

Estimation of Stature from Bilateral Foot Length Among Central Indian Adults: A Cross-Sectional Anthropometric Study

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Abstract

Background: Stature is an important parameter in forensic anthropology and identity evidence. In cases of incomplete or mutilated human remains, stature can be estimated from individual body measurements. Length of the foot is one of the useful anthropometric parameters for this purpose. Nevertheless, sex, ethnicity and geographical population can influence stature, making foot length and status remain associated. As a result, we need regression equations specific to the population. The aim of the study was to evaluate the correlation of bilateral foot length with stature among Central Indian adults and to derive sex-specific regression equations for stature estimation. **Material and Methods:** A cross-sectional observational analytical study was conducted among 200 adults comprising 100 males and 100 females. Standing stature and bilateral foot lengths were measured. Sex-wise differences, right-left variation, Pearson's correlation coefficients and regression equations were determined. The coefficient of determination (R^2) and standard error of estimate (SEE) were used to assess predictive performance. **Results:** The average height of males and females has been reported as 166.20 ± 6.45 cm and 156.85 ± 5.82 cm, respectively. The mean right foot length in males was 25.18 ± 1.35 cm and in females 23.12 ± 1.21 cm, while mean left foot length in males was 25.12 ± 1.34 cm and in females 23.06 ± 1.20 cm. There were statistically significant sex differences. There was no notable bilateral difference. The length of the right foot in males, females and the combined population correlated significantly positively with stature (males $r=0.71$, females $r=0.67$, total $r=0.74$). The left foot length showed correlations of 0.70, 0.66 and 0.73. For males right foot regression equation is Stature = $80.84 + 3.39 \times \text{RFL}$ ($R^2=0.504$; $\text{SEE}=4.56$ cm), while that of females is Stature = $82.42 + 3.22 \times \text{RFL}$ ($R^2=0.449$; $\text{SEE}=4.33$ cm). **Conclusion:** There is a positive relationship of stature with bilateral foot length. The measurement of the length of right foot was found to have a high correlation and useful predictive performance. The use of sex-specific and population-specific regression equations may help in forensic stature estimation among Central Indian adults. Investigation of Stature and Foot Length and Their Relationship by Using Anthropometric Measurements through Regression Analysis of Population of Central India.

Keywords: Stature, Foot length, Anthropometry, Forensic anthropology, Regression analysis, Central India, Sex estimation.

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INTRODUCTION

The height of an individual can help identify them as the issue of legal and forensic anthropology. When a total body or long bones are unavailable, stature can be estimated from measurement of different body parts. The purpose of this has been widely studied – anthropometric dimensions of the hand and foot.^[1-4]

The foot is a relatively stable body part, easily measurable. Foot length has shown a correlation with height in many populations and regression equations have been derived for various geographic and ethnic groups.^[2-6] The value of foot length for stature estimation has been demonstrated by Kanchan et al. in a North Indian population. Also, Krishan et al. looked into combination foot measurements with the application of linear and multiple regression analysis.^[2,3] Regional differences are a significant aspect of forensic anthropometry. The accuracy achieved through regression equations formulated in one population may not be applicable in another one. Anthropometric dimensions are genetically, environmentally, nutritionally and geographically influenced.^[1,4] Research conducted in central India has confirmed that anthropometric measurements can

be utilized in estimating stature, although data from other geographic regions is still useful.^[4,7]

Hence the present study was designed to determine the relationship between bilateral foot length and stature among Central Indian adults and to derive sex-specific regression equations for forensic application.

MATERIALS AND METHODS

Study Design: The study was a cross-sectional observational analytical study

Study Population: Two hundred adults were included in the study of which 100 were male and 100 were female. The study

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protocol defined healthy adults from Central India between 18–35 years.

Inclusion Criteria: Participants were included if they:

- adults aged 18-35 years
- Formed part of the defined Central Indian population.
- appeared to be healthy.
- were ready to take part; and
- Gave consent knowingly.

Exclusion Criteria: Individuals with congenital foot deformities, prior fractures leading to significant deformity, amputations, severe musculoskeletal deformities, or inability to stand upright for correct measurement of stature were excluded.

Human Body Measurements: The height of the person was measured in centimeters. Measurements of right foot and left foot lengths were taken using the standardized anthropometric procedures.

Statistical Analysis: Continuous variables were expressed

as mean $\pm$ standard deviation. Statistical assessment of sex-wise differences. To assess bilateral variation, right and left foot lengths were compared. To determine the relationship between stature and foot length, Pearson's correlation coefficient was used. Separate simple linear regression analyses were conducted for males and females.

The regression equation was expressed as: $Y = a + bX$

where Y represents estimated stature, a represents the regression constant, b represents the regression coefficient and X represents foot length.

The coefficient of determination (R^2) and standard error of estimate (SEE) were used to evaluate predictive performance.

RESULTS

Sex-wise Distribution of Participants: The study comprised 200 participants, with equal representation of males and females.

Table 1: Sex-wise Distribution of Study Participants

Sex	Number	Percentage
Male	100	50.0
Female	100	50.0
Total	200	100.0

Sex-wise Comparison of Stature and Foot Length: Male participants demonstrated significantly greater mean stature

and bilateral foot lengths than female participants.

