Original article

Estimation of human height from the length of tibia

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Abstract

Introduction: Assessing the height of individuals, from measurements of different parts, has always been an immense interest to the anatomists, anthropologists and forensic medicine experts.

Aim of the study: To estimate the stature of body from tibial length was the aim of the present study.

Methods: The maximum percutaneous tibial length (T) and the corresponding height (S) of 50 adult males and 50 adult female's subjects of the southern part of West Bengal were measured accurately. The data were analysed by parametric statistics.

Observations: There was high correlation between tibial length and height. Regression equations for estimation of stature were calculated thus:

For males: $S = 71.361 + 2.575 (T)$ [S.E. of estimate ± 2.943]

For females: $S = 65.344 + 2.691 (T)$ [S.E. of estimate ± 1.974]

The mean age of the sample was 25.95 years. The mean height of male subjects was found to be 164.05 cm. and this was higher than that of females which was 156.38cm.

The mean percutaneous length of tibia (x) was found to be 35.99 cm. for males and 33.83 cm for females.

A relationship between the percutaneous tibial length (x) and height (y) was established by calculating the correlation coefficient (ryx) which nearly approached + 1 both for males and females and it was concluded that height and percutaneous tibial length are highly correlated.

Discussion: It was deduced that the Trotter and Gleser's formula and Pan's formula closely correspond with the formulae used in this study for estimation of stature. Regression lines were drawn with 95% confidence limits for direct estimation of stature from the given tibial length and the regression coefficients were significant ($p<0.05$).

Conclusion:, The individuals with greater percutaneous tibial length have, as expected, a higher height.

Introduction

"Identification is an individual's birth right". Personal identification denotes determination of individuality of a person. It may be complete (absolute) or incomplete (partial).Complete identification signifies absolute fixation of individuality of a person. Partial identification implies ascertainment of only some facts about the identity of the person while other still remain unknown. Age, sex and stature are the primary characteristics of identification **[1].** Stature is one of the various parameters of identification. It is well known that there is definite relationship between the height of the person and various parts of the body like head, trunk and lengths of the upper and lower limbs. Assessing the height of individuals, from measurements of different parts, has always been an immense interest to the anatomists, anthropologists and forensic medicine experts **[2].**

The stature of individual is an inherent character and is considered as one of the important parameters of personal identification. In absence of documented skeletal material, the researcher has focussed their attention toward living population groups of India and has taken relevant bone lengths over the skin and correlated them with the stature to find out the degree of relationship between them and subsequently formulated multiplication factors and regression formulae from long bones for reconstruction of stature **[2].**

Adult stature and body mass are fundamental characteristics of individuals and populations with relevance to a range of issues from long -term evolutionary processes to shorter term stress markers **[3].**

The tibia is situated at the medial side of the leg, and except the femur, is the longest bone of the skeleton. It is prismoid in form, expanded above, where it enters into the knee-joint, contracted in the lower third & again enlarged but to a lesser extent below. In the males its direction is vertical and parallel with the bone of the opposite side, but in the female it has a slightly oblique direction downward & laterally, to compensate for the greater obliquity of the femur. It has a body & two extremities **[4].**

The upper extremity is large & expanded into two eminences, the **medial & lateral condyles.** The body or shaft has three borders & three surfaces. The lower extremity which is smaller than the upper is prolonged downwards on its medial site as a strong process, the **medial malleolus[4].** Apart from sex, age, physical bony deformity, etc., the stature of a person is also a vital point for identification **[5].**

Aims & Objectives

1. To measure the length of Tibia.
2. To measure the height of the body (stature).
3. To establish a relationship between length of Tibia & Stature of the body.
4. To estimate the Stature of body from Tibial Length.
5. To correlate various statistical parameters.

Materials and Methods

The present study was undertaken to formulate a regression equation for estimation of **stature** of the population of southern part of West Bengal, India, from the length of a long bone **tibia** in adult age group.

Study design: Cross sectional study.

