

## Estimation of Stature of Eastern Indians from Measurements of Tibial Length

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### Abstract

Estimation of stature of an individual from tibial length is well tested parameter for identification and reconstruction of an individual's physique, utilized in anthropological research and medico legal cases. Earlier work in Eastern Indian population was done about a century back. Present work is undertaken to assess whether the earlier works done in this population are still applicable at present with reformation of population associated with change in time. The present study was undertaken to deduce a regression equation formulae for prediction of stature from tibial length and vice versa; the authors also wanted to make a comparison (test of significance) of stature and dry tibial length separately for males and females. The present study is based on the measurements of tibial length and body height of total 518 cadavers between 23 to 75 years of age. The maximal tibial length was measured by oblique caliper. The supine length was measured by steel tape. Obtained data was analyzed and attempt was made to find out correlation and to derive a regression formula between tibial length and supine length of an individual. A good correlation of stature was observed with tibial length and it was statistically highly significant. The regression equation for Eastern Indian males is  $S = 71.2333 + 2.5792 T$  and that of Eastern Indian females is  $S = 65.345 + 2.6914 T$ . The difference between the estimated stature of males by application of the present regression equation and that of Nat [1] or Pan [2] was much less (underestimation of 2.8202 cm and 0.2202 cm respectively). However for females, Nat [1] did not offer any multiplying factor and applying the Pan's factor and adjusting for the wet tibia, an underestimation of 3.27 cm was obtained. Thus, while Pan's factor for males closely followed the present regression estimations, which for females yielded a wider difference. Quite paradoxically, Trotter's and Gleser's [3] regression equation for black negroes was the closest approximation (apart from the Pan's multiplication factor for male) of our regression equation and applicable for the population of Eastern India. In conclusion the author(s) opine that to calculate the stature of eastern Indian females, the present regression equation should be used. The results of the present study would be useful for Anthropologists and Forensic Medicine Experts. But, some questions still remain: has the stature of only Eastern Indian females increased since last century? If so why? Is there any evolutionary relation between Eastern Indians and Black Negroes? Much more future studies have to be conducted in different regions of India to come to a definite conclusion.

**Keywords:** Anthropometry; Correlation coefficient; Regression equation; Maximal tibial length; Supine length; Medicolegal aspect; Forensic medicine

### Introduction

Human bones just lie in the ground slowly degrading to atoms from which they were originally created, often the only reminder of past life. Height of a person, which itself is a sum of the length of certain bones and appendages of the body represent certain relationship with form of proportions to the total stature. It takes a very important role both in anthropological research and identification necessitated by medico legal experts. Height estimation by measurement of various long bones has been attempted by several workers with variable degree of success. One exhaustive work was done by Pan for estimation of stature from long bones including tibia. However the work was done more than a century ago and a more recent study is felt necessary due to various reasons. Any particular population gets reformed by the process of migration, invasion and sometimes also by natural ways such as famines, disaster that lead to natural auto selection. The region in which the present author has worked remains a testimony to many such past unfortunate incidents. There are indications that mobility in general has declined between European Mesolithic and late Neolithic, and that body size and shape may have become more variable throughout the continent following the Upper Paleolithic (The strange Horizon, a journal of Anthropology: 1996-1997). Stature prediction from measurement of long bones with the help of correlational calculus was first introduced by Professor Pearson [4]. Telkka [5] studied 115 male and 39 female

dry skeletons. He took the maximum length of tibia for the purpose of finding out the stature of Finnish population; he opined about the need of a separate formula for estimation of stature of different racial population. Dupertius and Hadden [6] summarized that long bones of inferior extremity usually gives a closer estimate of stature than long bones of upper extremities. Allbrook [7] attempted to measure percutaneous tibial lengths from the medial condyle to the tip of medial malleolus with knee semi-flexed and foot partly everted and deduced the following formulae:  $88.78 + 2.30 T$  (where,  $T$ =Tibial length). Lundy [8] concluded that length of the lower extremity provides the best estimate to measure stature of an individual. Nineteenth century was nearing its end when anthropologists convened an international meeting in Geneva [9] and promulgated the need of measuring oblique length of bones for correct estimation of stature. Mohanty [10] attempted to

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correlate percutaneous tibial lengths (from the medial condyle to the tip of medial malleolus) and stature of 1000 adult individuals belonging to the state of Orissa.

The present study was undertaken to deduce a regression equation formulae for prediction of stature from tibial length and vice versa; the authors also wanted to make a comparison (test of significance) of stature and dry tibial length separately for males and females.

23 years was selected as the lower limit of age group of the cadaver samples; this was done to eliminate the influence of the epiphyseal growth factor in formulation of the regression equations. The upper age limit was taken as 75 years. The maximum length of Tibia, a bone of inferior extremity was measured obliquely in the present study.

