

Estimation of Stature from Hand and Foot Anthropometric Measurements: An Observational Study

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Abstract

Background: Stature estimation is important in forensic investigations, anthropological studies, and medicolegal examinations, particularly when complete skeletal remains are unavailable. Hand and foot anthropometric measurements provide useful alternatives for estimating stature.

Aim and Objectives: To assess the relationship between stature and selected hand and foot dimensions, compare anthropometric measurements between males and females, and develop regression equations for stature estimation in the Central Indian population.

Materials and Methods: A cross-sectional observational study was conducted among 400 adults, comprising 200 males and 200 females, at Index Medical College Hospital and Research Centre, Indore, Madhya Pradesh, from January 2023 to July 2026. Stature and selected hand and foot measurements were recorded using standardized techniques. Data were analyzed using descriptive statistics, Pearson's correlation, and linear and multiple regression analyses.

Results: Mean stature was 170.8 ± 6.5 cm in males and 158.8 ± 5.8 cm in females. Males showed significantly higher anthropometric measurements than females ($p < 0.001$). Right foot length demonstrated the strongest overall correlation with stature ($r = 0.84$), followed by left foot length ($r = 0.83$) and righthand length ($r = 0.78$). Right foot length explained 51.8% of stature variation in males and 56.3% in females. The best multiple regression model, incorporating hand length, foot length, middle finger length, and foot breadth, explained 82.4% of stature variation, with a standard error of estimate of 3.51 cm.

Conclusion: Hand and foot anthropometric measurements are useful for stature estimation in the Central Indian population. Foot length was the strongest individual predictor, while combining multiple measurements improved predictive accuracy.

Keywords: Stature estimation; Anthropometry; Hand length; Foot length; Regression analysis; Forensic identification.

Introduction

Stature is one of the most important biological identifiers of an individual and is influenced by genetic, nutritional, environmental, ethnic, and geographical factors. In forensic investigations, disaster victim identification, and medicolegal examinations, estimation of stature becomes essential when only fragmentary or dismembered human remains are available.^{1,2}

Anthropometry, the systematic measurement of the human body and its parts, provides a scientific basis for establishing biological identity. Among the various body dimensions, long bones of the lower limb are traditionally considered the most reliable predictors of stature; however, these bones may not always be recovered in intact condition. Therefore, measurements of the hand and foot are valuable alternatives for stature estimation because they are compact, durable, easily measurable, and often preserved even when major skeletal elements are unavailable.^{3,4}

Several studies have demonstrated a strong positive correlation between stature and hand length, hand breadth, foot length, and foot breadth. Regression equations derived from these measurements can provide reasonably accurate stature estimates, particularly when population-specific standards are used.^{5,6} Because body proportions differ across sex, age, ethnicity, and geographic regions, regression formulae developed in one population may not be directly applicable to another.^{7,8}

In the Indian context, studies conducted among North Indian, South Indian, and tribal populations have reported significant correlations between hand and foot dimensions and stature.^{9,10} However, limited population-specific data are available for the Central Indian population. Previous work in Central India has shown that hand length and foot length can be useful predictors of stature, but comprehensive studies incorporating multiple hand and foot anthropometric variables in both sexes remain necessary.^{11,12}

Materials and Methods

Study design and setting

The present study was conducted using a cross-sectional, descriptive, observational design to assess the relationship between selected hand and foot anthropometric measurements and stature among adult individuals. The study was carried out in the Department of Anatomy, Index Medical College Hospital and Research Centre, Indore, Madhya Pradesh, India, from January 2023 to July 2026.

Study population

The study population comprised adult males and females aged 18–32 years belonging to the Central Indian population. A total of 400 participants, including 200 males and 200 females, were included in the study. The sample size was determined based on previously published literature on anthropometric measurements and stature estimation, and it was considered adequate for sex-wise comparison, correlation analysis, and development of regression equations for stature estimation.

Inclusion criteria

Participants were included if they:

- Were aged between 18 and 32 years.
- Were born and brought up in the defined Central Indian population.
- Were willing to participate voluntarily.
- Provided written informed consent.

Exclusion criteria

Participants were excluded if they had:

- Congenital or acquired deformities affecting stature, hands, or feet.

- A history of injury or fracture affecting the limbs or stature.
- Amputation of any part of the upper or lower limb.
- Diseases or pathological conditions influencing anthropometric measurements.
- Previous surgical procedures affecting the measured body regions.
- Any condition preventing accurate anthropometric assessment.

