

Stature Estimation From Tibial Length

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Abstracts: Background and objectives: Stature of an individual is an important parameter of personal identification. In this study stature was estimated from the percutaneous measurement of length of Tibia in living. Methodology: 400 students (200 male and 200 female) in age group of 18-21 years were studied. Heights of the subject in standing position, percutaneous length of Tibia were measured on both sides. Regression formulae and Multiplication factors were derived for both sexes for right and left Tibia for estimation of stature Results: In both sexes stature estimated by regression formulae for percutaneous length of tibia was similar to average measured stature with an error of less than 1 cm. In both sexes stature estimated by derived multiplication factor for length of tibia was similar to average measured stature with an error of less than 1cm. There was no significant difference in the percutaneous measurement of length of right and left tibia in both sexes, thus showing bilateral symmetry in the length of Tibia in both sexes. Interpretation and Conclusion: This study will be of help to the forensic experts when whole leg only is available for forensic investigation for estimation of stature and in anthropological studies. Regression formulae are more dependable than multiplication factor for estimation of stature. [Kaore A et al NJIRM 2012; 3(2) : 51-56]

Key words: forensic expert , Multiplication factor, regression formula, Stature, Tibia.

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Introduction: The stature of an individual is an inherent character and is considered as one of the important parameter of personal identification.^{1,2} The problem of identification mainly arises when unknown human dead body, or mutilated part of dead body , leg are brought to forensic expert for examination.²

The forensic scientists are well aware of the fact that the complete skeleton is rarely available at the scene of crime. Thus the scientists may have no choice than to use mathematical method of stature reconstruction. This is of obvious advantage that it is workable even if a single long bone of upper or lower extremity is available for examination.¹

In most advanced countries documented skeletal remains are available to the forensic scientists. In India documented skeletal remains are not available for establishing the norms of stature reconstruction. In the absence of documented skeletal material the researchers have focused their attention towards living population groups of India and have 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.³ Thus almost all the studies conducted by researchers in India pertains to use of percutaneous measurement of long bones and their fragments for reconstruction of stature.^{1,3,4,5.} All these studies have reported significant difference in the proportion of the limb bone dimensions due to environmental, hereditary and dietary factors of the population, thus affecting length of long bones and thereby the stature of a person.^{1,6,7} Therefore opinions based on the study of residents of one state are not necessarily applicable to residents of another state.⁸

The lower limb length is the greatest contributor to the standing height, hence most predictive equation are based on length of lower limb, the femur, Tibia and fibula.^{3,4,9,10} Tibia accounts for 22% of the total body length.¹¹

Landmarks on the other long bones are more difficult to identify than that of Tibia, hence percutaneous measurement of tibia is taken as a subject matter . With the help of percutaneous tibial length (PCTL) it is possible to determine the

height of deceased person whose mutilated leg portion is only available.

The total height of the individual is apparently more after death. According to Trotter and Gleser⁹ (1952) the increase in height after death is 2.5cm, when the measurement is taken in recumbent position. This increase in height in cadavers is due to loss of muscle tone, relaxation of large joints .

Estimation of stature of an individual in India by using formulae given by western workers involves an error of 5-8%¹². There is no universally acceptable formula to express relationship between stature and length of long bones of an individual. There are variations in the length of limb bones relative to stature and according to race, sex, side of body, climate, heredity, nutritional status.^{9,13} This proves that each race requires its own formula.

Thus this work is undertaken because --

- At present we depend on foreign formula which do not fit correctly with our population.¹⁴
- With improved socioeconomic conditions especially in India the height of new generation is increasing. Population is getting taller and therefore relationship between height and length of long bones is changed, therefore fresh formulae are needed for each generation.^{9,14}
- Our study may be useful for
 - Medico legal purpose where only part of dead body may be available.¹⁵
 - In anthropological studies.¹⁶

Material and Methods: All methods and procedures applied within this study are approved by human ethics committee of the Navodaya Medical College, Raichur.

Sample size - In the present study 400 students were taken, 200 Male and 200 female, in the age group between 18-21 years from Navodaya Group of institutions and RIMS, Raichur. This age group was selected because multiplication factor remains more or less constant in this age group. The following parameters were noted-Name, age,sex, Height in cms (crown heel length) ,Length of right and left side of tibia in cms.

MEASUREMENT TECHNIQUE: The measurements were taken by using standard anthropometric instruments in centimeters, according to the technique described by Vallois.¹⁷ All the measurements were taken by the same observer and with the same instrument, to avoid any technical and/or interobserver error and to maintain reproducibility. To eliminate discrepancy due to diurnal variation the measurements were taken at fixed time between 2pm – 5pm. The measurements were taken three times and their mean value was considered for estimation of height.

STATURE (Standing Height):- Height of the subject was measured in standing position on a standard stadiometer with both feet in close contact with each other, the trunk braced along the vertical board, and the head adjusted in Frankfurt plane. The measurement was taken in centimeters by bringing the horizontal sliding bar to the vertex.