## Material and Methods

A busy morgue was chosen to obtain a sizeable number of fresh samples. The study was undertaken at the Department of Forensic Medicine at Calcutta Medical College, Calcutta Police morgue; the cadavers were from different parts of Eastern India, mostly from districts of Kolkata, 24 Parganas and Midnapore of West Bengal and also from adjoining states of Jharkhand and Orissa. Out of a total of 550 samples, 32 were rejected due to skeletal deformities in limbs and pelvis. The present study was made up of 294 male cadavers (56.76%) and 224 female cadavers (43.24%).

Maximum convexity of lateral condylar profile was determined and it was taken as one of the two reference points. The oblique length of tibia (Geneva conference) of left side was measured from the former point to the lowest point of medial malleolus of the corresponding side. The supine length was measured by steel tape in centimeters and the maximal tibial length was taken with the help of oblique calipers. The error of both the steel tapes and calipers was not more than 1 mm in 100 centimeters. The supine length of cadavers was taken after fixing the head in Frankfurt plane and the foot was kept at right angles to the table by a right angled wooden block. Left tibia was chosen arbitrarily for measurements of tibia to maintain uniformity. All the measurements were taken only by the first author to avoid interpersonal variation of measurements. With subtraction of 5 mm from the wet bone length, dry tibial length was obtained [11]. All the statistical values like mean, range, sample standard deviation, population standard deviation, regression coefficient, intercept, regression equation, standard error of estimate and correlation coefficient were calculated by using the software named MAT-LAB 7.1.

## Observations and Results

For Males→  $S=71.2333+2.5792 T$

For Females→ $S=65.345+2.6914 T$

Where, S= Stature (in centimeters); T= Dry Tibial length (in centimeters)

To test the reliability of the sample equations, the relevant formulae was used to calculate the 't' value. The 't' value calculated for males and females was much higher than the critical values of 't' <sub>(0.05)</sub> with 40 degree of freedom (n-2) and 't' <sub>(0.05)</sub> 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. The square of standard error of estimate of male and female sample was compared using an "F test". The F value was calculated to be 2.223. From the statistical tables (Tables 1-4) it was found that the [critical F value] – {F <sub>0.05 (40,30)</sub>} was 2.011; since the computed F exceeded the critical F

Statistical Parameters	Males	Females
1. Sample size	294	224
2. Cadaver supine length (Y)		
Mean	164.0602	156.38
Range	146.4-176.7	142.0-167.7
Sample standard deviation	7.6120	6.0263
Population S. D.	± 7.593	± 6.011
3. Dry tibial length (X)		
Mean	35.9905	33.825
Range	29.2-40.7	28.9-38.2
Sample standard deviation	2.7341	2.1224
Population S. D.	± 2.730	± 2.118
4. Correlation coefficient	0.9264	0.9479
5. Standard error of estimate	1.6664	1.6829

**Table 1:** Descriptive Statistics of the Samples (N=518).

For Males :	
• Regression coefficient (b)	= 2.5792
• Constant/intercept (a)	= 71.2333
• Regression equation	= 71.2333+2.5792x
• SE of estimate	= ± 1.6664
• Correlation coefficient (ryx)	= 0.9264
For females:	
• Regression coefficient (b)	= 2.6914
• Constant/intercept (a)	= 65.3450
• Regression equation	= 65.3450+2.6914x
• SE of estimate	= ± 1.6829
• Correlation coefficient (ryx)	= 0.9479

**Table 2:** Formulation of new regression equation of stature from tibial length.

Study	Male	Female	Sex Combined
Present study	$S=71.2333+2.5792 T$	$S=65.345+2.6914 T$	$S=64.052+2.756 T$
Pearson (99)	$S=78.664+3.378T$	$S=74.744+2.532T$	
Tr.Glesser <sup>1</sup>	$S=78.62+2.52T$	$S=61.53+2.9T$	
Tr.Glesser <sup>2</sup>	$S=86.02+2.19T$	$S=72.65+2.45T$	
Patel (64)			$S=65.51+2.203T$
Joshi (65)			$S=80.97+2.206T$

<sup>1</sup>=study of white Americans, 1952 and 1977.

<sup>2</sup>= study of Black Negroes, 1952 and 1977.