Selection criteria and sample size:

1. **100 subjects were selected randomly for the study** from the General Medicine out Patient Department (OPD) of N.R.S Medical College and Hospital, Kolkata and there were **50males and 50 females, belonging to the age group of 25 - 64 years.**
2. In order to eliminate the influence of the epiphyseal growth factor in formulation of the regression equations, adults belonging to the age group of 25 – 64 years were selected.
3. Subjects with any obvious congenital or acquired deformity of spine or extremities

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were not included in the study. **The subjects gave their written consent for this study.**

The following parameters have been noted: Name, age, sex, height in cms, Length of left tibia in cms was recorded in appropriate format.

Measurement Technique: The measurements were done by standard anthropometric instruments in centimetres, according to the technique described by Vallois**[6]**. Each of the measurements was taken three times and their mean value was noted for estimation of height.

Height: Standing Height (from vertex to heel) was measured when the subject was standing barefooted on a standard **stadiometer** in anatomical position**.** The head was adjusted in Frankfurt plane (tilted slightly upwards) and the height was measured in centimetres by bringing horizontal slide bar to the vertex and using measuring steel tape.

Tibial Length: The subject was asked to stand and keep his/her foot on an wooden tool to maintain the angle between the flexor surfaces of leg and thigh at 90° to make the following bony landmarks more prominent which were marked with a skin marking pencil.

a) Upper point: The medial most superficial points on upper border of medial condyle of left tibia.
b) Lower point: tip of left medial malleolus.
c) Distance between the two points was measured in centimetres with the help of a spreading calliper to determine tibial length. The separation of the arms of the callipers was measured from the same steel tape.

The records obtained were documented in the format detailed below.

Case record format

SL.NO.	APPROXIMATE AGE OF SUBJECT(IN YEAR)	SEX	PERCUTANEOUS LENGTH OF TIBIA (IN CM)	HEIGHT OF SUBJECT(IN CM)

The bivariate pair (percutaneous length of tibia and height) was tested for linearity and the relationship between the pair, i.e., the correlation coefficient (

$$r_y = \frac{\sum xy - 1/n \sum y \sum x}{\sqrt{\left[\sum x^2 - 1/n\left(\sum x\right)^2\right]\left[\sum y^2 - 1/n\left(\sum y\right)^2\right]}}$$

It may be noted that a regression equation is represented by a straight line **Y=a+bx.** For computation of the slope or regression coefficient (b) the following formula was adopted.

$$b = \frac{\sum xy - \left(\sum x \sum y\right)/n}{\sum x^2 - \left(\sum x\right)^2/n}$$

All data were 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 **[8]**

a=y- bx, where y and x are the sample means of y and x respectively.Replacing the values of 'a' and 'b', the regression equation of the sample population was obtained. Regression equations for male and female cadavers were obtained separately. ‘F’ or quick estimations of stature from dry tibial length, graphical representations of the regression equations were made. The regression lines were plotted by substituting the maximum, minimum and mean values of the tibial length in the regression equations which are likely to be the confidence limits for 'a' and 'b'and the equations were calculated using the following formula **[9].**

a ± t (0.05) X S and b ± t (0.05) X S, where S 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 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 dependency 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 **[10]:**

At first’t’ value was calculated using the formulae

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

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) **[7]:**

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

Where x, = some value of x [here minimum, maximum and mean values were taken]

T = Critical t score for ‘a’ = 0.025

To know whether the regression coefficient of males and females were significantly different or not, calculations of F values were done by the following method **(Williams, 1984) [11]:**

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

Figure: 1 & 2– Stadiometers to measure the height

Figure: 3- Spreading Calipers – (open and closed), to measure the percutaneous length of tibia [PCLT].

Figure: 4 - Height of a subject is being measured with the help of a Stadiometer.

Figure: 5 – Percutaneous length of Tibia is being measured with the help of spreading callipers in the same subject.

Results and analaysis

The sample of the present study included 100 subjects (Males = 50, Females = 50) from the southern part of West Bengal. Age of Males varied between 25 years to 64 years and that of Females between 25 years to 55 years (Table –1). The Mean age of the male subjects was 37.14 years and that of the female subjects was 34.47 years. The mean age of the whole sample (n=100) was 35.95 years (**Table –1**) (Fig. – 9).

