

Estimation of stature by morphometry of percutaneous tibia

Kavyashree A.N¹, Bindurani M.K^{2*}, Asha K.R³, Lakshmi Prabha⁴

^{1,2}Associate Professor, ³Professor, ⁴Professor and HOD, Dept. of Anatomy, Sri Siddhartha Medical College, Tumkur, Karnataka, India

***Corresponding Author:**

Email: drbindumk@rediffmail.com

Received: 17th January, 2018

Accepted: 15th June, 2018

Abstract

Introduction: Stature estimation is an indispensable part of the identification process of human skeletal remains or body parts. Height is also fundamental to assess growth and nutrition and calculating body surface area. Studies on anthropometric measurements of lower limbs among living people have been used as an important tool by forensic anthropologists to reconstruct the living stature of unidentified skeletal remains.

Aims and Objectives: The aim of the present study was to estimate the stature from percutaneous tibial length (PCTL) by formulating linear regression equations and also by using multiplication factors, which would be useful in the field of forensic anthropology.

Materials and Methods: Sample size measured 350 subjects of Sri Siddhartha Medical College, Tumkur, age group ranging from 17 to 22yrs were considered for the study. Height and PCTL were measured using the standard anthropometric technique.

Results: Stature was estimated from PCTL using simple regression analysis. The height of males was significantly higher than that of females. The mean height in females and males was 158.87cm and 170.88 cm respectively; and mean PCTL was 38.54cm and 33.99cm in male and female respectively which was significantly ($p < 0.0001$) greater for male compared with female. The regression formula derived for male was $y = 109.885 + 1.58x$ and for female was $y = 122.385 + 1.07x$. The predicted height (y) so derived was in close approximation with that of the observed height.

Conclusion: Stature can be estimated using the anthropometric measurements of tibia in an intact mutilated leg.

Keywords: Height, Tibial length, Anthropometry, Regression equation.

Introduction

Stature estimation of an individual can be done from long bones like tibia and femur. They have shown a direct correlation with height of an individual.¹

Lower limb length plays an important role in estimation of standing height of an individual hence most predictive formulas are based on length of tibia, femur and fibula.² Stature can be estimated by adopting Anatomical method by examining a complete skeleton, or by following mathematical method where measurement of a single long bone of upper or lower extremity may serve the purpose because there is a strong relation between skeletal element and stature. This means that measurement of any bone or combinations of bone reflect stature.³

Height is fundamental to assess growth and nutrition, calculating body surface area, and predicting pulmonary function in childhood. It is known that measurement of trunk and limbs exhibit consistent ratios among themselves relative to total body height. The ratios between body segments vary according to age, sex and race of the individual. Establishment of height can be estimated from fragments of bones in archeological procedures or in forensic examinations after mass disasters or genocide. It may be used in estimation of pharmacokinetic parameters and evaluation of nutritional status.⁴

Materials and Methods

This anthropometric study was conducted in Sri Siddhartha Medical College, Tumkur. Study was conducted with permission of Institutional ethical committee and informed consent from the students. Sample size measured 350 students, age group ranging from 17 to 22 yrs. Measurements were taken by the same observer and with the same instrument, to avoid any technical or inter-observer bias. Standing height (Stature) of the subject was measured in a standing position on a standard stadiometer with feet in close contact with each other, with the trunk straight along the vertical board, and the head adjusted in Frankfurt plane.

Tibial length of each subject was measured. Subject was asked to stand and keep his foot on a wooden stool. Angle between flexor surface of leg and thigh was maintained at 90degree. Two points were marked. Upper point was the medial most superficial point on upper border of medial condyle and lower point was the tip of medial malleolus. Distance between the two points was measured with the help of spreading caliper, to determine tibial length in centimeters (cms).

Results

The statistical analysis software was used. Bilateral percutaneous tibial length (PCTL) was observed in both males and females (Table 1). Student t test revealed no significant difference between per-cutaneous length of

right and left tibia in both genders. This is indicative of bilateral symmetry in length of tibia in both gender.

The mean PCTL for male was 38.54cm and for female was 33.99cm.

The study revealed that PCTL varied even in individuals of same height revealing the fact that tibial length can be variable in different individuals. The mean height in females and males were 158.87cm and 170.88 cm respectively; and mean PCTL was 38.54cm and 33.99cm in male and female respectively which was significantly ($p < 0.0001$) greater for males compared with females. (Table 2).

Correlation coefficients (r) of height and PCTL for male and female were 0.7391 and 0.564 respectively which were statistically significant (Table 3). Since there was high correlation between the height and PCTL, a simple regression formula was derived to predict height from PCTL. The regression formula derived for male was $y = 109.885 + 1.58x$ and for female was $y = 122.385 + 1.07x$, here x is the value of PCTL. The predicted height (y) so derived was in close approximation with that of the observed height.

