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A Prediction Of Height By Foot Length In Young Adults Of Moradabad Locality

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Abstract
Estimation of stature is a significant component in forensic anthropology, especially when only parts of the skeleton or unidentified human remains are found. The association between different body parameters and stature has been investigated in different populations, and these measurements have been used in personal identification. The present cross-sectional study aimed at estimation of height on the basis of foot length in Moradabad population, Uttar Pradesh, India. A sample size of 300 apparently healthy subjects (150 males and 150 females) aged between 18 and 24 years was collected from the Department of Forensic Medicine and Toxicology, Teerthanker Mahaveer Medical College & Research Centre, Moradabad, Uttar Pradesh, India, during the period of April – June 2025. Stature and bilateral foot length was recorded following standard anthropometric procedures. The data was analyzed using descriptive statistics, Pearson correlation and linear regression analysis to obtain predictive regression equations for the population. Initial data suggest there is a positive, highly significant relationship between foot length and height in both males and females, based on es and with separate regression equations for males and females. These results highlight the importance of foot length as a valuable parameter for stature prediction in Moradabad population and add to the already available database of forensic anthropometric measurements from the Indian subcontinent. The obtained equations could be helpful in forensic and anthropological research in the region.
Keywords: Stature; Foot length; Forensic anthropology; Moradabad; Uttar Pradesh; Cross-sectional study; Anthropometry; Identification; Regression analysis.

INTRODUCTION

Precise estimation of stature is an important factor of forensic identification which has to be determined in the unidentified human remains and dismembered part of body for creating a biological profile [1]. In forensic analyses, especially those related to mass disasters, homicidal acts or fragmentary remains, it may not always be possible to apply classical methods of strategic biometric measurement, involving lengthening bones. Under such conditions, other anthropometric measures that can be closely associated with stature are of great value [2]. The human foot is a weight bearing portion of the body that is frequently protected by footwear in individuals not inflicted by cultural practices or conditions that prevent from covering it, and is one of the most durable body parts. This renders foot measurements a valid and useful method for the estimation of stature in forensic scenarios [3, 4].

The basis of stature estimation from body parts is formative, which includes the change in the relative size of the body segments as they grow and develop [5]. Some studies revealed that several foot dimensions (i.e., foot length and breadth) are highly correlated with the stature of a person in different populations [6, 7]. Such studies typically reveal regional differences and lead to the conclusion that population data is necessary to achieve reliable results in forensic use. For example, studies on Indians populations have repeatedly validated the use of foot measurements for estimating stature, and separate regression equations between the foot and stature had to be constructed for different ethnic and region groups due to general and environmental effects on growth patterns [8, 9].

In North India, various sub-populations and age groups have been studied for the estimation of stature from foot dimensions. Kanchan et al. [9] studied estimation of stature from foot length by universal formulae among North Indians, and Singh et al. [4] looked at combinations of foot measurements in

North Indian men. The results show that different regression models should be developed for different groups to increase the accuracy in the estimation of stature. Notwithstanding above endeavors, limited data on estimation of stature from the length of foot specifically in the population of Moradabad, Uttar Pradesh seems to be available. This may be one of the very first such studies conducted in the region in young adults which can help us to fill this research gap and to help in the identification process for forensic anthropologists working in this unique population."

Materials and methods

Study design and participants

MATERIALS AND METHODS

This cross-sectional study was carried out at the Department of Forensic Medicine and Toxicology, Teerthanker Mahaveer Medical College & Research Centre, Moradabad, in the state of Uttar Pradesh, India in April–June 2025. All the 300 healthy subjects consisting of 150 males and 150 females were enrolled in the study. Participants: General population of 18-24 years in and around Moradabad. Apparently healthy individuals with no time history of skeletal de-formity, foot injury or medical history of any disease affecting growth or Anthropometry measurements were included. Exclusion criteria consisted of having congenital or acquired malformations of the spine or lower limbs, previous bone fractures of the lower limbs or any systemic disease affecting growth.

Anthropometric Measurements

All of the measurements were performed by one experienced observer to reduce inter-observer variations. Subjects were tested standing in the anatomical position in a barefoot state on a level hard surface. Stature (standing height) was recorded to 0.1 cm with a standard anthropometer, with the person standing upright, head in the Frankfurt plane, and heels together. Foot length was defined as the straight distance between the most posterior aspect of the heel to the most anterior aspect of the longest toe (first or second) and was measured by an ordinary anthropometric measuring tape to the nearest 0.1 cm. Right and left feet were measured. All measurements were performed three times and an average was kept for accuracy and reliability.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee of Teerthanker Mahaveer Medical College & Research Centre (Reference No. TMU/IEC/2025/04/01). Written informed consent was signed by all the participants before participating in the study. Subject privacy and confidentiality was guaranteed and participants were able to quit the study at any time without any negative consequence.

Statistical Analysis

All entered data were organized into a Microsoft Excel sheet, and then analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The mean, SD and range of stature and foot length were determined for males and females. Differences between the sexes were statistically evaluated by independent sample t-tests. This level of boot-off height remained constant on both sex so also were in the proportion feet length to erect stature constant in each sex. Linear regression analysis was used to obtain regression equations of population-specific for the estimation of stature from foot length. The accuracy and predictability of the determined regression equations was assessed by computing the standard error of estimate (SEE) and the coefficient of determination (R2). The p value of less than 0.05 was regarded to be statistically significant.

RESULTS

Table 1 Descriptive statistics of stature and foot length data of the subjects of the study. Mean height of men was significantly taller than that of women ($p < 0.001$), as expected due to sexual dimorphism. Mean foot length measurements in males were also significantly higher compared to females ($p < 0.001$).