Ethical approval and consent

The study was initiated after obtaining approval from the Institutional Ethics Committee of Index Medical College Hospital and Research Centre, Indore. Written informed consent was obtained from all participants before data collection. Confidentiality of all participant information was maintained throughout the study.

Anthropometric instruments

Anthropometric measurements were obtained using standardized instruments, including a sliding Vernier caliper for hand and foot dimensions, a stadiometer or stature meter for stature measurement, and a standard weighing scale for body weight. Demographic and anthropometric observations were recorded on a structured data-collection proforma. Measurements were taken according to predefined anatomical landmarks and standardized procedures to minimize observational errors and inter-observer variation. Right and left measurements were recorded separately in millimetres wherever applicable.

Measurement of stature

Stature was defined as the vertical distance between the highest point of the vertex of the head and the floor. It was measured with the participant standing barefoot in an erect posture on the platform of the stadiometer. The feet were appropriately positioned, arms were hanging freely by the sides, and palms faced the thighs. The head was maintained in the appropriate anatomical position, and the movable headpiece of the stadiometer was brought into contact with the vertex. The measurement was then recorded.

Measurement of hand parameters

Hand length was measured as the projected distance between the midpoint of the line joining the radial and ulnar styloid processes and the tip of the middle finger. The forearm and hand were maintained in a straight position, with the metacarpophalangeal and interphalangeal joints fully extended.

Hand breadth was measured as the distance between the radial side of the second metacarpophalangeal joint and the ulnar side of the fifth metacarpophalangeal joint.

Middle finger length was measured on the palmar aspect of the hand from the midpoint of the proximal finger crease to the tip of the middle finger.

Proximal phalangeal length was measured from the middle of the metacarpophalangeal crease to the proximal phalangeal crease.

Middle phalangeal length was measured from the middle of the proximal phalangeal crease to the middle of the distal phalangeal crease.

Distal phalangeal length was measured from the middle of the distal phalangeal crease to the tip of the middle finger.

Measurement of foot parameters

Foot length was measured as the distance between the most posterior prominent point of the heel and the most distal point of the longest toe, with the foot fully extended.

Foot breadth was measured as the distance between the most medially placed point on the head of the first metatarsal and the most laterally placed point on the head of the fifth metatarsal, with the foot maintained in an appropriate position.

Data-collection procedure

Following informed consent, demographic details including age and sex were recorded. Body weight and stature were measured first, followed by assessment of the selected hand and foot parameters. The relevant anatomical landmarks were identified before each measurement, and standardized techniques were followed throughout data collection. Measurements of the right and left hands and feet were recorded separately. All observations were entered into a structured proforma and subsequently transferred to a computerized database for statistical analysis.

Quality control

Quality-control measures were implemented throughout the study to ensure reliability and consistency of observations. The same standardized instruments were used, and their proper functioning was checked before data collection. Anatomical landmarks were identified consistently, and measurements were performed using standardized procedures, preferably by the same investigator. Completed data sheets were reviewed for accuracy and completeness before statistical analysis.

Study variables

The variables assessed included age, sex, stature, body weight, right and left hand length, right and left hand breadth, middle finger length, proximal phalangeal length, middle phalangeal length, distal phalangeal length, right and left foot length, and right and left foot breadth.

Statistical analysis

The collected data were entered into Microsoft Excel and analysed using IBM SPSS Statistics software. Descriptive statistics, including mean, standard deviation, range, coefficient of variation, and standard error, were calculated for the anthropometric variables. Pearson's correlation coefficient (r) was used to assess the relationship between stature and selected hand and foot dimensions. Linear regression analysis was performed to develop equations for stature estimation from relevant anthropometric parameters. Student's t -test was used to compare mean values between groups wherever applicable. A p -value of less than 0.05 was considered statistically significant.

Results

A total of 400 participants, comprising 200 males and 200 females, were included in the study. The largest proportion of participants belonged to the 21–25-year age group (25.0%), followed by 26–30 years (24.3%). Mean age was 28.7 ± 7.1 years. Mean stature was 170.8 ± 6.5 cm in males and 158.8 ± 5.8 cm in females, with an overall mean of 164.8 ± 8.3 cm.

Males showed higher mean values than females for all measured hand and foot parameters. Mean right hand length was 19.08 ± 0.76 cm in males and 17.52 ± 0.70 cm in females, while mean right foot length was 26.12 ± 1.03 cm and 23.84 ± 0.91 cm, respectively. All stature and anthropometric measurements showed statistically significant sex differences ($p < 0.001$).