All the regression equations formulated for the estimation of height based on the tibia length were significant and moderately good. Higher R^2 values and lesser SEE values in males than in females indicate that the estimation of height using linear regression equations in males will be better than in females.

The positive correlation of length of tibia (mean = 38.54 cm) on X-axis and height of male subjects (mean = 170.88cm) on Y-axis (Fig. 1), indicating that increase in length of tibia leads to increase in total height is depicted in a scatter plot. The average M.F for male and female was 4.43 and 4.67 respectively and the average stature based on M.F is 170.88 for male and 158.87 for female (Table 4).

Discussion

As said that "stature reveals identity" and in the field of forensic anthropometry height estimation is considered as an important step for identification.⁴ Anthropometry was first used in 17th century by a German physician J. Sigismund Elshwtz.⁵ Forensic anthropologists have often been using the skeletal remains to reconstruct the living stature. Due to lack of availability of documented skeletal remains, researchers have followed the measurement of long bone dimensions among living people.⁶ Tibia being subcutaneous, is approachable to measure in living population.⁷ Several studies have been conducted on reconstructing stature from long bones.⁸ Studies have also reported significant differences in proportion of limb dimensions due to hereditary, environmental, ethnic and dietary factors, which influence the stature of a person.^{9,10} Rollet, was the pioneer to develop regression equations for estimation of stature from various long bones.¹¹

In the present study, correlation between tibial length and height is established by framing regression equations among Indian population. Student t test revealed no significant difference between percutaneous length of right and left tibia in both genders. This is indicative of bilateral symmetry in length of tibia in both genders. These observations are similar to a study conducted by Trivedi et al., on population of Gwalior region.¹ Similar findings have been reported by Bhavna and Surinder Nath⁶ and many other authors.

In the present study estimated mean height in males and females are 170.88cm and 158.87cms respectively. Chavan et al estimated the mean height of male and female to be 167.89 cm \pm 6.21 cm and 151.41 cm \pm 5.04 cm respectively.¹² Present study findings is similar to the average stature calculated by Kaore et al, 170.089cm for Indian male population with an average error less than 1cm.¹³

In the present study, the mean PCTL for male was 38.54cm and for female was 33.99cm. Similar results were obtained in the study conducted by Trivedi et al¹ (Table 5).

Present study findings reveal that the mean PCTL is higher in case of males than in females. Correlation coefficients (r) of height and PCTL for male and female were 0.7391 and 0.564 respectively which were statistically significant. Similar positive correlation was observed in several studies. (Table 6)

In a study conducted on Shia Muslims, height was estimated using several lower limb measurements, among which the tibial length exhibited highest value of correlation and least value of standard error estimate. Alternate method by using multiplication factors were also considered but concluded that regression equations provided greater reliability.⁶ Similar study done on Kerala population by Ahmad et al showed highest degree of correlation between tibial length and height of an individual.¹⁴ A study conducted among Indian population by Khatun et al, also revealed a positive correlation between height and tibial length in both genders.¹⁵ Regression equations in the present study showed higher R^2 values and lesser SEE in males. Similar observations were noted in a study on Shia Muslims by Bhavna & Nath et al, concluding that tibial length among males provide best estimate of stature. Tibial length exhibited the overall highest correlation with stature when compared with other parameters. The standard error of estimate (SEE) was least with tibial length similar to the present study, suggestive that the tibial length would provide the most dependable estimate of stature among male Shia Muslims.¹⁶ In a study done by Trivedi et al, the regression formula derived for male was $y_0 = 105.971 + 1.53 x$ (PCTL) \pm 7.452 and for female was $y_0 = 103.76 + 1.43 x$ (PCTL) \pm 4.69.⁹

In the present study, the regression formula derived for male was $y = 109.885 + 1.58x$ and for female was $y = 122.385 + 1.07x$, where x is the value of PCTL.