Thus the regression equations, those have been obtained, are from data contributed mostly by this younger age group. The frequency of the older age groups, especially >38 years was negligible (1.4%). The percutaneous tibial length **(PCTL)** and the corresponding height, were depicted in **Table 2** (Fig.6,7, 8,).The mean height of **male subjects was found to be 164.05 cm.** and this as expected, was higher than that of **females which was found to be 156.38cm.** The *sample standard deviation* (Sy) for both males (±7.685) and females (±6.l07), closely approximated the *population standard deviation* (c y) of males (± 7.593) and females (± 6.011) respectively **(Table 3)**.

The mean percutaneous length of tibia (x) was found to be 35.99 cm for males and 33.83 cm for females. For PCTL, the *sample standard deviation* (Sx) for males was ± 2.763cm.and for females was ± 2.152cm; showed negligible difference with the *population standard deviation* (IT x) **(Table 3)**.

To find out whether height (y) was related to percutaneous tibial length (x), the correlation coefficient (ryx) were calculated. For males, ryx was found to be 0.926 and for females it was 0.948; both nearly approaching + 1**(Table 3)**.

With this finding, that x and y were highly correlated (correlation coefficient approaching + 1), a relationship between the percutaneous tibial length (x) and height (y) was established.

Y and X are related by the equation (y= a + bx) which represents a straight line. Regression coefficient was **b** and intercept / constant or additive factor was **a**.

The regression equations as calculated are as follows (Table 4).

For male: S = 71.361 ± 2.575 (T)

For female: S = 65.344 ± 2.691 (T)

Where S = Height and T = Percutaneous tibial

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length.

The regression lines of the above equations were drawn**,** so that height(y axis) was plotted against percutaneous tibial lengths (x axis) separately for males and females **(Fig.7, 8).** It was seen that the regression lines were nearly parallel and that for the same percutaneous tibial length, the corresponding stature for males, as read from the graph, was higher than for females.

The standard error of estimate of the equation for males was ± 2.943 and that of females to be ± 1.974 (**Table 4**). The S.E. (Standard Error) of estimate was quite low, especially that of females. Hence the scatter of data along the regression lines was minimal and from the *goodness of fit* of the data points in drawing, the regression line was easily achieved. To determine how reliable the sample equations are likely to be the confidence limits for 'a' and 'b', those were calculated and tests of significance of ‘a’ and 'b' were carried out.

Hypothesis testing of regression coefficient (b):

Could the sample value b (males) and b (females) have arose when the population values B was zero (implying a horizontal population regression line)?

To answer this question, a hypothesis test was carried out. The null hypothesis B= 0 and new hypothesis that B>O was set up. 5% significance level was chosen for testing the hypothesis.

't' value calculated for males and females was much higher than the critical values of 't' (0.05) with 40 of degree of freedom (n-2) and 't' (0.05) with 30 degree of freedom (n-2) respectively. Hence the null hypothesis was rejected. Thus it is not realistic to assume that the regression coefficient of the population is zero.

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 tibial length.

Thus, considering the minimum and maximum values of percutaneous tibial [PCTL] length, it was seen that, for males, in 95% of the time, the estimated height would lie between 144.1 and 149.02cm. (for minimum end of the regression line) and between 174.35 and 178.01 cm (for the maximum end of the line) **(Fig-8)**; the corresponding values for females were 142.41 & 143.83 cm and 164.94 &171.36 cm. respectively**(Fig-7)**.

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 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).

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

For this the following null hypothesis was set up "The difference between the two regression coefficients b males and b females is due to entirely sampling error. The two samples are drawn from the population with the same regression co-efficient B.

Since the computed ‘F’ exceeded the critical ‘F

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value', the null hypothesis was rejected and it was concluded that the regression coefficient **b male** is significantly different from **b female**. Thus the same formula cannot be used and a separate formula as suggested for males and females has to be used for the estimation of height.

Thus after determining the percutaneous tibial length and height were positively correlated, the formulated regression equations were seen to be statistically significant.

