

Estimation of Stature by Foot Anthropometric Measurements in Undergraduate Medical Students of Chhattisgarh Region

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ABSTRACT

Background: Estimation of stature is an important aspect of forensic anthropology and medicolegal identification, particularly when complete human remains are unavailable. Foot anthropometric measurements are considered reliable predictors of stature because of their strong anatomical relationship with body height; therefore, this study aimed to estimate stature using foot anthropometric measurements among undergraduate medical students in the Chhattisgarh region.

Methods: A cross-sectional observational study was conducted among 248 undergraduate medical students (110 males and 138 females) aged 18–25 years. Stature, right and left foot length, and right and left foot breadth were measured using standard anthropometric techniques. Data were analysed using IBM SPSS Statistics version 26.0. Pearson's correlation coefficient and Student's *t*-test were applied, and a *p*-value <0.05 was considered statistically significant.

Results: Male participants exhibited significantly greater stature and foot dimensions than female participants (*p*<0.001). Right foot length showed the highest correlation with stature (*r* = 0.604), followed closely by left foot length (*r* = 0.600). Foot breadth measurements also demonstrated significant positive correlations with stature, although the strength of association was comparatively lower.

Conclusion: Foot anthropometric measurements, particularly foot length, are reliable indicators for stature estimation among undergraduate medical students in the Chhattisgarh region. These findings provide population-specific baseline data and may assist forensic identification and medicolegal investigations where only partial human remains are available.

Key-words: Stature estimation; Foot anthropometry; Foot length; Foot breadth; Forensic anthropology; Undergraduate medical students; Chhattisgarh

INTRODUCTION

Stature is a fundamental biological characteristic widely used in forensic anthropology and medicolegal investigations for establishing the identity of unknown individuals. Accurate stature estimation becomes particularly important when complete human remains are unavailable due to decomposition, mutilation, explosions, natural disasters, or other traumatic events.

In such situations, anthropometric measurements of different body parts provide a practical and reliable approach for estimating stature. Anthropometry provides a simple, reliable, and scientifically accepted method for estimating stature and establishing personal identity using measurable body dimensions ^[1].

Among various anthropometric parameters, foot measurements have been widely recognized as reliable indicators for stature estimation because of their proportional relationship with body height. The human foot bears body weight, maintains postural balance, and develops proportionately with overall skeletal growth. Foot length and foot breadth are relatively stable measurements after skeletal maturity and are less affected by environmental factors than several other body dimensions. Consequently, these measurements

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have been extensively used for estimating stature and evaluating their correlation with body height in forensic anthropological studies [2].

Foot anthropometry offers several practical advantages in forensic investigations. In many medicolegal situations such as air crashes, earthquakes, bomb explosions, railway accidents, and criminal dismemberment, complete bodies are rarely recovered. However, the feet often remain preserved because of footwear and the anatomical strength of the lower extremities. Accurate estimation of stature from foot dimensions can therefore provide valuable information for narrowing the identity of unknown individuals. The procedure is simple, inexpensive, non-invasive, and can be performed using basic anthropometric instruments, making it suitable for routine forensic practice [3].

Several studies conducted in different countries have demonstrated significant positive correlations between stature and foot anthropometric measurements. However, the strength of these relationships differs according to sex, ethnicity, geographical location, nutritional status, and genetic background. Therefore, regression equations developed in one population cannot be directly applied to another population without compromising prediction accuracy. Population-specific anthropometric standards are essential for obtaining reliable and scientifically valid stature estimates [4].

India is characterized by considerable ethnic, cultural, and geographical diversity, resulting in marked variations in anthropometric characteristics among different regional populations. Although numerous Indian studies have investigated the relationship between stature and foot dimensions, relatively limited information is available for young adults belonging to the Chhattisgarh region. Establishing regional anthropometric databases is important not only for forensic identification but also for anthropological research, clinical anatomy, ergonomics, and medicolegal practice. Such databases contribute significantly towards improving the accuracy of stature estimation in specific populations [5].

The present study was undertaken to evaluate the relationship between foot anthropometric measurements and stature among undergraduate medical students in the Chhattisgarh region. Bilateral foot length and foot breadth were measured using standard anthropometric techniques to determine their correlation with stature. The findings are expected to

provide population-specific baseline data and contribute to forensic anthropology, medicolegal investigations, and the development of reliable stature estimation models for the regional population [6].

MATERIALS AND METHODS

Study Design and Setting- A cross-sectional observational study was conducted in the Department of Forensic Medicine and Toxicology, Pt. Jawahar Lal Nehru Memorial Medical College, Raipur, Chhattisgarh, India.

Study Population- The study included 248 undergraduate medical students (110 males and 138 females) aged 18–25 years. Participants were recruited using a convenience sampling technique from students who voluntarily agreed to participate in the study.