Pearson correlation analysis demonstrated significant positive correlations between stature and all measured anthropometric parameters ($p < 0.001$). Right foot length showed the strongest overall correlation with stature ($r = 0.84$), followed by left foot length ($r = 0.83$) and right hand length ($r = 0.78$). Correlations for right foot length were $r = 0.72$ in males and $r = 0.75$ in females.

Simple linear regression analysis identified right foot length as the strongest individual predictor of stature. It explained 51.8% of stature variation in males and 56.3% in females, with standard errors of estimate (SEE) of 4.61 cm and 3.91 cm, respectively. Right hand length explained 41.0% of variation in males and 46.2% in females.

Multiple regression models demonstrated improved predictive performance when several anthropometric measurements were combined. The best-performing overall model included hand length, foot length, middle finger length, and foot breadth, with a correlation coefficient of 0.91, an (R^2) of 0.824, an adjusted (R^2) of 0.822, and an SEE of 3.51 cm ($p < 0.001$). In sex-specific models, the best male model had an (R^2) of 0.79 and an SEE of 3.16 cm, while the best female model had an (R^2) of 0.83 and an SEE of 2.67 cm.

Comparison of actual and estimated stature showed no statistically significant differences in males (170.8 ± 6.5 vs. 170.6 ± 4.9 cm, $p = 0.44$), females (158.8 ± 5.8 vs. 158.9 ± 4.6 cm, $p = 0.58$), or the overall study population (164.8 ± 8.3 vs. 164.7 ± 7.2 cm, $p = 0.49$). These findings indicate that hand and foot anthropometric measurements, particularly foot length combined with other parameters, may be useful for stature estimation.

Table 1. Distribution of study participants according to sex and age

Age group (years)	Male, n (%)	Female, n (%)	Total, n (%)
18–20	24 (12.0)	28 (14.0)	52 (13.0)
21–25	48 (24.0)	52 (26.0)	100 (25.0)
26–30	49 (24.5)	48 (24.0)	97 (24.3)
31–35	37 (18.5)	34 (17.0)	71 (17.8)
36–40	26 (13.0)	25 (12.5)	51 (12.8)
>40	16 (8.0)	13 (6.5)	29 (7.3)
Total	200 (100.0)	200 (100.0)	400 (100.0)

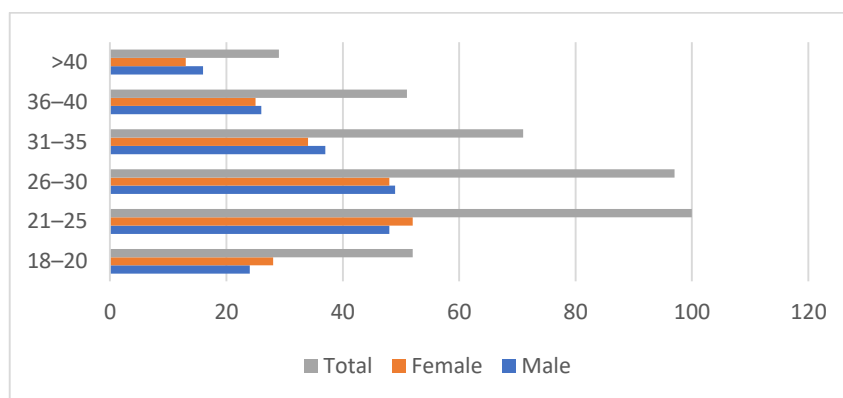


Figure 1. Distribution of study participants according to sex and age

Table 2. Descriptive statistics of stature according to sex

Variable	Male (n = 200), Mean $\pm$ SD	Female (n = 200), Mean $\pm$ SD	Overall (n = 400), Mean $\pm$ SD
Age (years)	28.9 ± 7.2	28.5 ± 6.9	28.7 ± 7.1

Stature (cm)	170.8 ± 6.5	158.8 ± 5.8	164.8 ± 8.3
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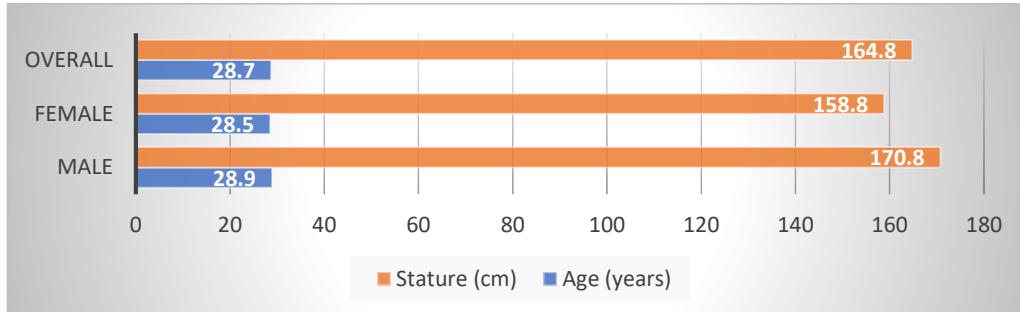