Table-1 Frequency distribution of age of subjects

Class intervals	Mid point (x) of	Frequency (f)	
(years)	class interval		
		Males	Females
25 -35	30	24	29
35 -45	40	19	17
45- 55	50	6	4
55 -65	60	1	0
Total (Ef)		N=50	N=50
Mean (Years) = E fx/Ef		37.14	34.47
Mean age of both sexes (Years)		35.95	
Range (Years)		25 to 64	25 to 55
60			

Table -2 Dependent and independent variables of samples

Sl no.	Male SUBJECTS(n=50)			Female SUBJECTS (n=50) .	
	Percutaneous tibial Tibial length (x) (in (in cm)	Height (y) (in cm)		Percutaneous tibial Tibial length (x) (in in cm)	Height (y) (in cm) cm)
1.	29.2	148.3		36.1	162.5
2.	30.6	149.6		35.4	160.1
3.	31.0	150.8		36.4	166.6
4.	31.6	152.8		36.2	158.0
5.	31.9	156.0		34.0	156.5
6.	33.3	156.4		34.0	156.5
7.	33.8	156.7		29.9	145.5
8.	34.0	160.5		31.5	150.9
9.	34.0	160.6		32.8	152.3
10.	34.1	161.5		35.3	165.5
11.	34.4	160.2		28.9	142.0
12.	34.4	161.2		34.8	158.8

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13.	34.1	160.8		30.7	148.0
14.	350	163.5		31.5	150.0
15.	35.6	165.5		33.6	156.6
16.	35.6	162.8		34.2	157.2
17.	35.8	163.5		34.6	159.3
18.	36.0	165.7		35.2	160.8
19.	36.1	158.4		31.8	150.3
20.	36.3	170.7		33.9	156.0
21.	36.4	169.0		34.9	158.6
22.	36.4	165.0		32.8	153.9
23.	36.5	162.5		36.2	163.7
24.	368	165.5		34.1	157.0
25.	37.0	164.4		30.4	146.5
26.	37.7	168.5		33.2	154.9
27.	37.5	175.5		34.6	157.6
28.	40.7	172.7		38.2	167.6
29.	38.5	166.5		33.8	155.9
30.	40.2	172.7		35.9	162.4
31.	37.0	166.5		31.5	153.9
32.	38.6	172.7		34.8	158.7
33.	37.3	168.9		29.9	145.5
34.	33.3	157.3		36.4	166.6
35.	38.9	171.1		34.8	158.8
36.	39.0	172.0		34.6	157.6
37.	38.2	170.0		38.2	167.6
38.	38.6	171.3		36.1	162.5
39.	38.4	170.3		36.4	166.6
40.	40.6	176.7		30.7	148.0
4l.	39.8	173.0		27.4	141.0
42.	37.4	169.1		28.2	142.0
43.	35.0	163.5		29.3	146.1
44.	35.6	165.5		31.5	150.0
45.	35.8	163.5		33.6	152.0
46.	40.7	172.5		31.8	150.7
47.	41.8	175.5		32.8	153.9
48.	38.6	169.7		30.4	146.5
49.	37.3	168.9		30.7	148.0

50.	33.3	157.3		28.9	142.0

	Table – 3		
	Descriptive statistics of the **sample (n=100)**		
	Statistical parameters	**Males**	**Females**
A	Sample Size (n)	50	50 ~
B	Cadaver supine length (y)		
	Mean (Y)	164.05	156.38
	Range	146.5-176.7	142.0-167.6
	Sample S.D (Sy)	±7.685	±6.107
	Population S.D. (cry)	±7.593	±6.011
C	Dry tibial lengths (x)		
	Mean (x)	35.99	33.83
	Range	29.2-40.7	28.9-38.2
	Sample S.D (Sy)	±2.763	±2.152
	Population S.D. (cry)	±2.730	±2.118
D	correlation co-efficient (ryx)	0.929	0.948
	E) Standard error of estimate	±2.943	±1.974

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Table-4 Formulation of new regression equations of height from percutaneous tibial length

