.519 x length of left ulna.
Using both ulna in male height (H) is H = -12.039 ± 6.876 x length of right ulna +0.335 x length of left ulna.

TABLE:-5 Descriptive statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
AGE	250	30	20	50	33.98	.563	8.904	79.273
RTULNA	250	7.90	22.20	30.10	27.0192	.09111	1.44053	2.075
LTULNA	250	7.70	22.30	30.00	26.9532	.08957	1.41626	2.006
HEIGHT	250	41.00	142.00	183.00	164.2000	.60884	9.62663	92.672
Valid N (listwise)	250							



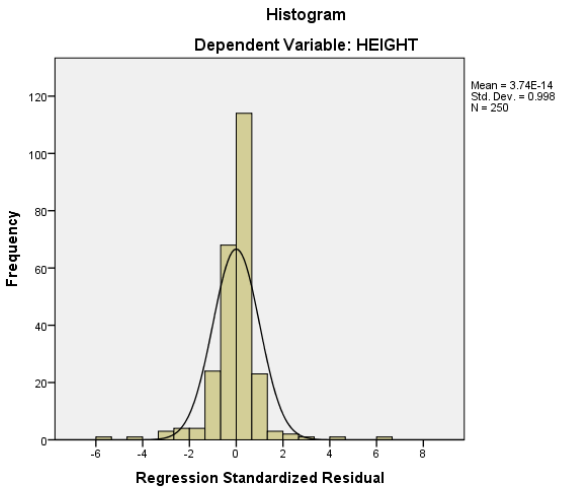


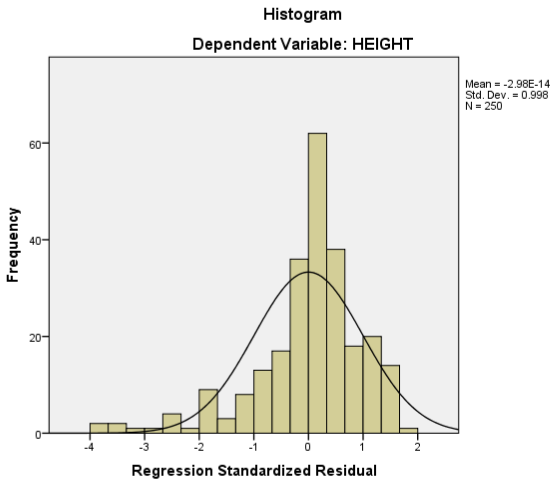
Regression equations

Using right ulna in female height (H) is H = 43.03 ± 4.409 x length of right ulna.

Using left ulna in female height (H) is H = 43.172 ± 4.413 x length of left ulna.

Using both ulna in female height (H) is H = 43.030 ± 3.646 x length of right ulna +0.765 x length of left ulna.





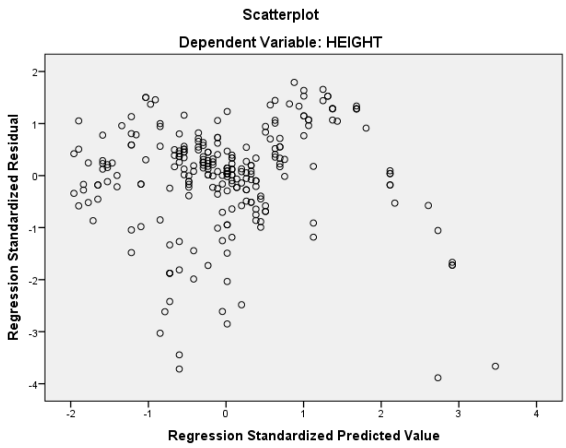


TABLE:-6 Descriptive statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
AGE	250	30	20	50	33.99	.523	8.269	68.381
RTULNA	250	8.80	21.00	29.80	24.1756	.10249	1.62045	2.626
LTULNA	250	8.70	21.00	29.70	24.1248	.10233	1.61793	2.618
HEIGHT	250	32.70	135.00	167.70	149.6304	.46653	7.37655	54.413
Valid N (listwise)	250							

Confidence intervals of prediction of stature (Y values):

The 95% confidence intervals for the predicted values of HEIGHT 'y' gives an idea of the range of values within which estimated stature as derived from the formulae, may lie for a given value of percutaneous ulnar length.

Confidence levels of the constant (A):

It may be said with 95% confidence that the value of A (population constant factor) lies between the limits a ± t (0.05) X estimated S.E. associated with 'a', where 'a' is the sample constant factor of the regression equation. Hence for males 'A' lies between 71.36 ± 12.137 i.e. 83.3 and 59.2 and for females it lies between 65.34 ± 11.546 i.e. 76.9 and 53.8.

