ORIGINAL ARTICLE

ESTIMATION OF HEIGHT FROM THE LONG BONES OF LOWER LIMB AND FOOT DIMENSIONS IN SOUTH INDIAN POPULATION

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ABSTRACT: Establishment of an identity is very much important in both civil and criminal cases. Stature is one of the criteria of personal identification. Many studies have shown that limbs exhibit consistent ratios relatives to the total height of a person. A very little work has been done for stature estimation from foot length, foot width, and tibia length and fibula length in Kerala state. The present study is an attempt to evaluate a possible correlation between stature of an individual & four parameters of Lower limb; foot-length, foot-width, fibula length & tibia length individually in a local population of Kerala. A sample of 359 medical students studying in KMCT Medical College & Hospital was considered & measurements were taken for each of the parameters. Stature and lower limb length measurements of each one of them were taken using standard instruments.. It was found that all the four parameters showed a correlation with stature but at different degrees. Tibia length showed the highest degree of correlation (r=0.877). Mathematical formulae for estimating stature were developed for each of these parameters through basic linear regression. It can be concluded that the present study has provided regression equations for four different parameters that can be used for stature estimation in the population of Kerala.

KEYWORDS: Skeletal remains, Height, Stature, Tibia-Length, Fibula-Length, Foot-Width, Foot-Length.

INTRODUCTION: The anatomic parameters of human body such as height, weight and the size of some specific parts of it have been thoroughly studied in literature for various purposes.[1-10] Estimation of stature has a significant importance in the field of forensic anthropometry. Establishing the identity of an individual from mutilated, decomposed, & amputated body fragments has become an important necessity in recent times due to natural disasters and man-made disasters. Stature evaluation based on the lengths of the limb bones, is one of the oldest problems in the history of anthropology. In fact, height as a measure of biological development of both an individual and a population is commonly used in physical anthropology.

Foot prints are of immense value in establishing the identity of a suspect in criminal forensic investigation as most of the time these are the only evidence available left by the perpetrator at the scene. Because foot length has a biological correlation with stature, the latter can be estimated from foot or shoe prints.[(2,11-21)]

Human development and growth is a function of a variety of factors such as age, race, gender and nutritional status. These factors are unique to different types of demography. Therefore, different nomograms are required for different population sets. For this reason, the application of the general formula to a particular population is does not yield accurate

estimations. Many studies have shown the correlation of stature with body appendages[4,22] & with long bones.[23] Population based differences exist in both metric and morphological features of the skeleton and these have changed over time. Therefore, it is vital for biological anthropologists to conduct up-to-date research on diverse population groups residing in different geographic zones.

The Indian population is made up of different ethnic populations & them having their own variations in statures and physical measurements.[4,22,24] It is established that there are no universally applicable formulae for stature estimation from the length of long bones as the relationship between them is influenced by the demography of the individual. Thus, the need for race, age and sex specific stature estimation formulae for a population as diverse as that of India is proved beyond doubt.

For the scope of this paper, the authors have selected the demography of the state of Kerala. The lack of anthropometric data concerning the local population of Kerala was felt for various medico legal purposes.

The present study was aimed at & concentrated on estimation of stature, of the population of Kerala. Anthropometric measurements of upper limb were calculated & correlated with stature to find multiplication factors & regression formulae. A study was carried out at the Department of Forensic Medicine & Toxicology, KMCT Medical College and Hospital, Calicut, Kerala. In the present study an attempt has been made to estimate the height from Tibia-Length, Fibula-Length, Foot-Width, Foot-Length.

MATERIAL AND METHODS: This study was conducted on 359 medical students of the KMCT Medical College & Hospital. The procedure, aims & objectives of the study were informed & explained in a group. A written valid informed consent was taken from each of the participants. Also the individuals having skeletal or pathological abnormalities of limb, foot or spine are exempted from the study.