For Males	Regression co-efficient (b)	2.575
	Constant (additive factor / inter	71.361
	Regression equation	S=71.361±2.575T
	SE of estimate	±2.943
	Correlation co-efficient (ryx)	0.926
For Females	Regression co-efficient (b)	2.691
	Constant (additive factor / intercept)	65.344
	(a) Regression equation	S=65.344+2.6918T
	Correlation co-efficient (ryx)	0.948

PERCUTANEOUS TIBIAL LENGTH (in CM)

HEGHT IN CENTIMETERS

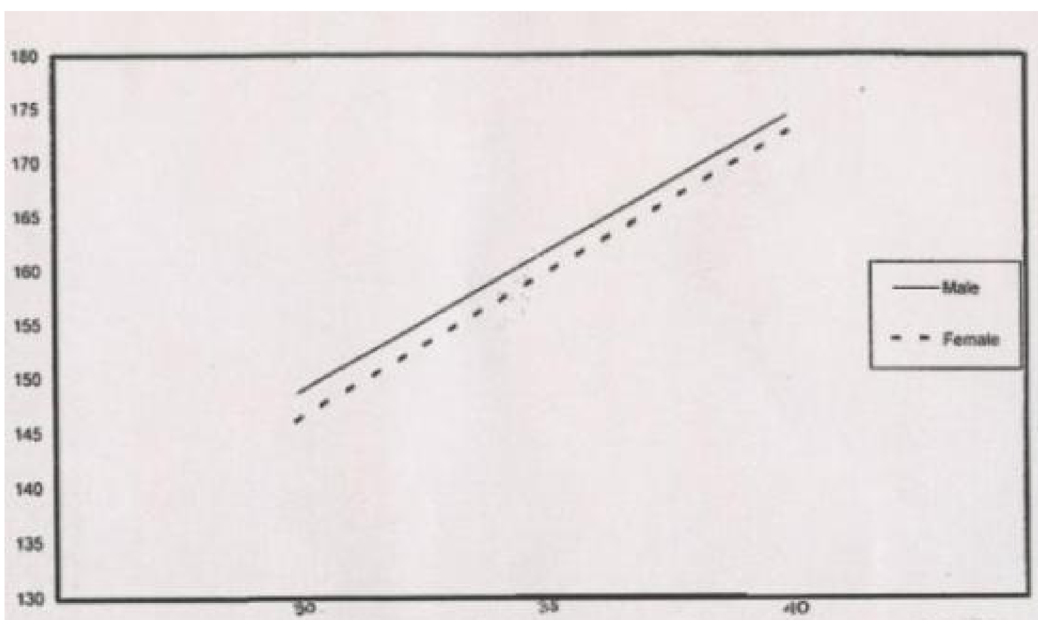

Figure – 6

REGRESSION LINE FOR ESTIMATION OF STATURE FROM PERCUTANEOUSTIBIAL LENGTH

PERCUTANEOUS LENTH OF TIBIA (INCENTIMETERS)