Figure 2- Descriptive statistics of stature according to sex

Table 3. Descriptive statistics of hand and foot measurements according to sex

Measurement	Male, Mean ± SD	Female, Mean ± SD
Right hand length (cm)	19.08 ± 0.76	17.52 ± 0.70
Left hand length (cm)	18.96 ± 0.75	17.44 ± 0.69
Right hand breadth (cm)	8.47 ± 0.42	7.63 ± 0.38
Left hand breadth (cm)	8.40 ± 0.41	7.58 ± 0.37
Right middle finger length (cm)	8.16 ± 0.39	7.42 ± 0.35
Right foot length (cm)	26.12 ± 1.03	23.84 ± 0.91
Left foot length (cm)	26.01 ± 1.02	23.76 ± 0.90
Right foot breadth (cm)	9.63 ± 0.48	8.72 ± 0.43
Left foot breadth (cm)	9.57 ± 0.47	8.68 ± 0.42

Table 4. Sex-wise comparison of stature and anthropometric measurements

Variable	Male, Mean ± SD	Female, Mean ± SD	t-value	p-value
Stature (cm)	170.8 ± 6.5	158.8 ± 5.8	19.30	<0.001
Right hand length (cm)	19.08 ± 0.76	17.52 ± 0.70	21.29	<0.001
Left hand length (cm)	18.96 ± 0.75	17.44 ± 0.69	21.12	<0.001
Right hand breadth (cm)	8.47 ± 0.42	7.63 ± 0.38	20.91	<0.001
Left hand breadth (cm)	8.40 ± 0.41	7.58 ± 0.37	20.85	<0.001
Right middle finger length (cm)	8.16 ± 0.39	7.42 ± 0.35	19.84	<0.001
Right foot length (cm)	26.12 ± 1.03	23.84 ± 0.91	23.32	<0.001
Left foot length (cm)	26.01 ± 1.02	23.76 ± 0.90	23.24	<0.001
Right foot breadth (cm)	9.63 ± 0.48	8.72 ± 0.43	19.74	<0.001
Left foot breadth (cm)	9.57 ± 0.47	8.68 ± 0.42	19.65	<0.001

All stature and anthropometric measurements showed statistically significant sex differences ($p < 0.001$).

Table 5. Pearson correlation between stature and hand/foot measurements

Measurement	Male r	Female r	Overall r	p-value
Right hand length	0.64	0.68	0.78	<0.001

Left hand length	0.63	0.67	0.77	<0.001
Right hand breadth	0.39	0.42	0.51	<0.001
Left hand breadth	0.37	0.41	0.49	<0.001
Middle finger length	0.57	0.61	0.69	<0.001
Right foot length	0.72	0.75	0.84	<0.001
Left foot length	0.71	0.74	0.83	<0.001
Right foot breadth	0.43	0.46	0.55	<0.001
Left foot breadth	0.42	0.45	0.54	<0.001

Table 6. Simple linear regression models for stature estimation

Predictor	Sex	Regression equation	R	R ² (%)	SEE (cm)	p-value
Right hand length	Male	Stature = 107.1 + 3.34 × RHL	0.64	41.0	5.03	<0.001
Right hand length	Female	Stature = 97.8 + 3.48 × RHL	0.68	46.2	4.34	<0.001
Right foot length	Male	Stature = 103.2 + 2.59 × RFL	0.72	51.8	4.61	<0.001
Right foot length	Female	Stature = 101.4 + 2.41 × RFL	0.75	56.3	3.91	<0.001
Right hand breadth	Male	Stature = 125.7 + 5.32 × RHB	0.39	15.2	5.57	<0.001
Right hand breadth	Female	Stature = 122.5 + 4.76 × RHB	0.42	17.6	5.29	<0.001
Right foot breadth	Male	Stature = 118.7 + 5.41 × RFB	0.43	18.5	5.46	<0.001
Right foot breadth	Female	Stature = 117.3 + 4.76 × RFB	0.46	21.2	5.19	<0.001

RHL: right hand length; RFL: right foot length; RHB: right hand breadth; RFB: right foot breadth. Right foot length was the strongest individual predictor of stature.