TIBIAL LENGTH:-For measuring the tibial length subject was asked to stand and keep his/her foot on an iron stool to maintain the angle between flexor surface of leg and that of the thigh at 90°. Then two points were marked with skin marking pencil

- 1) Upper point - The medial most superficial point on upper border of medial condyle.
- 2) Lower point – Tip of medial malleolus. Distance between two points was measured with the help of spreading caliper to determine tibial length.(Fig. 1)

Figure 1: Method of measurement of percutaneous length of tibia



Result: The data collected was treated statistically using the standard programme of SPSS version 10.0, to obtain mean, standard error of mean, test of significance and coefficient of correlation to assess the variations for all the living stature measurements from percutaneous tibia among male and female. In males, the height varied from 151.50 to 184.40 cm. The average height being 170.08 cm. The coefficient of variation is 0.0370. Small value of C.V. indicates that variation in male height i.e. observation can be considered as homogeneous.

Length of right tibia ranges from 26.10 to 43.50, the average length of tibia is 35.77 cms .The length of left tibia ranges from 26.10 to 43.40, the average length of tibia is 35.73 cms .By comparing the length of tibia between right and left side, it is observed that, there is no statistically significant difference in the length of tibia of right and left side ($p>0.05$). This shows, bilateral symmetry of both sides.(Table no 1.)

Table 1 :Comparison between right and left side of tibia in males

TIBIA	RIGTH	LEFT
NO OF SAMPLE	200	200
RANGE IN CMS	26.10 – 43.50	26.10 – 43.40
MEAN	35.77	35.73
S.D	2.73	2.71
C.V	0.0763	0.0758
S.E.M	0.193	0.191
t-value	1.643	
p-value	$p>0.05$	

Regression formula for calculating the living stature from the length of tibia in male was calculated as follows:Regression formula $y = a + b x$
Where y = estimated height, x = tibial length (x_1 or x_2), b = constant
the correlation coefficient values r_1 and r_2 are implies that there is positive correlation between height and both side tibial length. In male, height can be estimated by using formula derived for estimation of height from length of right or left side tibia.

$$y_1 = 104.42 + 1.836 x_1$$

$$y_2 = 104.08 + 1.847 x_2$$

Regression formula is derived for estimation of height from length of tibia of right and left side and can be used by substituting values of right tibial length for x_1 and left tibial length for x_2 . From these regression equations, the stature calculated is 170.089cms with the average error less than 1 cm in male.(Table No. 2)

Table 2: Formulation of regression formula for calculating the living stature from length of tibia in males

TIBIA	RIGTH	LEFT
INDEPENDENT VARIABLE(x)	LENGTH OF TIBIA(x_1)	LENGTH OF TIBIA(x_2)
INTERCEPT (a)	104.42	104.08
REGRESSION COEFFICIENT (b)	1.836	1.847
CORRELATION COEFFICIENT(r)	0.798	0.796
COEFFICIENT OF DETERMINATION (R ²)	0.636	0.634
CHI –SQUARE	15.74	16.22
SIGNIFICANCE	$p>0.05$	$p>0.05$
REGRESSION FORMULA $y = a+bx$	$y_1 = 104.42 + 1.836(x)x_1$ $x_1 = 35.77$	$y_2 = 104.08 + 1.847(x)x_2$ $x_2 = 35.73$

In female, the height varied from 140.5 to 181.90 cm. The average height being 156.20 cm. In females the length of right tibia ranges from 21.50 to 39.50, the average length of tibia is 32.19 cms.The length of left tibia ranges from 21.40 to 46.50, the average length of tibia is 32.144 cms.

Table 3: Comparison of right and left side of tibia in females

TIBIA	RIGTH	LEFT
NO OF SAMPLE	200	200
RANGE IN CMS	21.50 – 39.50	21.40 – 46.50
MEAN	32.19	32.144
S.D	2.76	2.963
C.V	0.0858	0.092
S.E.M	0.1953	0.2095
t-value	0.4875	
p-value	$p>0.05$	

By comparing the length of tibia between right and left side, it is observed that, there is no statistically significant difference in the length of tibia of right and left side ($p>0.05$). This shows, bilateral symmetry of both sides.(Table No 3)

In female, height can be estimated by using formula derived for estimation of height from length of right or left side tibia.

$$y_1 = 102.16 + 1.678 x_1$$

$$y_2 = 111.86 + 1.379 x_2$$

Regression formula is derived for estimation of height from length of tibia of right and left side, and can be used by substituting values of right tibial length for x_1 and left tibial for x_2 . From these regression equations, the stature calculated is 156.187cms with the average error less than 1 cm in female.(table no 4).