HEGHT IN CENTIMETERS

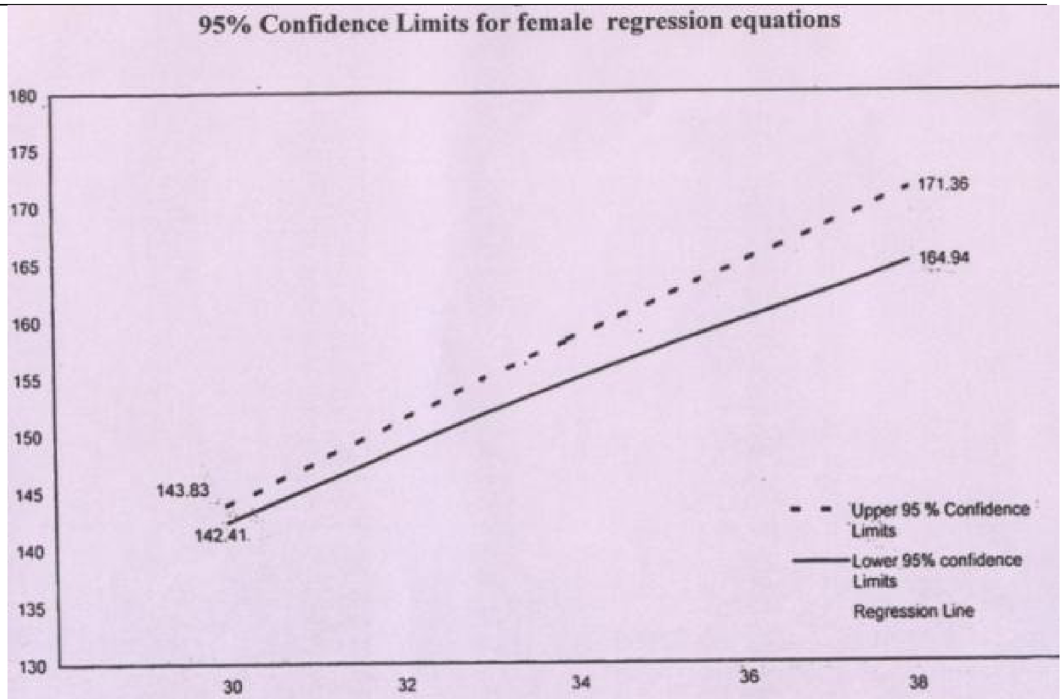

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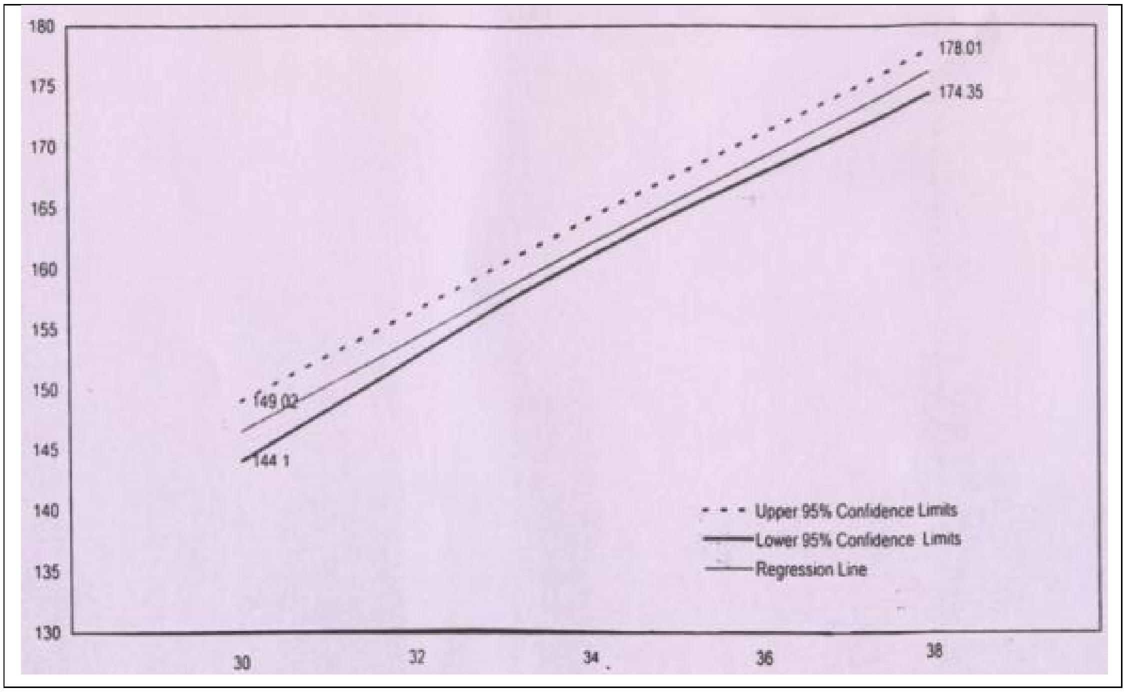
Figure – 7