Inclusion Criteria

- Healthy undergraduate medical students aged 18–25 years.
- Students belonging to the Chhattisgarh region.
- Individuals who provided written informed consent for participation.

Exclusion Criteria

- Participants with congenital deformities of the foot.
- History of fracture, surgery, trauma, or any deformity affecting foot measurements.
- Individuals with locomotor disability or musculoskeletal disorders influencing stature or foot dimensions.
- Participants unwilling to participate in the study.

Anthropometric Measurements- Stature was measured in the standing anatomical position using a standard stadiometer with the participant standing barefoot, erect, and looking straight ahead in the Frankfurt horizontal plane. Measurements were recorded to the nearest 0.1 cm.

Foot anthropometric measurements were obtained with participants standing in a relaxed position. Right Foot Length (RFL), Left Foot Length (LFL), Right Foot Breadth (RFB), and Left Foot Breadth (LFB) were measured using a standard spreading caliper and measuring scale following standard anthropometric landmarks. All measurements were recorded to the nearest 0.1 cm. To minimize measurement error, each parameter was

measured twice by the same observer, and the average value was used for statistical analysis.

Statistical Analysis- The collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Independent Student's t-test was used to compare anthropometric measurements between genders. Pearson's correlation coefficient (r) was calculated to assess the relationship between stature and foot anthropometric measurements. A p -value <0.05 was considered statistically significant, while $p <0.001$ was considered highly significant.

Ethical Approval- The study was carried out among undergraduate medical students after obtaining approval from the Institutional Ethics Committee. All procedures were performed in accordance with institutional ethical guidelines.

RESULTS

A total of 248 undergraduate medical students were included in the present study, comprising 110 (44.35%) males and 138 (55.65%) females. The mean stature of male participants was 171.46 ± 7.28 cm, whereas female participants had a mean stature of 156.69 ± 7.05 cm. The overall mean stature of the study population was 163.24 ± 9.98 cm (Table 1).

Table 1: Demographic Characteristics and Gender-wise Distribution of Study Participants Included for Stature Estimation Using Foot Anthropometric Measurements

Gender	Number of Participants (n)	Percentage (%)	Mean Stature (cm) $\pm$ SD
Male	110	44.35	171.46 ± 7.28
Female	138	55.65	156.69 ± 7.05
Total	248	100.00	163.24 ± 9.98

Gender-wise comparison of foot length measurements demonstrated that males had significantly greater foot lengths than females. The mean right foot length was 25.17 ± 2.13 cm in males and 23.07 ± 1.19 cm in females, while the mean left foot length was 25.09 ± 2.14 cm and

23.06 ± 1.18 cm, respectively. The overall mean right and left foot lengths were 24.00 ± 1.97 cm and 23.96 ± 1.95 cm, respectively. These differences were statistically highly significant ($p < 0.001$) (Table 2).

Table 2: Gender-wise Comparison of Right and Left Foot Length Measurements among Study Participants

Gender	n	Right Foot Length (cm) Mean $\pm$ SD	Left Foot Length (cm) Mean $\pm$ SD	p-value
Male	110	25.17 ± 2.13	25.09 ± 2.14	<0.001
Female	138	23.07 ± 1.19	23.06 ± 1.18	<0.001
Overall	248	24.00 ± 1.97	23.96 ± 1.95	

Similarly, foot breadth measurements were significantly greater among male participants than females. The mean right foot breadth measured 9.76 ± 0.73 cm in males and 9.00 ± 0.59 cm in females, whereas the mean left foot breadth was 10.08 ± 2.25 cm in males and 9.00

± 0.60 cm in females. The overall mean right and left foot breadths were 9.34 ± 0.76 cm and 9.47 ± 1.64 cm, respectively. Gender differences in both foot breadth measurements were also found to be statistically highly significant ($p < 0.001$) (Table 3).

Table 3: Gender-wise Comparison of Right and Left Foot Breadth Measurements among Study Participants

Gender	n	Right Foot Breadth (cm) Mean $\pm$ SD	Left Foot Breadth (cm) Mean $\pm$ SD	p-value
Male	110	9.76 ± 0.73	10.08 ± 2.25	<0.001
Female	138	9.00 ± 0.59	9.00 ± 0.60	<0.001
Overall	248	9.34 ± 0.76	9.47 ± 1.64	

Pearson's correlation analysis demonstrated a significant positive association between stature and all foot anthropometric measurements. Right foot length ($r = 0.604$) exhibited the strongest positive correlation with stature, followed closely by left foot length ($r = 0.600$). Both measurements showed highly significant correlations ($p < 0.001$). Right foot breadth demon-

strated a moderate positive correlation ($r = 0.437$, $p < 0.001$), while left foot breadth also showed a statistically significant positive correlation ($r = 0.307$, $p < 0.001$). Overall, foot length measurements showed stronger correlations with stature than foot breadth measurements, indicating that foot length is a better predictor of stature in the studied population (Table 4).