**Table 3:** Different regression equations popularly used to calculate stature (s) from tibial length (t).

Study	Male	Female
Nat (1931)	4.48	-
Pan (1924)	4.49	4.46
Lal (1972)	4.268	4.109
Siddique and Shah (1944)	4.2	-
Singh and Sohal (1952)	4.18	-

**Table 4:** Different multiplication factors (inches) popularly used to calculate stature (s) from tibial length (t).

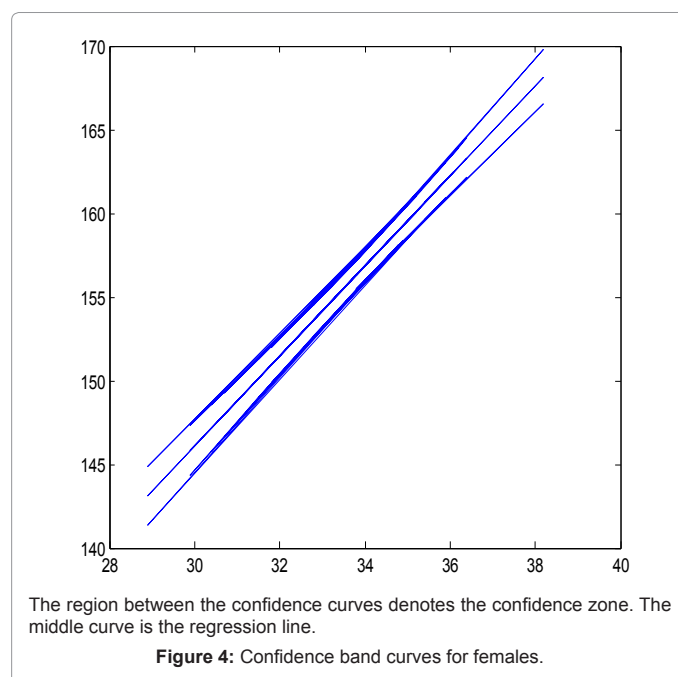
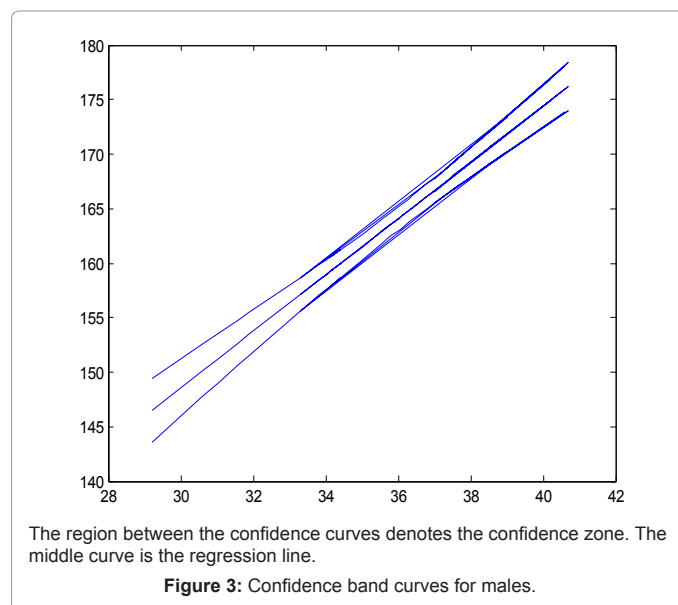
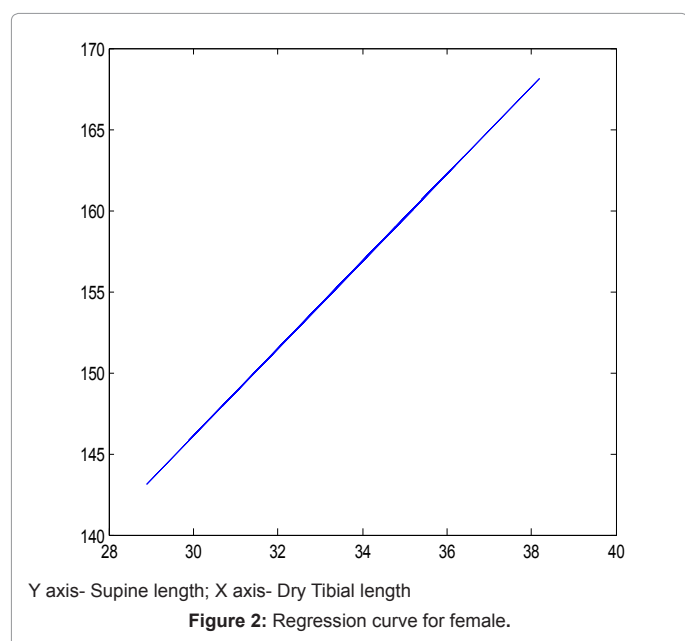
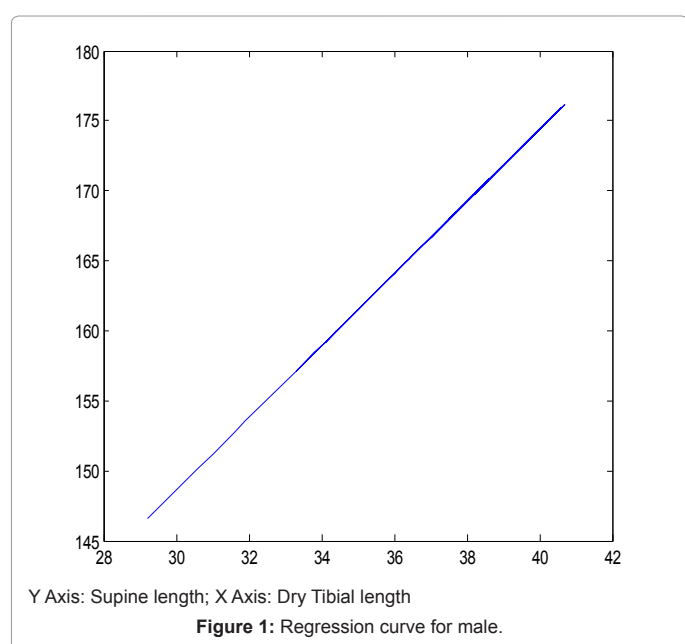
value, the null hypothesis was rejected and it was concluded that the regression coefficient  $b_{\text{male}}$  is significantly different from  $b_{\text{female}}$ . Thus, the same formulae cannot be used and separate formulae for males and females have to be used for correct estimation of stature Z.