Table 1: Descriptive indices of stature and foot length (N=300)

Variable (cm)	Sex	N	Mean ± SD	Range (Min-Max)
Stature	**Male**	150	170.5 ± 6.2	158.0 - 185.0
	Female	150	158.2 ± 5.8	145.5 - 172.0
Right Foot Length	**Male**	150	26.5 ± 1.5	23.0 - 29.5

	Female	150	24.0 ± 1.3	21.0 - 27.0
Left Foot Length	**Male**	150	26.4 ± 1.4	22.8 - 29.3
	Female	150	23.9 ± 1.2	20.8 - 26.8

Correlation: Pearson's correlation test showed strong positive and statistically significant correlation between foot length and stature for both sexes (Table 2). In the case of males, the correlation coefficient between right foot length and height was 0.85 ($p < 0.001$), and for left foot length was 0.84 ($p < 0.001$). In females, right and left foot length were the most strongly correlated to stature ($r = 0.82$, $p < 0.001$ and $r = 0.81$, $p < 0.001$). That these r values are exceptionally high implies that foot length is a very good estimate of stature in this sample.

Sex specific regression equations were developed using linear regression analysis for estimation of stature from foot length. The equations developed, and R2 and SEE are shown in Table 2. The value of R2 shows that foot length explains ~72-65% of the variance in stature. The standard error of estimation (SEE) values, which are an indicator of how well the models predict stature, were quite low, indicating a high rate of predictability for the models.

Table 2: Estimation of stature in Malaysian population based on regression equations derived from foot length

Group	**Regression Equation**	**R^2**	**SEE (cm)**
Males (Right Foot Length)	Stature = 95.2 + 2.85 * Right Foot Length	0.72	3.4
Males (Left Foot Length)	Stature = 96.1 + 2.80 * Left Foot Length	0.71	3.5
Females (Right Foot Length)	Stature = 88.5 + 2.90 * Right Foot Length	0.68	3.7
Females (Left Foot Length)	Stature = 89.2 + 2.88 * Left Foot Length	0.65	3.9
Combined (Right Foot Length)	Stature = 85.0 + 3.00 * Right Foot Length	0.60	4.5
Combined (Left Foot Length)	Stature = 85.5 + 2.95 * Left Foot Length	0.58	4.7

Note: All regression equations are significant ($p < .001$).

DISCUSSION

The objective of this cross-sectional study was to explore the correlation between foot length and stature in young adults of Moradabad (Uttar Pradesh), as well as provide population-based regression equations for stature estimation. Furthermore, our results indicate a high positive correlation between foot length and height in men and women, which is in line with several reports in forensic anthropometry [1, 2, 3]. The present findings of significantly higher mean stature and foot length by male in comparison to female is an accepted global biological diversity and is a well documented observation on studying all populations sets including Indian population as well [4,5,6]. This intrinsic difference points out the importance of establishing sex-specific regression equations to estimate stature, since unified formulae would probably generate greater error [7, 8].

In high coefficient of correlation (0.81-0.85) between foot length and stature in our study is equivalent to, and in some instances even greater than that in other Indian populations. For instance, Krishan et al. [9] found significant association in North Indian population and Geethanjali et al. [7] also found similar results in a South Indian population. The uniformity of these correlations seen across different geographical regions in India demonstrates the applicability of foot length as a method of stature estimation in the Indian subcontinent, despite regional variation of the absolute values. Indeed, the R2-values found in our study (0.65-0.72) show that foot length accounts for a substantial amount of stature variance, demonstrating that these models have good predictive ability. These results are comparable to or slightly better than those presented in Singh et al. [4] in North Indian males (R2 values up to 0.418) and other researches who used foot dimensions for stature prediction [10]. The relatively low values of the standard error of estimate (SEE) (3.4-3.9 cm) also strengthen the accuracy of our developed regression equations which means that the estimated stature would be almost close to the actual stature.

A comparison of our regression equations with those from other studies in India shows similarities and differences can be explained on the basis of differences in population characteristics, geographical areas, and methods employed. For instance, the overall linear model relationship (Stature = a + b * Foot Length) is the same between studies though a and b will differ. This highlights the relevance of population-specific formulae for legal medicine. The study by Atal et al. [10] on North Indian participants also generated

regression equations, and although the comparison of coefficients is difficult without their raw data, the gross indication that foot length is a powerful determinant is similar. This data forms an important source of information for forensic scientists and anthropologists in this region of the world. The fact that these are the data from Moradabad, U.P., adds a regional specificity to the already known and helps to make the identification processes more accurate in this region.

One of the strong points of our study is that we included an equal number of males and females in a relatively narrow age range in order to reduce age differences as much as possible and obtain strong sex-specific data. Our results are also reliable because they use standardized anthropometric procedures and were obtained by only one observer. The cross-sectional nature of this study on the other hand provide a snapshot of the population at a particular point in time. Longitudinal research might provide additional information on changes in foot dimensions as well as their association with stature over time. Another point is that, although foot length is a strong predictor, by adding other foot measurements or demographic variables could possibly increase the precision of the stature estimation in multivariate regression models, as previously reported [4,9]. These avenues may be explored in future to develop a more comprehensive and accurate prediction models for the population of Moradabad.

CONCLUSION

This cross-sectional study has demonstrated a significant correlation between foot length and stature among Moradabad population, UP and derived important population-specific regression equations for stature estimation. The sex-based differences were also prominent, and these clearly indicate that sex-specific formulae should be employed for forensic cases. These data have a high utility value in building up the current anthropometric data of the Indian subcontinent and could be useful as reliable and efficient tool in forensic anthropologists and investigating agency in personal identification in cases of difficult to solve completely decomposed human remains, which are beyond recognition by conventional methods. The derived equations could be a useful tool to reduce the number of potential identities in forensic casework in this region of the world.

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