Confidence levels of regression co-efficient (B):

The 95% confidence limits for B (the population regression coefficient) lie between b ± t (n-2) (0.025) where 'b' is the sample regression coefficient of the regression equation.

Thus it can be said with 95% Confidence Interval that for males, the value of the regression coefficient lies within 2.575 ± 0.336 (i.e. between 2.9 and 2.2) and for females it lies between 2.691 ± 0.337 (i.e. between 3.0 and 2.4).

TABLE:-7 Frequency distribution of age of subjects

Class intervals	Mid point (x) of class interval	Frequency (f)	
(years)		Males	Females
20-30	25	103	97
31-40	35	75	90
41-50	45	72	63
Total (Ef)		N=250	N=250
Mean (Years) = E fx/Ef		33.98	33.98
Mean age of both sexes (Years)		33.98	
Range (Years)		20-50	20-50

TABLE:-8

Reachers	Regression equation(Males)	Regression equation(Females)	Regression equation(Both sexes)	
Mondal M K,Jana T K[8]		Estimated Height (cm) = 45.89 + 4.39 x Left ulnar length (cm) ± 7.03.Estimated Height (cm) = 58.72 + 3.89 x Right ulnar length (cm) ± 9.17.		
Prasad A[9]	H = 93.45 + 2.92X	H = 113.89 + 2.37X	H = 132.43 + 1.49X	X= average length of right and left Ulna.
Yadav S K[10]			Y=77.74+3.33X	X=average length of right and left Ulna.
Maloykumar[11]	Estimation of height from left ulna; Y2= 76.289+ 3.256X2 ± 9.082 Estimation of height from right ulna; Y1 = 50.642+ 4.1896X1 ± 7.7302			
Allbrook[12]			Stature= 88.94 + 3.06(ulna length) ±4.4 (SE)	
Athwale M.C[13]			Stature = 56.9709cm+ 3.9613 × average length of right and left ulna (cm) ± 3.64cm.	
Thummar, Patel[14]	Y_1 =81.11 +3.117X_1 Y2=65.76 +3.667X_2	Y_1=17.10 + 5.314X_1 Y_2 =18.95 +5.335X_2	Y_1=21.17 +5.212X_1 Y_2 =14.92 +5.440X_2	
Present Study	Using both ulna in male height (H) is H = -12.039 ± 6.876 x length of right ulna +0.335 x length of left ulna.	Using both ulna in female height (H) is H = 43.030 ± 3.646 x length of right ulna +0.765 x length of left ulna	Using both ulna in total population height (H) is H =2 3.001 ± 6.562 x length of right ulna +1.334 x length of left ulna.	

Different formulae popularly used to calculate height (H) from percutaneous Ulnar length (U).

DISCUSSION

The present study included 500 subjects from the southern part of West Bengal. Since the study was carried out in one of the busy OPD in this region, one may assume that a representation sample from this region has been obtained.

Age distribution:

The present generation, as continues to grow for a long time than persons of yesteryears. Subjects whose age was below 20 years, was deliberately excluded so as to avoid the effect of epiphyseal growth, if any on stature.

The mean age of the whole sample of subjects (n=500) was 33.98 years. It can be analyzed from the Table 8 that the subjects were almost equal in proportion in all the age groups and all sexes.

This has two implications. First, that the regression equations that has been obtained are from data contributed mostly by the middle age group.

The contribution of the older age groups was almost equally important. Some authors had suggested (Trotter and GIeser 1958) [15] that to estimate stature 0.06 x (age in years), 30 cm should be subtracted for aged individuals. In case of the present formulae however, this correction falls well within the expressed error.

Secondly, in this part of the country, identification related to forensic cases of crime and antisocial activities, mostly involve middle age group. Since the estimation of height by using the present formulae would be much more accurate for this age group than for other groups, this would be an added advantageous point. The present study deals with observations on correlation of total standing height with length of ulna. In Anthropological studies and Forensic examinations, prediction of stature from incomplete and decomposing skeletal remains is vital in establishing the identity of an unknown individual. The stature of an individual mainly being genetically predetermined is an inherent characteristic, the estimate of which is considered to be an important assessment in the identification of unknown human remains. Therefore, formulae based on the length of ulna provide an alternative stature predictor under such circumstances. The ulna has easily identifiable surface landmarks making the measurement possible. The average height of adult males within a population is significantly higher than that of adult females. The result obtained in this study is in agreement with the above statement. Studies on secular changes and allometry have demonstrated different limb proportions between sexes and among population.

Allbrook : Derived regression formulae for estimation of stature from length of ulna as Stature= 88.94 + 3.06(ulna length) ± 4.4 (SE)

AthwaleM. C studied 100 Maharashtrian males of age ranging from 25- 30 years and derived regression formulae for estimation of stature and left radius (cm) +3.66cm. Stature = 56.9709cm+ 3.9613×average length of right and left ulna (cm) ± 3.64cm.