Table 4: Correlation of Stature with Foot Anthropometric Measurements among Undergraduate Medical Students

Foot Anthropometric Measurement	Pearson's Correlation Coefficient (r)	p-value	Strength of Correlation
Right Foot Length	0.604	<0.001	Strong Positive
Left Foot Length	0.600	<0.001	Strong Positive
Right Foot Breadth	0.437	<0.001	Moderate Positive
Left Foot Breadth	0.307	<0.001	Moderate Positive

DISCUSSION

The present study evaluated the utility of foot anthropometric measurements for stature estimation among undergraduate medical students of the Chhattisgarh region. The findings demonstrated significant sexual dimorphism, with male participants exhibiting significantly greater foot length and foot breadth than female participants. These observations are consistent with the findings of Jain *et al.* and Shende *et al.*, who also reported significantly larger foot dimensions among males in North Indian populations, suggesting that sex-related skeletal differences should be considered while developing stature estimation models [7,8].

In the present study, the mean right and left foot lengths were significantly higher in males than females, and both parameters showed a strong positive correlation with stature. Right foot length demonstrated the highest correlation coefficient ($r = 0.604$), followed closely by left foot length ($r = 0.600$). Similar observations have been reported by Kanchan *et al.*, who concluded that foot length is one of the most reliable anthropometric parameters for stature estimation because it maintains a stable proportional relationship with body height. Their study also demonstrated that regression equations based on foot length provide greater predictive accuracy than those derived from other individual foot measurements [8,9].

The present investigation also revealed statistically significant differences in right and left foot breadth between male and female participants.

Although both foot breadth measurements were positively correlated with stature, the correlation coefficients ($r = 0.437$ and $r = 0.307$) were lower than those observed for foot length. Comparable findings have been documented in previous forensic anthropometric studies, where foot breadth contributed to stature estimation but demonstrated lower predictive accuracy than foot length. This difference may be attributed to the fact that foot breadth is influenced not only by skeletal dimensions but also by body build, nutritional status, and soft tissue distribution [10,11]. Therefore, foot breadth may serve as a supportive anthropometric parameter; however, foot length remains a more reliable indicator for stature estimation because of its stronger correlation with body height.

The present findings support the application of foot anthropometry in forensic medicine, particularly in situations involving fragmented human remains, footprints, or mass disaster victim identification. Since foot measurements can be obtained easily, rapidly, and with minimal equipment, they serve as practical anthropometric parameters for estimating stature when complete skeletal remains are unavailable. Previous studies have similarly emphasized the usefulness of foot dimensions and population-specific regression equations for establishing the biological profile of unknown individuals during medicolegal investigations [12,13].

The correlation coefficients observed in the present study differ slightly from those reported in other regional studies, which may be explained by variations in ethnicity, geographical distribution, nutritional status,

genetic background, age composition, and sampling methods. These differences further emphasize the importance of developing population-specific anthropometric standards rather than applying universal regression equations. Therefore, the present study provides useful baseline data for the Chhattisgarh population and supports the incorporation of regional anthropometric databases into forensic identification practices ^[14]. The findings may also facilitate the development of population-specific regression equations, thereby improving the accuracy of stature estimation in forensic and medicolegal practice.

The present study has certain limitations. The participants were recruited from a single medical institution in the Chhattisgarh region; therefore, the findings may not be generalizable to other populations with different ethnic or geographical backgrounds. The study included only healthy undergraduate medical students within a limited age group, which may not represent the entire adult population. Furthermore, only linear foot anthropometric measurements were evaluated, whereas additional parameters such as footprint dimensions and regression equation validation in independent populations were not undertaken. Future multicentric studies involving larger and more diverse populations are recommended to improve the accuracy and external applicability of stature estimation models.

CONCLUSIONS

The present study demonstrated that foot anthropometric measurements, particularly foot length, are reliable indicators for estimating stature among undergraduate medical students of the Chhattisgarh region. Significant sexual dimorphism was observed, with male participants exhibiting greater foot dimensions than females. Among all the measured parameters, right foot length showed the strongest correlation with stature, indicating that foot length is a more accurate predictor than foot breadth. These findings provide population-specific baseline data and support the application of foot anthropometry in forensic identification and medicolegal investigations where complete human remains are unavailable. Further multicentric studies involving larger and more diverse populations are recommended to validate and refine population-specific regression models for wider forensic application.

CONTRIBUTION OF AUTHORS

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