95% CONFIDENCE LIMIT FOR FEMALE REGRESSION EQUATION



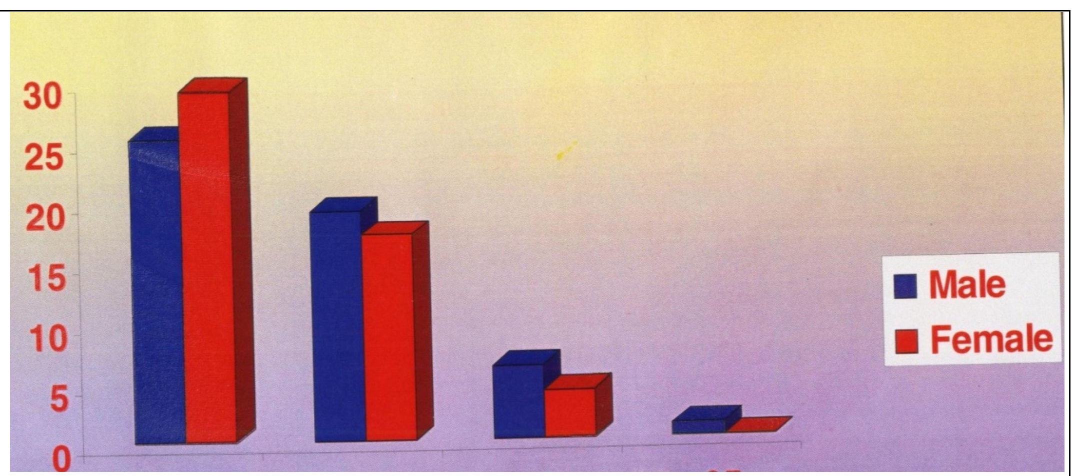
PERCUTANEOUS TIBIAL LENGTH (CM) WAS DEPICTED HORIZONTALLY AND THE HEIGHT (CM) WAS DEPICTED VERTICALLY.

Figure – 8 95% CONFIDENCE LIMIT FOR MALE REGRESSION EQUATION

Figure - 9

Frequency distribution of age of subjects

NO OF SUBJECTS



25-35YR 35-45YRS 45-55YRS 55-65YRS

AGE IN YEARS

Discussion

It was as back as in 1888, when Rollet published his work in a tabular from to estimate the stature from lengths of long bones. He had included humerus, radius, ulna, femur and fibula besides tibia **[12].**

Later, in 1892 and 1893, Manouvrier reassessed Rollet's data According to him, the bones of subjects above sixty years of age to time of death may decrease in length by around 3 cm. of calculated stature **[13].**

Pearson (1899) laid down certain basic rules for stature reconstruction. An important one, especially related to anthropology and forensic problems, is as follows **[14]:**

Pearson's regression formula used for the estimation of living stature from "cadaver, long bone length" - (From tibia (T) alone and femur (F) and tibia (T) together) - for both males and females **[14]:-**

Males	Females
Regression formula	Regression formula
S = 78.664 + 3.378 T	S = 74.744 + 2.352T
S= 71.272 + 1.159 (F + T)	S = 69.154 + 1.26 (F+T)
S = 71.441 + 1.220 F+ 1.080T	S = 69.561+1.117F+1.125T

Age distribution:

Subjects whose age was below 25 years, was deliberately excluded so as to avoid the effect of epiphyseal growth on stature. The mean age of the whole sample of subjects (n=100) was 35.95 years. It can be analysed from the Table 20 that most of subjects i.e. 53% belonged to the age group '25 to 35 years'.The regression equations that has been obtained are from data contributed mostly by this younger age group.The contribution of the older age groups especially >55 years was negligible (1.4%) **(Fig. 9).**Some authors like Trotter and Gleser **[15]** had suggested that to estimate stature by the formula : 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. Thus the factor of decrease in stature with older age group as some authors have noted, does not have much influence in the formulation of the present regression equations**[5].**Secondly, in this part of the country, identification related to forensic cases of crime and antisocial activities, mostly involve younger age group. Since the estimation of **height** by using the present formulae would be much more accurate.