Lal and Lala [16] worked on a population of 258 of age ranging from 12 to 21 years in north Bihar and stated that ulnar mean multiplication factor was comparable in all series. They claimed that ulnar multiplication factor is better guide for calculation of height when it is not definitely known to which part of the country the individual belongs.

Maloy Kumar derived regression equation for estimation of stature from the length of ulna in males of West Bengal in age range of 20-50 years.

a) Estimation of height from right ulna; $Y1 = 50.642 + 4.1896X1 \pm 7.7302$

b) Estimation of height from left ulna; $Y2 = 76.289 + 3.256X2 \pm 9.082$

Ilayperuma I. et. al. [17] derived regression equations for stature estimation from length of ulna in both males and females in Srilankan population.

Thummar B et.al derived regression equation for estimation of stature from length of right and left ulna in both males and females.

For males regression equation for right ulna is Y = 181.11+3.117X and for left ulna equation is Y = 65.76+ 3.667X 1

For females equation for right ulna is Y = 17.10+5.34X and for left ulna equation is Y = 18.95+5.33X 2

Regression analysis for prediction of height in all cases

For right ulna Y =21.17+5.212X 1

For left ulna Y = 14.92+5.440X 2

In the present study, the correlation coefficient(r) of the height and the length of the left ulna was 0.968 and that for the right ulna was 0.974. The value of r implied that there was a positive correlation. This implied a significant contribution of the length of the ulna towards the height. The simple linear regression equation which has so far been derived can be used for the estimation of the height.

The findings are at par with the findings of the previous researchers, as were reported in 1952. Trotter M et al., [18] estimated the stature of American whites and Negroes from the ulna with linear regression equations. A study done by Lundy JK et al. (1985) [19] discussed the regression equation and the mathematical and the anatomical method of estimating the living stature from the long limb bones in the South African population. The reports of Agnihotri AK et al. (2009) [20] from Mauritius and those of Barbaosa VM et al. (2012) [21] from Portugal also found the linear regression model to depict an individual's stature from the percutaneous ulnar length.

In India, Lal CS et al. (1972) worked on a population of 258 in north Bihar, whose ages ranged from 12 to 21 years, for the estimation of the height from the surface anatomy of the long bones e.g. the tibia and the ulna. The ulnar mean multiplication factor was comparable in all the series. They claimed that the ulnar multiplication factor was a better guide for the calculation of the height, when it was not definitely known as to which part of the country the individual belonged. A similar study was done by Nath BS et al., [22] in Delhi in 2007.

Devi S et al. (2006) [23] computed the correlation coefficient (r = 0.619 for males and 0.584 for females) and the regression equation formula for the estimation of stature by using the upper arm length among the living population of the Maring tribes of the Pallel area in the Chandel district, Manipur. In the Bengali population, Mondal M et al. (2009) [24] postulated the height estimation in males from the ulna. The present study could highlight such a relationship in females.

Since the height of an individual progressively increases upto a certain age (till adolescence) and then decreases after a certain age due to vertebral column erosion, so the inclusion of a wider range of age groups could overcome its limitation for its applicability of the regression model. Moreover, a multi-centric approach in West Bengal will also supplement the findings in the Bengali population in future. But still the regression formulae which are proposed will be of immense practical use in the clinical practice and in medico-legal, anthropological and archaeological studies, where the total height of a subject can be calculated if the ulnar length is known.

Data of the dependent variable, height, with respect to the independent variable, percutaneous ulnar length were analysed by parametrical statistics.

Here a random sample of size 500 from the population has been drawn and observations x on X and y on Y had been made where X and Y were random variables associated with the population members to give a set of observation (x., YI), (X2 y2) (x, Yn) . A linear relationship between x and y on the basis of these measurements was then established separately for males and females. Of particular interest was in the case where variables X and Y jointly followed a bivariate normal distribution. This bivariate normal distribution was defined by the parameters x, sx, y, yy. These parameters were computed separately for males and females.

The *sample standard deviation* (Sx) of height for both males (±7.685) and females (±6.107) closely approximated the *population standard deviation* (Sy) of ±7.593 and ± 6.011 respectively. Thus, it was understood that the sample very closely represented the actual population from which it was drawn.

Correlation:

To find out whether stature (y) was related to percutaneous ulnar length (x) and whether a relationship between them existed or not, the correlation coefficients (ryx) were calculated. Supposing if X and Y were the random data of the population, the correlation co-efficient between X and Y is given by p, which is thus a measure of correlation or linkage between X and Y. The sample estimate of p is the sample correlation coefficient ryx.

For males ryx was found to be 0.926 and for females it was 0.948. Since both nearly approached + 1, it was concluded that height and percutaneous ulnar length are highly correlated.