The predicted height so derived was in close approximation with that of the observed height. (Table 3). Different equations have been derived in various studies. This explains that regression formulae are both population and sex specific.¹⁷

Few authors undertook studies on eastern Indian population to assess whether the earlier results are still applicable at present with reformation of population associated with change of time. They concluded that to calculate the stature of eastern Indian females, present regression equations should be applied, as there was differences in the results formulated.¹⁸

In the present study, simple linear regression analysis was used to derive an equation relating two quantitative variables. The positive correlation between PCTL and height was established in the form of equation of straight line. Results showed that the degree of correlation was higher as indicated by the closeness of the points and also by the slope of line as shown in scatter plots (Fig. 1 & 2).¹⁹

Each multiplication factor is the ratio of the stature to the respective physical measurements. A mean multiplication factor was then calculated for each measurement. These mean multiplication factor were used for estimating the stature from those variables.³

A study conducted by Aarti et al showed greater mean M.F.s among males in the measurements of fibular breadth and fibular length thereby unfolding the

fact that the males and females have variable proportions of their lower limb dimension with stature and also observed in case of other living populations.¹⁰ Similar observations were mentioned in study on Shia Muslims and that the percentage error in the estimated stature diminishes adequately on using regression equations in contrast to the multiplication factors. Therefore depending upon the availability of the body part pertaining to the lower limb, stature may be estimated using linear regression equations or M.Fs with reasonable accuracy. These variations indicate that multiplication factors may vary according to their genetic composition or geographical variations (Table 7). This calls the need for a revised formulation of multiplication factors to have greater accuracy in the predicted stature among the living populations.¹⁶ One of the study has also mentioned about Trotter's and Gleser's formula, Pan's formula which were also used earlier for estimation of stature.¹⁹

In the present study, the average M.F for male and female was 4.43 and 4.67 respectively and the average stature based on MF is 170.88 for male and 158.87 for female.

The stature-group-specific formulae calculated in few studies were found to be more accurate than all other equations for subjects at the height extremes and concluded that stature-group-specific formulae are more reliable for forensic cases.²⁰

Table 1: Descriptive statistics of right and left side of tibial length and height in both sexes

	Female		Male	
	Rt	Lt	Rt	Lt
Range	23 - 43.2	23 - 44.6	30.8 - 45.8	30.5 - 46.5
Mean	33.96	34.03	38.52	38.56
Standard Error	0.24	0.24	0.25	0.25
Standard Deviation	3.27	3.3	3.21	3.22
C.V %	9.63	9.7	8.33	8.35
Df	370		324	
t Stat b/w sides	0.208		0.109	
P value	0.417		0.457	
P summary	NS		NS	
Average(R+L)	33.99		38.54	

Table 2: Differences between average PCTL and height in both the genders

Statistics	Female		Male	
	Height (cm)	Average PCTL (cm)	Height (cm)	Average PCTL (cm)
Range	38	21.6	35.2	16
Mean	158.87	33.99	170.88	38.54
S.E	0.45	0.17	0.53	0.18
Std. Deviation	6.18	3.28	6.8	3.21
C.V.%	3.89	9.65	3.98	8.33
Student t test b/w male and female for average tibia length				
t, df	t=18.45 df=696			
P value	<0.0001			
P value summary	**** Significant			
Student t test b/w male and female for height				
t, df	t=17.28 df=347			
P value	<0.0001			
P value summary	**** Significant			

PCTL= per-cutaneous tibial length; Rt= right; Lt= left; Ns= not significant; df= degree of freedom

Table 3: Formulation of regression equations for estimation of height based on tibial length

	Male Observed average ht-170.877					Female Observed average ht-158.871
	Rt	Lt	T	Rt	Lt	T
Independent variable(x) = PCTL	38.5202454	38.55889571	38.53957055	33.95537634	34.02634409	33.99086022
Intercept (a)	112.2027295	110.5604355	109.8851824	122.5427757	123.7818784	122.3854271
Regression coefficient (b)	1.523213845	1.564278851	1.582584272	1.069880412	1.031233013	1.073392683
Correlation coefficient(r)	0.720014401	0.740091064	0.73917918	0.56649635	0.551268312	0.564930323
Coefficient of determination (R2)	0.518420738	0.547734783	0.54638586	0.320918115	0.303896752	0.31914627
Std. error of estimate (SEE)	4.731464195	4.585199786	4.592032587	5.107277675	5.170889148	5.113936229
Significance (p)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Regression formula (y = a+bx)	y=112.203+1.52x	y=110.56+1.56x	y=109.885+1.58x	y=122.54+1.069x	y=123.78+1.03x	y=122.385+1.07x
Predicted ht (y)	170.8773	170.8773	170.8773	158.871	158.871	158.871

Table 4: Multiplicative factor (M.F) for tibia length in both the genders

	Male		Female	
	Rt	Lt	Rt	Lt
PCTL	38.52	38.56	33.96	34.03
M.F	4.44	4.43	4.68	4.67
Average M.F	4.43		4.67	
Calculated average ht	170.8773		158.871	

Table 5: Mean PCTL obtained in various studies

Trivedi et al. (2014)	38.54 in males,33.9 in females
Anitha et al. (2016)	37.43 on right,37.50 on left
Bhavana & Nath (2007)	36.48 in males
Ahmed et al. (2014)	39.284
Kaore et al. (2012)	35.77 in males,32.19in females
Chavan et al. (2009)	37.32cm ±2.18 cm in male and 34.44cm ± 2.10 cm in female
Chandravaidya et al. (2013)	37.93_+2.08males,33.94+ 2.06 females
Present study (2018)	38.54 in males,33.9 in females

Table 6: Correlation coefficients obtained in various studies.

