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An Observational Study On Height Estimation From Foot Dimensions Among the Santali Tribal Women Of Murshidabad District, West Bengal, India

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Abstract: Estimation of stature from different body dimension is important in medico-legal cases for personal identification. Present study aims to estimate stature from foot dimensions (both length and breadth) among the adult tribal women of Murshidabad district. This study was sex- and community-specific cross-sectional study, comprises a total of 381women (age range 18-70 years). Three anthropometric measurements such as height, foot length and foot breadth were taken from the participants. Mean height was found to be 149.38±5.21 cm. Mean values of right foot length and breadth were higher in comparison to left foot length and breadth. A significant positive and moderate correlation was found between height and foot length ($r>0.5$) but the correlation between height and foot breadth was weak but positive ($r>0.2$). This study will be helpful to the anthropologists, anatomists and medico-legal experts in understanding of relative status of the studied population in context of anthropometric variants.

Keywords: Height, Foot length, Foot breadth, Correlation, Santali women

Introduction

Human height or stature is a linear measure, including skull, vertebral column, pelvis and lower extremities; hence there is significant association found between total height and different body dimensions specially for linear fragments (Uhrová et al., 2015). Anthropometry is widely accepted for identification of an individual in medical and forensic sciences for crime investigation (Narde & Dongre, 2013) from different body parts found.

Personal identification may be complete or incomplete: incomplete identification means the ascertainment of only some facts while the other remains unknown (Agarwal et al., 2018). Anthropologists, anatomists and forensic experts have great interests in reconstructing height of living individuals from various skeletal remains (Narde & Dongre, 2013). There are two process of identification: Mathematical and anatomical; mathematical models involves formation of regression formulae, which is now widely accepted by forensic scientists, anatomists or anthropologists as some parts of body could easily be used to predict anthropometry of another part (Oghenemavwe & Egwede, 2022). During adolescence, the ossification and maturation of the foot occurs earlier in comparison to other long bones, so there is more possibility of accuracy in height estimation from foot dimensions (Singh et al., 2013). It has been found that foot measurement provides important predictive information about height of an individual and reliability was also found very high than any other long bones (Malik et al., 2015).

Various studies have been conducted on height estimation and correlation between these two anthropometric measures from foot length on various populations by so many researchers (Singh et al., 2013; Narde & Dongre, 2013; Malik et al., 2015; Uhrová et al., 2015; Phang et al., 2017; Agarwal et al., 2018; Asadujjaman et al., 2020; Shetty et al,. 2020; Sharma et al., 2021; Hsieh et al., 2022; Oghenemavwe & Egwede, 2022; Rafiyan et al., 2023; Sagar et al., 2024; Seal et al., 2025). Some mentionable studies from West Bengal are conducted by Sen and Ghosh (2008); Moitra et al. (2017) and Rang et al. (2023). As per our search method, there was no data related to estimation of stature in any tribal community from the studied area. Hence, the objective of the present paper was to determine the relationship between height and foot length and breadth by calculating correlation coefficients and to establish a regression model for height among the Santali (tribal) women.

Material and Methods

Area and Population

Present community-specific cross-sectional study was conducted among the adult Santali women of five villages of Murshidabad district (viz. Kusumkhola, Churamanidanga, Benipur, Chatradanga and Azimganj) of West Bengal. Total number of participants was 381 and belonged to the age group of 18-70 years. The sampling method was stratified random sampling and the data were collected during the month of March, 2025. Subjects with any abnormality in foot were excluded from this study. Verbal consent was taken from each participant before data collection.

Anthropometric measurements

Three measurements were taken such as height (HT), foot length (both right and left) (RFL and LFL) and foot breadth (both right and left) (RFB and LFB) by the first author. HT (in cm) was measured by anthropometric rod following the standard procedure as recommended by Weiner and Lourie (1981). Foot length (FL) and foot breadth (FB) (in cm) were measured using sliding caliper. FL is represented by the distance from the most prominent part of the heel to the most distal part of longest toe and FB is represented by the distance between the most prominent point of head of first metatarsal to the head of the fifth metatarsal.

Statistical analysis

The data was analyzed using SPSS (v.26). Mean (±SD) of all the anthropometric variables were calculated. Pearson correlation was done to check the correlation (r) between HT and foot dimensions. Regression analysis was performed to estimate the regression equation. A p value <0.05 was considered as statistically significant.