They were placed in the standard anatomical position with the head held in the Frankfurt horizontal plane. All of the measurements were taken from the left side. The dimensions were taken in 0.1 cm unit with standard anthropometric instruments such as stadiometer (for height), measuring tape and standard vernier caliper. To ensure accurate results, all the measurements were done by one person to avoid interpersonal errors. All the measurements were taken thrice and then mean was recorded. The students were measured for the following parameters:

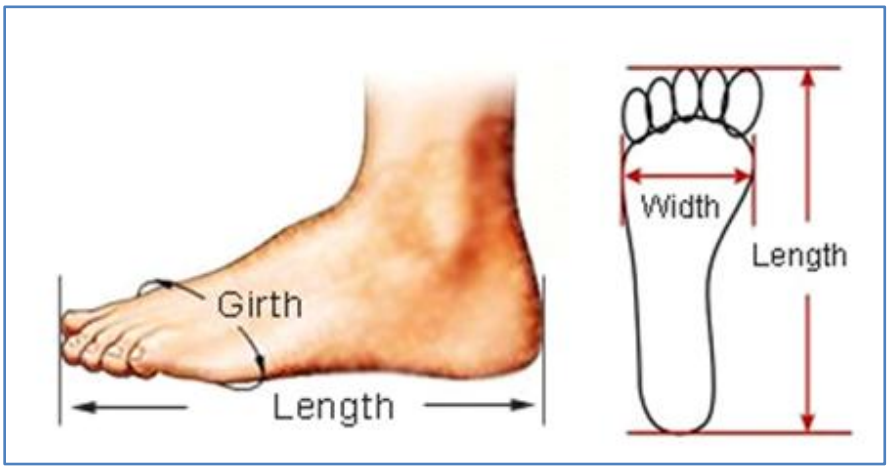
Height: The height of the individual was measured between vertex and the floor, when the person is standing erect, in anatomical position and the head in the Frankfort plane, using a standing height measuring instrument. Height was measured to the nearest 0.1 cm.

Tibia length: The subject is seated with the tested leg resting on opposite knee, so that the medial aspect of tibia faces upwards. Measurement is taken from medial articulation of the knee joint to the distal most point of medial malleolus.

Fibula length: it was measured between the head of fibula to the distal most point of lateral malleolus using a standard measuring tape. This is done by person sitting over the stool and knee joint flexed at 90 degree. At that position head of fibula feel easily.

Foot length: It was measured between the most posterior part (center) of the heel to the most anterior part of the longest toe (2^{nd} toe/1^{st} toe) using a standard measuring tape.

Foot width: It was measured between the head of first metatarsal to the head of fifth metatarsal using a standard vernier caliper.



STATISTICAL ANALYSIS AND RESULT: The primary outcome was the regression equation for each parameter. Correlation coefficient (-1 to +1) was calculated for each parameter as were range, mean and standard deviation.

We analyzed our data using SPSS (version 17.0).

	Range		Mean	Standard deviation
	Minimum	Maximum		
Height	144.0	188.0	160.328	8.4439
Tibialength	32.3	47.5	39.284	2.5655
Fibulalength	33.1	48.0	39.852	2.5718
Footwidth	5.0	11.2	8.813	0.7645
Footlength	20.0	29.0	23.916	1.5631

TABLE 1

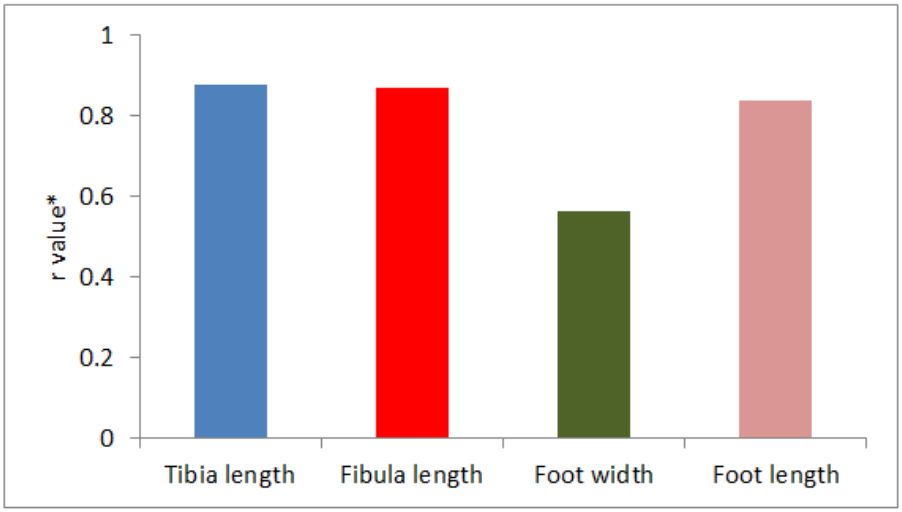


FIGURE 1: CORRELATIONS WITH HEIGHT

*- r values significant at p<0.001

Height & Tibia length:

Height = 46.969 + 2.886*Tibia length (r=0.877, p<0.001, SEE= 4.0669)

1) **Height &Fibula length:**
   Height = 46.881 + 2.847*Fibula length (r=0.867, p<0.001, SEE= 4.2132)

2) **Height &Foot width:**
   Height = 105.518 + 6.219*Foot width (r=0.563, p<0.001, SEE= 6.9876)

3) **Height &Foot length:**
   Height = 52.255 + 4.519*Foot length (r=0.836, p<0.001, SEE= 4.6337)

	Mean	SD
Actual height	160.328	8.4439
Predicted height from Tibia length	160.344	7.4065
Predicted height from Fibula length	160.340	7.3227
Predicted height from Foot width	160.332	4.7456
Predicted height from Foot length	160.006	9.0581

TABLE 2: COMPARISON OF ACTUAL HEIGHT AND HEIGHT CALCULATED FROM REGRESSION ANALYSIS

DISCUSSION: The estimation of height from long bones and other parameters of body have been done by many workers all over the globe. But the estimation of height using foot dimensions as parameters are rarely done. The present study deals with the estimation of height using the tibia length, fibula length, foot length and foot width. Our study showed there is a strong correlation between the all parameters used in the study, Tibia length shows the highest degree of correlation and Foot -width shows the least degree of correlation.

Macdonnel (1901) studied English criminals and derived the regression formulae for estimation of height from foot length 166.457 +4.031 (foot 25.688 +/-2.9cms)

Qamra et al, (1980) computed linear regression equation for estimation of height from foot length and foot width in 1015 subjects between the ages of 17-35 years. It was concluded that foot length was a better tool for analysis of stature.

Ibinado et al., (2009) studied 477 subjects and found out that right foot length of male =26.92+/-1.o2 whereas right foot length of female =25.00+/-1.33. Mean value for left foot length of male = 26.92+/-0.13 cm and that for female =24.75+/-0.17 cm. In this study average length of foot was found to be 23.916 +/- 1.56.

Patel et al., (1964) did study in Gujarati population and find out the correlation between foot length and height. In their study the correlation coefficient between height and foot length was 0.65 male and 0.80 in female. In this study the correlation coefficient between height and foot length was 0.836.[27]

Giles et al., (1991) also suggested that the foot length displays a better biological correlation with the height.

Gorden et al., (1992) estimated stature from foot dimensions and found out that using both foot length and foot width gives better estimate than using foot length alone.

Singh and Phookan (1993) examined Thai male population and found out that foot length gives better results than foot width.

Ozden et al., (2005) conducted study on Turkish population and found out that there is a definite correlation between height and foot dimensions of all individuals. The regression equation was found to be Stature=47.93+1.083(maximum foot length) +0.788(shoe length X 1.083(shoe number).

Nath et al., (1999) he studied Rajputs and Brahmin of Srinagar, Garhwal U.P, and developed multiplication factors to estimate the height from foot length. These were 6.87 for Rajput male and 6.64 for Brahmin male and 6.73 for Rajput female and 6.68 for Brahmin female.

Agnihotri et al., (2007) developed a relationship between foot length and stature using linear and curvilinear regression analysis on a study group comprising 250 medical students aged 18-30 years and it was concluded that highest value for coefficients of determination R (2)= 0.769 and multiple correlation coefficient r=0.877.

Krishan and Sharma (2007) examined the relationship between stature and dimensions of hand and feet among Rajputs of Himachal Pradesh on a group of 246 subjects aged 17-20 years old. In their study the highest correlation coefficient existed between stature and foot length.

Grivas et al., (2008) evaluated the relationship between foot length and stature in a sample of 5093 juveniles in Greece. It was suggested that foot length can estimate the weight and stature of a juvenile.