Authors	Males	Females
Saini et al (2013)	0.98	0.95
Khatun et al (2016)	0.86	0.85
Chandravaidya et al (2013)	0.836	0.69
Ahmed et al (2014)	0.877	-----
Bhavana & Nath (2007)	0.765	-----
Present study(2018)	0.7391	0.564

Table 7: Multiplication factors derived in various studies

	Male	Female
Bhavana &Nath(2007)	4.6	4.59
Chavan et al (2009)	4.77	4.88
Trivedi et al (2014)	4.32	4.306
Present study (2018)	4.43	4.67

Abbreviation

PCTL-Percutaneous tibial length

Rt-Right

Lt-Left

MF-Multiplication factor

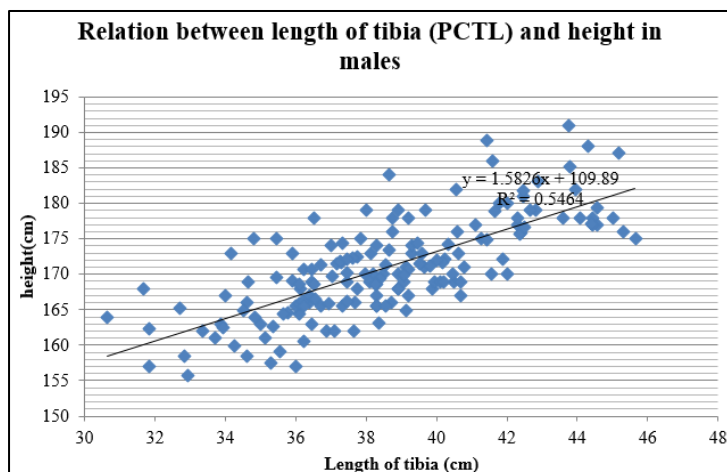


Fig. 1: Scattered plot with linear regression line of height in males on length of tibia

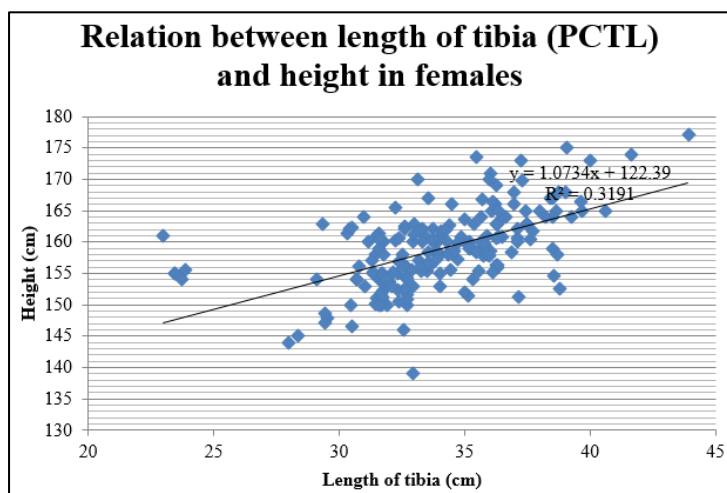


Fig. 2: Scattered plot with linear regression line of height in females on length of tibia

The positive correlation of length of tibia (mean=33.99cm) on X -axis and Height of female subjects (mean=158.87cm) on y -axis (Fig. 2), indicating that increase in length of tibia leads to increase in total height of female subject ($r = 0.5649$, $P < 0.0001$).

Conclusion

The present study reveals bilateral symmetry in the length of Tibia in both genders. The height of males is significantly higher than that of females and the mean height in females and males. Since there was high correlation between the height and PCTL, a simple regression formula was derived to predict height from PCTL. The predicted height so derived was in close approximation with that of the observed height. Multiplication factors were calculated to determine the stature from tibial length. The regression equations formulated for the estimation of height based on the tibial length were significant and moderately good. So

the stature can be determined from available body parts by using the data and the regression equations derived. Stature estimation has been considered as one of the parameters of forensic anthropology and will assist in establishing the biological profile of a person.

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How to cite this article: Kavyashree AN, Bindurani MK, Asha KR, Prabha L. Estimation of stature by morphometry of percutaneous tibia. *Ind J Clin Anat Physiol*. 2018;5(3): 308-313.