Descriptive statistics of the present study;

Data of the dependent variable, height (y), with respect to the independent variable, percu-taneous tibial length (x) were analysed by parametrical statistics. A linear relationship bet-ween x and y was established separately for males and females **(Table 2)**. Of particular int-erest was in the case where variables X and Y jointly follow ed a bivariate normal distribu-tion. This bivariate normal distribution was defined by the parameters x, Sx, y, Sy. These parameters were computed separately for males and females **(Table 3).**

The sample standard deviation (Sx) of height for both males (±7.685) and females (±6.107) closely ap -proximated the population standard deviation (Sy) of ±7.593 and ± 6.011 respectively **(Table 3)**. 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 tibial 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. For males ryx was found to be 0.926 and for females it was 0.948 (Table Since both nearly approached + 1, it was concluded that height and percutaneous tibial length are highly correlated, the individuals with greater percutaneous tibial length have, as expected, a higher height. The computed ryx for both males and females was thus considered significant at the 0.05% of significance ($p<0.05$)

Linear regression analysis:

(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 tibial length (x) and height (y)** was aimed to be established in the form of equation of straight line.

The degree of correlation is indicated not only by the closeness with which the points approximate to a straight line but also by the slope of the line i.e., the rate at which y changes with x. In the present study both were statistically significant.

Tests of significance:

Having determined the slope (b) and constant factor (a), it is relevant to examine how far the se variables are helpful in the prediction of stature. Hypothesis testing of slope / regression coefficient: The 't' values calculated for males and females were much higher than the critical values of 't'(0.05) .

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

With 95% confidence limits, B (the population regression coefficient), it was found to be 2.575±0.336 for

males and 2.691±33.7 for females. Similarly, with 95% confidence, the value of A (population constant factor) was 71.36±12.137 for males and for females was 65.34±11.546 which indicate definitely that the regression equations are significant.

Regression coefficient of males and females are significantly different as was noted by a'F test', the computed F exceeded the critical F value [5].

Comparison of different formulae:

1. The popular formulae used for estimation of stature from a given length of tibia are summarized in **Table 5.** Most Indian researchers have formulated Multiplying Factors rather than regression equa -tions assuming constant prop-ortionality of the tibia with stature. However, this assumption is not always correct as Meadows and Jantz (1995) had shown that tibia was positively allometric with stature. **[16].**
2. Some author derived a common regression equation, others derived a multiplying factor applicable to males **[17, 18,19 ,20,21].**
3. The difference between the multiplying factors for males in stature is only 0.36 cm(by Nat and Pan) **[17,22].**
4. The results of the present study and those of the previous workers have been depicted in **Table 5.**For the comparison with those who have formulated a single regression to be valid, in the present study, according to a common regression equation from the pooled data of both males and females it was found that **S (HEIGHT) = 64.051+2.758 T**

(PERCUTANEOUS TIBIALLENGTH) (Fig. – 6). The regression equation of Patel under estimated the stature by 17.99 cm while such wide underestimation was also seen by application of multiplying factors of Siddique &Shah (underestimation by12.87 cm.) and that of Singh &Sohail (underestimation by 13.59 cm) **[18, 20, 21]**. Thus, clearly their formula or multiplication factor cannot be applied for estimation of height for the population of eastern India**.**

5. **Table 5:**Comparison of estimated height (cm) from different formulae **[14, 17, 18,19, 20, 21, 22, 23, 24] -**

	Male mean	Female mean	Sex combined	w	Difference
	=35.99	=33.83	mean =35.05		from the
					present study
Present study	164.3	156.38	160.72		0.0
Patel **			145.06		-17.99
Joshi **			158.29		-2.43
Nat *	161.24				-2.79
Pan	163.84	153.11			(-0.19,-3.27)++
Shah					
Singh &Sohail*	150.44				-13.59
Pearson	200.24	154.38			(+36.21, +2.42)
Tr. Gl.	169.32	159.64			(+5.29,
(White					+3.26)++
Americans)					
Tr. Gl.	164.84	154.87			(+0.81,
(Black Negroes)					1.27)++

Mean of the present sample for respective groups.

** Sex combined regression equations are compared.

* Multiplication factor for males only, as formulated, has been applied here for males.

++ (Difference in male formula, difference in female formula)

Conclusion

The present regression equations, which has taken into consideration the racial, geographical, secular and gender differences of percutaneous tibial length, could be employed for more accurate estimation of the height of an average population with significance in anthropometry and forensic medicine.

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