To test whether the correlation coefficients were significant or not the null hypothesis H : p =0. (p= population correlation co-efficient) was set up.

The computed 't' was found to be much greater than the critical 't' value at the chosen level of significance. The null hypothesis (p=O) was rejected. The computed ryx for both males and females was thus considered significant at the 0.05% of significance ($p<0.05$)

The positive correlation as obtained in case of both males and females, indicates that the individuals with greater percutaneous ulnar length will have, as expected, a higher height.

Linear regression analysis:

The main aim of the present study was to fit the *best straight line* through the bivariate variables that have been obtained.

For historical reasons, the straight line of best fit drawn through a set of points is called the regression line and the gradient of the line is referred to as the regression coefficient.

(Simple) linear analysis is a method of deriving an equation relating two quantitative variables. Since it has already been found that x and y were highly correlated, a relationship between the percutaneous ulnar length (x) and height (y) was aimed to be established in the form of equation of straight line.

Y=a+bx

Regression equations

Using right ulna in male height (H) is H = -12.339 ± 6.534 x length of right ulna.

Using left ulna in male height (H) is H = -11.519 ±6.519 x length of left ulna.

Using both ulna in male height (H) is H = -12.039 ± 6.876 x length of right ulna +0.335 x length of left ulna.

Regression equations

Using right ulna in female height (H) is H = 43.03 ± 4.409 x length of right ulna.

Using left ulna in female height (H) is H = 43.172 ± 4.413 x length of left ulna.

Using both ulna in female height (H) is H = 43.030 ± 3.646 x length of right ulna +0.765 x length of left ulna.

Regression equations

Using right ulna in total population height (H) is H = 22.69 ± 5.244 x length of right ulna.

Using left ulna in total population height (H) is H = 22.96 ± 5.245 x length of left ulna.

Using both ulna in total population height (H) is H =2 3.001 ± 6.562 x length of right ulna +1.334 x length of left ulna.

Tests of significance: To determine how reliable the sample equations which are likely to be the confidence limits for 'a' and 'b', have been found out.

Having determined the slope (b) and constant factor (a), it is relevant to examine how far these variables are helpful in the prediction of stature. If the variables are of no use, then the regression does not depend upon them, so that b=O and a=O. the following tests were carried out.

Hypothesis testing of slope / regression coefficient:

The null hypothesis B=O and a new hypothesis that B>O was set up at 5% significance level.

The 't' values calculated for males and females were much higher than the critical values of 't' (0.05) . Hence the null hypothesis was rejected.

Thus b $\neq 0$but b>O i.e., stature is indeed related to height in the present sample and regression equations truly depend upon the~

Confidence levels of the regression coefficient and constants (A and B)

To know how wide the variation of the regression coefficient would be, the 95% confidence limits for B (the population regression coefficient) were calculated.

It was found that the value of the regression coefficient for males lies within 2.575±0.336 and that for females, it lies between 2.691±33.7.

Similarly, it may be said statistically, with 95% confidence, that the value of A (population constant factor) for males lies between 71.36±12.137 and for females it lies between 65.34±11.546. These values provide definite indication that the regression equations are significant.

There is only a 1 in 20 chance that the values A and B fall outside these limits. Thus for estimation of height we can have an idea how accurate our equations are.

Testing whether the regression coefficient of males and females are significantly different:

The present worker tried to justify the formulation of two separate equations for males and females. This was important more so because most Indian researchers had formulated a regression equation or multiplying factor, taking both sexes together into account.

By comparing the squared standard error of males and females using a F test, it was found that the computed F exceeded the critical F value. The null hypothesis was rejected and thus the regression coefficient b male was significantly different from b female. Thus the same formula cannot be used and separate formulae are suggested for males and females for the estimation of stature.

Also it may be noted that since we had tested the null hypothesis B=O and found that it is not true; the F ratio tended to be large (and positive) irrespective of the direction in which b differs from O.

CONCLUSION

The maximum percutaneous ulnar length (u) and the corresponding height (S) of 250 adult male and 250 adult female subjects of the southern part of West Bengal were measured accurately. The mean age of the sample was33.98 years and the mean height was 164.20 cm (males) and 149.63 cm. (females). The data were analyzed by parametric statistics. There was high correlation between ulnar length and height.

From the present study, it has been concluded that

1. Mean height and length of ulna is more in males than in females.
2. Gender differences in mean height and length of ulna were found to be highly significant (P <0.05)
3. There is positive correlation between stature and length of ulna.
4. Simple linear regression equation so far derived can be used for estimation of height in this study.
5. If either of the measurement (length of ulna or total height) is known, the other can be calculated.
6. This fact will be of practical use in Medico legal investigations and in Anthropometry. Study would be useful for Anthropologist and Forensic Medicine experts.

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