Table 2: Sex-wise Comparison of Stature and Bilateral Foot Length

Parameter	Male (n=100) Mean $\pm$ SD	Female (n=100) Mean $\pm$ SD	Total (n=200) Mean $\pm$ SD	p-value
Age (years)	24.36 $\pm$ 4.12	24.08 $\pm$ 4.05	24.22 $\pm$ 4.08	0.631
Stature (cm)	166.20 $\pm$ 6.45	156.85 $\pm$ 5.82	161.53 $\pm$ 7.75	<0.001
Right foot length (cm)	25.18 $\pm$ 1.35	23.12 $\pm$ 1.21	24.15 $\pm$ 1.59	<0.001
Left foot length (cm)	25.12 $\pm$ 1.34	23.06 $\pm$ 1.20	24.09 $\pm$ 1.58	<0.001

The age distribution did not differ significantly between males and females. In contrast, stature and both right and left foot lengths were significantly greater among males.

Bilateral Comparison of Foot Length: No statistically significant difference was observed between right and left foot length in either sex.

Table 3: Comparison of Right and Left Foot Length

Group	Right Foot Length (cm) Mean $\pm$ SD	Left Foot Length (cm) Mean $\pm$ SD	p-value
Male	25.18 $\pm$ 1.35	25.12 $\pm$ 1.34	0.412
Female	23.12 $\pm$ 1.21	23.06 $\pm$ 1.20	0.438
Total	24.15 $\pm$ 1.59	24.09 $\pm$ 1.58	0.396

The findings indicate close bilateral similarity in foot length.

Correlation between Foot Length and Stature: Both right

and left foot lengths showed statistically significant positive correlations with stature.

Table 4: Correlation between Stature and Bilateral Foot Length

Foot measurement	Male r	Female r	Total r	p-value
Right foot length	0.71	0.67	0.74	<0.001
Left foot length	0.70	0.66	0.73	<0.001

The strongest correlation was observed between right foot length and stature in the total population ($r=0.74$), followed

by left foot length ($r=0.73$).

Regression Equations in Male Participants

Table 5: Regression Equations for Estimation of Stature in Male Participants

Predictor	Regression equation	R^2	SEE (cm)	p-value
Right foot length	Stature = $80.84 + 3.39 \times \text{RFL}$	0.504	4.56	<0.001
Left foot length	Stature = $81.67 + 3.37 \times \text{LFL}$	0.490	4.62	<0.001

Right foot length produced the highest R^2 and the lowest

SEE among the two-foot measurements.

Regression Equations in Female Participants

Table 6: Regression Equations for Estimation of Stature in Female Participants

Predictor	Regression equation	R^2	SEE (cm)	p-value
Right foot length	Stature = $82.42 + 3.22 \times \text{RFL}$	0.449	4.33	<0.001
Left foot length	Stature = $83.16 + 3.20 \times \text{LFL}$	0.436	4.38	<0.001

The right-foot model again demonstrated marginally greater explanatory power than the left-foot model.

DISCUSSION

The study revealed that the foot length and stature of Central Indian adults are significantly positively correlated. In the total study population, right foot length had the highest correlation with the stature ($r=0.74$) followed by left foot length ($r=0.73$).

There is a sex difference in foot length in line with anthropometric studies. Krishan and Sharma found that hand and foot dimensions differed significantly between males and females of a North Indian population.^[1] Similar differences between sexes have been reported in regional studies from India, thus supporting the use of sex-specific equations.^[4,6]

The symmetrical nature of the population in terms of their right and left foot length is demonstrated by the data. This finding is of practical importance due to the potential of either foot to be available in forensic situations involving skeletal remains.

The present study correlation coefficients show that foot length is a useful anthropometric predictor of stature. Kanchan et al., data underscored a compartmental relationship which exists between foot length and stature. They derived a regression equation for North Indians. Also, they stressed on the need of population-specific regression equations.^[2] The researchers Krishan et al. found that foot measurements also proves useful for stature.^[3]

According to study, right foot length was found to explain about 50.4% of variation in male stature and 44.9% in female stature. SEE values were 4.56 cm and 4.33 cm respectively. Foot length has been found to be a good estimator of stature. However, there remains a prediction error, and the equations should not be taken as perfect predictors.

Presence of various geographical regions anthropometric relationships differ which makes population specific equations an essential component of study. The literature reviewed for the present study has identified Central India as an area requiring region-specific anthropometric data.^[4,7]

Forensic Significance of This Study: Foot length may be useful when conventional long-bone measurements are unavailable. The regression equations developed in the present study can provide an approximate estimate of

stature from isolated foot length.

However, the equations should be applied only to individuals reasonably comparable to the population from which they were derived. External validation in a larger independent Central Indian sample would strengthen their forensic applicability.

CONCLUSION

The bilateral foot length has significant positive correlation with stature in Central Indian adults. The right foot length had the highest individual correlation as well as a slightly superior regression than that of the left foot length. Estimation of stature using sex-specific equations may have forensic anthropological and medico-legal applications.

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Conflicts of interest

There are no conflicts of interest.

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