Kanchan et al., (2008) examined the relationship between stature and foot dimensions among 200 Gujjars. They devised linear and multiple regression equations for estimating suture using foot dimensions.

Krishnan (2008) examined the relationship of stature to foot size of 1040 adult male Gujjar of North India (age 18-30years).The highest correlation coefficient were shown by toe length measurement (0.79-0.86).

Zeybek et al., (2008) developed formula for estimation of stature and gender through foot measurement. They devised linear and multiple regression equations for estimating suture using foot dimensions.

According to the study done by Bhavna etal., 2005 on male shia Muslims in Delhi, the regression equation was found to be

Height=119.74+ 1.92 x Foot length +/- 4.77.

They also found the multiplication factor to calculate height from foot length to be 6.76.

In this study Tibial Length was found to be the best estimate of stature.[25]

Han TS et al., 1996 did a study on subjects aged 17 – 70 years. They found that lower leg length is good predictor of height. men r^2 = 79%, SEE 3.2; women r^2 = 73%, SEE 3.4.[11]

Sen and Ghosh 2008, did a study on 35o male and females of Rabanshi sect of North Bengal. They found that foot length and foot width positively correlate with the stature of individual. The foot width was found to be more accurate. [26]

Chikhalkar B.G et al studied a sample of 300 medical students; 147 male & 153 female studying in Grant Medical College & Sir JJ Group of Hospitals for a possible correlation between stature of an individual & six parameters; hand-length, hand-width, foot-length, foot-width, forearm length & knee-to-ankle length. In their study of all the parameters, forearm length showed the highest degree of correlation (r = 0.6558) followed by foot-length (r = 0.6001). Knee-to-ankle length showed the least correlation(r = 0.2086)

The present study also shows a high degree of correlation for Tibia length (r=0.877), Fibula length (r=0.867) and foot length (r=0.836).

Tung Wai Auyeung, J. S. W. Lee, T. Kwok, J. Leung, P. C. Leung, J. Woo et al., (2009) Estimated stature by measuring Fibula and Ulna Bone Length in 2443 Older Chinese Adults and the mean errors were +0.52 cm (over-estimation) in men and +0.45 cm (over-estimation) in women and the SDs were ± 3.5 cm in both genders.[28]

Hasegawa I, Uenishi K, Fukunaga T, Kimura R, Osawa M et al., worked on stature estimation formulae from radiographically determined limb bone length in a modern Japanese population. Measurements were conducted on 434 living subjects (342 females and 92 males; 18-59years old). Regression formulae were constructed for females and males relative to the real body height measured in the erect position. Lower limbs of the femur and tibia were more accurate predictors (R=0.813-0.903) than the humerus was (R=0.670-0.708). [29]

CONCLUSION: Stature clearly constitutes an essential element in the description of a human population, or an individual, for physical, anthropological and biomechanical research. The lengths of some long limb bones were found to be highly correlated with stature Thus, several

regression equations have been proposed by which stature could be estimated by means of long bone length.

In the present study both left and right foot measurements have been given due consideration and in both males as well as females. Linear regression equations were derived for estimation of stature reliably and accurately that would be of immense value in the field of crime detection. Stature, foot-length, foot-width, fibula length & tibia length are positively and significantly correlated with each other.

While calculating the regression equation, it's found that there exists a linear relationship between the height and the foot-length, foot-width, fibula length & tibia length which is corroborating with the previous workers. But there is some difference in the equation which may be due to racial variation of the subjects. The study was conducted on a population group with individuals belonging to diverse population group residing/ studying in Kozhikode, Kerala. This is a study of the first kind in the Kerala region.

It will help in medico-legal cases in establishing the identity of an individual. The regression equation derived in the study can be used accurately and reliably for estimation of stature in a diverse population group. Hence, it is possible to determine the height of a person by using the data and the formulae derived from the present work fairly accurately within a standard error of the estimate which is acceptable from biological consideration in determining the height of known cross section of population.

As this study is done in living individuals so the results may not be applicable to the deceased individuals. In this study only healthy individuals are included so the results may not be applicable to persons having deformity or any congenital abnormality.

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