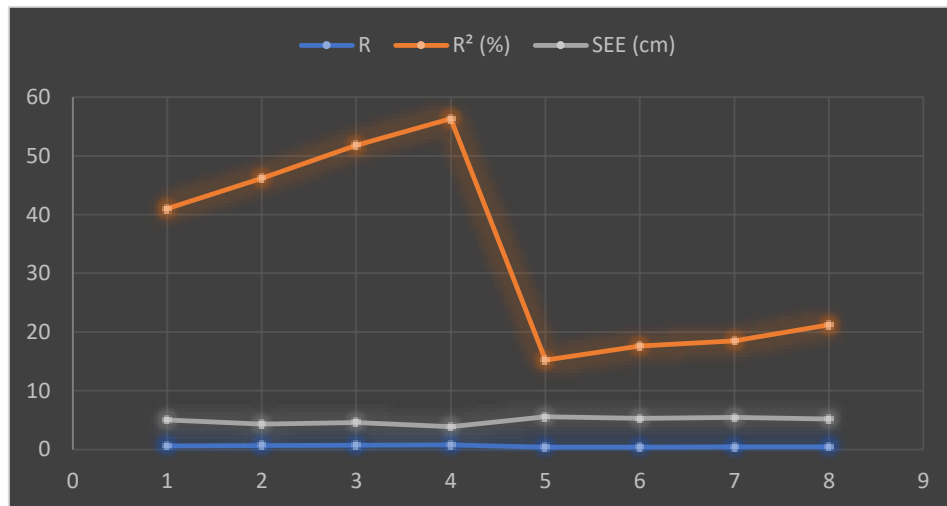


Figure 3- Simple linear regression models for stature estimation

Table 7. Multiple regression models for stature estimation

Model	Predictors	R	R ²	Adjusted R ²	SEE (cm)	p-value
Model 1	Right hand length + right foot length	0.88	0.774	0.773	3.96	<0.001

Model 2	Right hand length + right foot length + right hand breadth	0.89	0.792	0.790	3.81	<0.001
Model 3	Right hand length + right foot length + right foot breadth	0.89	0.801	0.799	3.73	<0.001
Model 4	Hand length + hand breadth + foot length + foot breadth	0.90	0.813	0.811	3.62	<0.001
Model 5	Hand length + foot length + middle finger length + foot breadth	0.91	0.824	0.822	3.51	<0.001

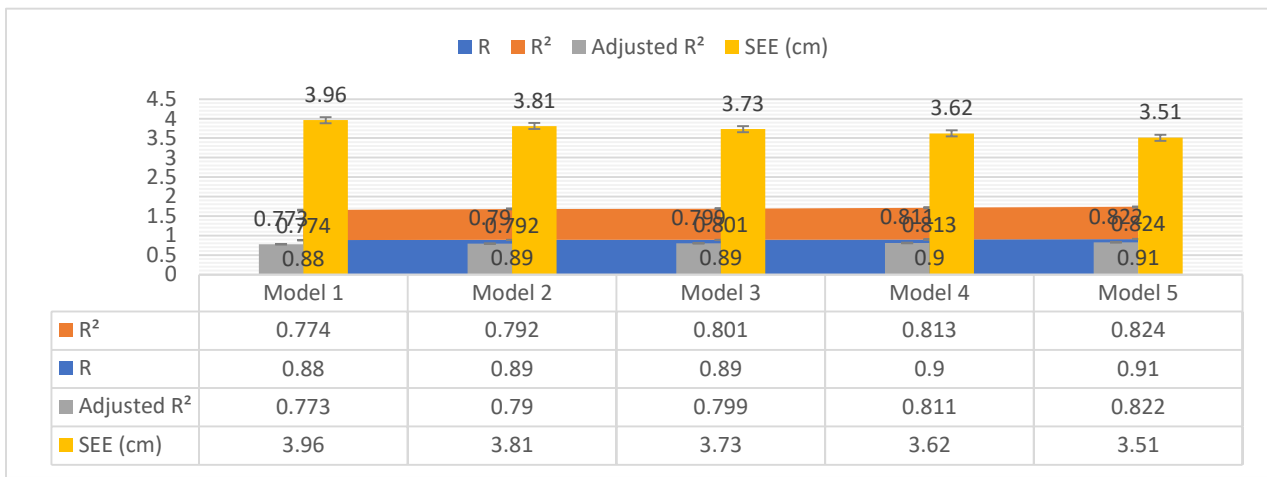


Figure 4. Multiple regression models for stature estimation

Model 5 showed the best predictive performance, explaining 82.4% of the variation in stature with the lowest standard error of estimate.