## Discussion

The mean age of the whole sample of subjects (n=518) was 36.081 years; 56% (287 Out of 518) were of age group 25 to 35 years. Hence, younger age group contributed mostly to form the present regression equation.

The standard error of estimate for males was calculated to be ( $\pm 1.6664$ ) and that of the females to be ( $\pm 1.6829$ ). This indicates that in two thirds of cases, the stature computed from this equation will correspond with the observed values within  $+1.6664$  and  $-1.6664$  for males and within  $+1.6829$  and  $-1.6829$  for females. The standard error of estimate of the regression equations are quite low, especially that of females. Hence the scatter of data along the regression lines is minimal and this achieves goodness of fit (Figures 1 and 2).

Most Indian researchers have formulated multiplying factors rather than regression coefficient, by assuming a constant proportionality of the tibia with stature. However, this assumption is not always correct as Meadows and Jantz [12] had shown that tibia was positively allometric with stature (Figures 3 and 4).



Patel et al. [13] and Joshi et al. [14], amongst many others derived a common regression equation. Nat [1], Siddique and Shah [15] and Singh and Sohal [16] derived a multiplying factor applicable only for males. It may also be noted that the difference between the multiplying factors for males between Nat and Pan is only 0.36 cm.

The estimated stature as calculated by applying the present regression equation was compared with that of derived from popularly used formulae; the result has been tabulated in table 5.

For the valid comparison with those who have formulated a common regression, it was very pertinent to formulate a common regression equation from the pooled data of males and females; the formula stands as follows:  $S$  (Stature) =  $64.052 + 2.756 T$

As can be seen from table 5, the regression equation of Patel

Study	Male	Female	Sex Combined	Difference From Present Study
Present Study	164.0602	156.38	160.74	0.0
Patel	-	-	145.06	-15.68
Joshi	-	-	158.29	-2.45
Nat	161.24	-	-	-2.8202
Pan	163.84	153.11	-	(-0.2202, -3.27)
Siddique and Shah	151.16	-	-	-12.9002
Singh and Sohal	150.44	-	-	-13.621
Pearson	200.24	154.38	-	(+36.24, +2.42)
Tr. Gl.	169.32	159.64	-	(+5.32, +3.26)
Tr. Gl.	164.84	154.87	-	(+0.84, -1.27)

**Table 5:** Comparison of estimated stature (cm) from different formulae.

underestimated the stature by 15.68 cm. Multiplying factors of Siddique and Shah [15] underestimated the stature by 12.9002 cm and that of Singh and Sohal [16] underestimated the stature by 13.621 cm. Thus, clearly, their formulae or multiplication factors cannot be applied for the population of Eastern India.

The difference between the estimated stature of males by application of the present regression equation and that of Nat [1] or Pan [2] was much less (underestimation of 2.8202 cm and 0.2202 cm respectively). However for Females, Nat did not offer any multiplying factor and applying the Pan's factor and adjusting for the wet tibia, an underestimation of 3.27 cm was obtained. Thus, while Pan's factor for males closely followed the present regression estimations that for females yielded a wider difference.

Considering the regression equations for Westerners, it was found that the application of Pearson's male formulae was not at all feasible for estimation of stature of this part of the country as it overestimated the stature by a wide margin of 36.24 cm, though its equation for females was quite close (overestimation by 2.42 cm). This is quite in contrast to Trotter and Gleser's [3] regression equation for Black Negroes whose formula for males overestimated the stature by only 0.84 cm and its formula for female underestimated stature by 1.27 cm. Thus, the Trotter's and Gleser's [3] regression equation for Black Negroes was the closest approximation (apart from the Pan's multiplication factor for male) of our regression equation and applicable for the population of Eastern India.

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