Table no. 4 Formulation of regression formula for calculating the living stature from length of tibia in females

TIBIA	RIGTH	LEFT
INDEPENDENT VARIABLE(x)	LENGTH OF TIBIA(x_1)	LENGTH OF TIBIA(x_2)
INTERCEPT (a)	102.16	111.86
REGRESSION COEFFICIENT (b)	1.678	1.379
CORRELATION COEFFICIENT(r)	0.737	0.650
COEFFICIENT OF DETERMINATION(R ²)	0.543	0.422
CHI –SQUARE	20.194	29.147
SIGNIFICANCE	$p>0.05$	$p>0.05$
REGRESSION FORMULA $y=a+bx$	$y_1 = 102.16+1.678 (x)x_1$ $x_1 = 32.19$	$y_2 = 111.86+1.379 (x) x_2$ $x_2 = 32.46$

The average multiplication factor for tibia is found to be 4.77 in male and 4.88 in female. With the help of this multiplication factor the average stature calculated 170.69 cm for male and 157.06 for female which showed the average error of 0.61 cm in male and 0.86 cm in female. (Table no 5)

The stature estimated from percutaneous tibial length with the help of formulated multiplication

factor was compared with stature estimated by regression formula, the average error was found to be 0.60 cm in male and 0.87 cm in female. The average error is less than 1cm; hence multiplication factor can be used as a second line formula for estimation of stature.

Table 5 Multiplication factor in both sexes for tibial length

SEX	MALE		FEMALE	
TIBIA	RIGTH	LEFT	RIGTH	LEFT
NO. OF SAMPLE	200	200	200	200
M.F	4.77	4.78	4.88	4.89
MEAN	4.77		4.88	

Discussion: In 1899 Pearson¹⁸ estimated stature through regression equation as 169.2cm in male and 159.7cm in female, which differs from our findings particularly where female stature is concerned. However Pearson calculated stature in French cadavers and that too only from right side of tibia length, where as the present study was carried out in Indian living subjects in which tibial length of right and left side was considered.

While comparing the estimated stature of 48 north Chinese male with that of Pearson's regression formula , Stevenson P.H¹⁹ in 1929 has already suggested that 'Better results from regression formula will be obtained by applying a formula peculiar to race itself than by applying a formula by second race.

In 1932 Mendes Correa²⁰ found that stature in living person was 20mm shorter than the cadaveric length. In 1957 Glaister J²¹ advocated that to get living stature of a person 12.5mm for male and 20 mm for female should be deducted from cadaveric stature.

In 1961 Allbrook DC ²² compared both estimated stature derived from length of dried tibia and from the average percutaneous tibial length. There was no difference in stature estimated from two different sets of tibia. The average stature was 170.06 cm for British male population.

In our study we estimated average stature 170.089cm for Indian male population with an

average error less than 1cm. After substituting percutaneous tibial length of Indian population in Allbrook's derived regression equation, the stature comes out to be 166.05 cms for male Indian population. Above analysis indicates that the regression formula derived by Allbrook D²² for estimating the stature in British population is at least not suitable to estimate the stature in Indian population.

In 1976 Kate and Muzumdar⁵ expressed similar view after comparing the derived regression equation for Maharashtrian and Punjabis with that of Pearson's regression formula derived from English bone. They stated that Pearson's regression equation does not give exact results in Indian population.

These findings correlate with that of Mukta Rani, Tyagi A.K, Verma S.K, Kohli A²³ who estimated stature in students of Delhi and found to be 169.5cm in male and 159.5cm in female. Our estimated stature also correlates well with that of Bhavana S and S. Nath¹ who estimated stature by measuring PCTL of male and female Shia Muslims of Delhi.

Their estimated stature was 167.66 cm for males and 154.40 cms for females. According to Lal C.S and Lala J.K²⁴ (1972) Multiplication factor (M.F) remains more or less constant in age group of 18-21years. In present study similar age group was selected for study.

According to Trotter and Gleser⁹ world population is getting taller and therefore relationship between height and length of long bones is changed and fresh formulae or M.F are needed for each generation, hence we attempted to find out fresh M.F for Indians.

Our values of M.F are comparable with those of Bhavana S and Surinder Nath¹ who gave the values for multiplication factor as 4.60 in males and 4.59 in females. In 1996 Yayim yili²⁵ has also quoted that the difference between the length of bones of left and right side to be negligible.

Our findings are similar to that of Agnihotri A.K, S.Kachhwaha, V. Jowaheer, A. Pratap Singh² who too observed that there was no statistically

significant difference in the length of right and left tibia in both males and females. In 2004 Mukta Rani Tyagi A.K, Verma S.K, Kohli A²³ studied the bilateral comparison from percutaneous measurement of tibia and expressed that left tibia is longer than right tibia in both sexes.

Conclusion: In both sexes stature estimated by regression formulae for percutaneous length of tibia was similar to average measured stature with an error of less than 1cm which was statistically insignificant $P > 0.05$. In both sexes stature estimated by derived multiplication factor for length of tibia was similar to average measured stature with an error of less than 1cm. This was statistically insignificant $P > 0.05$. There was no significant difference in the percutaneous length of right and left tibia in both sexes, thus showing bilateral symmetry in the length of Tibia in both sexes. Regression formulae are more dependable than multiplication factor for estimation of stature.

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