Table 8. Sex-specific multiple regression equations for stature estimation

Sex	Predictors	Regression equation	R²	Adjusted R²	SEE (cm)
Male	RHL + RFL	Stature = 92.84 + 2.01(RHL) + 1.42(RFL)	0.76	0.75	3.34
Male	RHL + RFL + RHB	Stature = 87.63 + 1.84(RHL) + 1.37(RFL) + 1.21(RHB)	0.79	0.78	3.16
Female	RHL + RFL	Stature = 84.71 + 2.18(RHL) + 1.51(RFL)	0.81	0.80	2.82
Female	RHL + RFL + RHB	Stature = 80.92 + 2.05(RHL) + 1.47(RFL) + 1.18(RHB)	0.83	0.82	2.67

RHL: right hand length; RFL: right foot length; RHB: right hand breadth. Female-specific models showed better predictive accuracy than male-specific models.

Table 9. Comparison between actual and estimated stature using the best regression model

Parameter	Actual stature (cm), Mean ± SD	Estimated stature (cm), Mean ± SD	Mean difference (cm)	95% CI	p-value
Male	170.8 ± 6.5	170.6 ± 4.9	0.2	-0.31 to 0.71	0.44

Female	158.8 ± 5.8	158.9 ± 4.6	-0.1	-0.46 to 0.26	0.58
Overall	164.8 ± 8.3	164.7 ± 7.2	0.1	-0.18 to 0.38	0.49

Discussion

The present study demonstrated a significant positive correlation between stature and selected hand and foot anthropometric measurements among 400 adult participants of the Central Indian population. Males had significantly higher mean stature, hand length, hand breadth, middle finger length, foot length, and foot breadth than females ($p < 0.001$), confirming clear sexual dimorphism. This finding is consistent with Krishan and Sharma (2007), who also reported significant sex differences in hand and foot dimensions among a North Indian population. Similarly, Rastogi et al. (2008) ⁵ observed that hand and foot measurements differed significantly between males and females and could be used for stature estimation in Indian populations.

In the present study, right foot length showed the strongest correlation with stature ($r = 0.84$ overall), followed by right hand length ($r = 0.78$). This is in agreement with Kanchan et al. (2008), ² who reported that foot length was strongly correlated with stature and was a reliable parameter for stature estimation. Ahemad and Purkait (2011), ¹³ in a study of 503 Central Indian males, also found a strong positive correlation between hand dimensions and stature, with hand length being the most useful hand parameter. The present finding that foot length is a better predictor than foot breadth is supported by Zeybek et al. (2008) ⁷ who reported higher correlation and predictive accuracy for foot length than foot breadth.

Simple regression analysis showed that right foot length explained 51.8% of variation in stature in males and 56.3% in females, while right hand length explained 41.0% and 46.2%, respectively. These results are comparable with Sanli et al. (2005) ³, who developed regression equations for stature estimation from hand and foot length and reported that both parameters were significant predictors of stature. In the present study, the multiple regression model including hand length, foot length, middle finger length, and foot breadth explained 82.4% of the variation in stature, with the lowest standard error of estimate (3.51 cm). This supports the observation of Rastogi et al. (2008) ⁵ that combined anthropometric measurements provide more accurate stature estimation than individual measurements.

The slightly higher right-sided measurements observed in the present study are consistent with the findings of Krishan and Sharma (2007) ^{1,4} who reported minor bilateral asymmetry in hand and foot dimensions. However, as the differences were small, either side may be used for stature estimation with appropriate population-specific equations. Overall, the findings of the present study are consistent with previous Indian and international studies and suggest that hand and foot anthropometry, particularly foot length and hand length, can be reliably used for stature estimation in the Central Indian population.

Conclusion

The present study demonstrated a significant positive correlation between stature and hand and foot anthropometric measurements in the Central Indian population. Foot length was the strongest individual predictor of stature, followed by hand length. Multiple regression models using combined hand and foot measurements provided the most accurate stature estimation. The derived sex-specific regression equations may be applied in forensic and anthropological contexts for estimating stature when direct measurement is not possible.

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