Results

The mean age of the participants was 39.61±14.37 years. Among the participants, height varied from 133.4 cm to 164.0 cm with mean 149.38±5.21 cm and the standard error was 0.267. The range for LFL varied from 15.2 to 25.1 cm with a mean of 22.37±1.28 cm. Again the RFL varied from 15.5 to 29.9 cm with a mean of 22.40±1.33 cm. Variation in foot breadth is also depicted in Table 1. The correlation (r) between height with LFL and RFL were 0.504 and 0.508 (at $p<0.01$) respectively whereas, the correlation with LFB and RFB were 0.305 and 0.283 (at $p<0.01$) respectively. The mean difference between right and left foot length (FL_{R-L}) was 0.02±0.48 cm and right and left foot breadth (FB_{R-L}) was 0.05±0.37 cm.

Table1: Descriptive statistics of Height and Foot dimensions of the studied participants

Variables	Range (cm)		Mean±SD	S.E	Correlation (r) with HT
	Minimum	Maximum			
HT (cm)	133.4	164.0	149.38±5.21	0.267	
LFL (cm)	15.2	25.1	22.37±1.28	0.065	0.504**
LFB (cm)	7.1	10.7	8.86±0.59	0.037	0.305**
RFL (cm)	15.5	29.9	22.40±1.33	0.085	0.508**
RFB (cm)	7.1	11.2	8.91±0.61	0.031	0.283**

**p<0.01

Table 2 illustrates the simple and multiple regression equations to estimate height from foot dimensions. Figure 1 (a and b) and 2 (a and b) are showing the linear relationship between height and foot dimensions (length and breadth) among the studied participants.

Table 2: Regression equation using regression coefficients from foot dimensions

Variables	Regression equation	Estimated stature (cm) using regression equation
Simple Regression		
LFL (cm)	103.52+2.050*LFL	149.39±2.62
LFB (cm)	125.71+2.671*LFB	149.39±1.59
RFL (cm)	104.95+1.983*RFL	149.37±2.65
RFB (cm)	128.00+2.398*RFB	149.39±1.47
Multiple Regression		
LF (L+B) (cm)	103.90+2.098*LFL-0.164*LFB	149.39±2.63
RF (L+B) (cm)	104.36+1.942*RFL+0.170*RFB	149.44±2.65

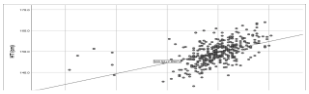

Figure1a: Scatter plot showing the linear relationship between height and left foot length among the studied women

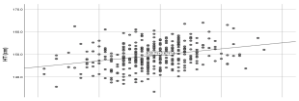

Figure1b: Scatter plot showing the linear relationship between height and left foot breadth among the studied women

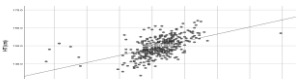

Figure2a: Scatter plot showing the linear relationship between height and right foot length among the studied women

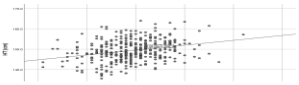

Figure2b: Scatter plot showing the linear relationship between height and right foot breadth among the studied women

Discussion

Height estimation is an important parameter in forensic investigation as it helps in establishment in personal identity of a deceased person (Krishan et al., 2011). Present study was conducted among adult Santali women with age range 18 to 70 years to predict the height from their foot dimensions (length and breadth of both sides). This kind of prediction is important for the conditions where the whole body parts are not available for personal identification.

The mean Height of the studied participants was 149.38 (±5.21) cm. According to the data represented in Table 3, present population was shorter than various studies reported by various Indian (Narde & Dongre, 2013; Moitra et al., 2017; Agarwal et al., 2018; Shetty et al., 2020; Sharma et al., 2021) and International authors (Malik et al., 2015; Phang et al., 2017; Oghenemavwe & Egwede, 2022). The mean of the LFL and RFL were 22.40±1.33 cm

and 22.37±1.28 cm respectively. The difference was (FL_{R-L}) very less and was not statistically significant. Likewise, the mean of the right and left FB were 8.91±0.61 and 8.86±0.59 cm respectively and their difference (FB_{R-L}) was not significant statistically. The measurements (both length and breadth) found to be higher for right side in our study population. Previous studies represent higher mean FL in comparison to ours (Narde & Dongre, 2013; Malik et al., 2015; Phang et al., 2017; Agarwal et al., 2018; Sharma et al., 2021; Oghenemaywe & Egwede, 2022). The mean FB was higher in case of other studies as shown in Table 3 (except the Nigerian females). The differences in stature and foot dimensions may be due to geographical, morphological, racial or ethnic variations and nutritional aspects (Narde & Dongre, 2013).

The correlation between height and FL/FB found to be positive in present study. The FL showed a moderate correlation (r>0.5) while, the FB showed weak correlation (r>0.2) among the present studied women. The correlation coefficient was higher in case of right FL and FB in comparison to the left side. The correlation was found to be lower than the previous studies except studies reported by Moitra et al. (2017) and Agarwal et al. (2018) (in case of left foot). Again, with comparison to foot breadth, the correlation was higher among the females of Nagpur (Narde & Dongre, 2013) than the present study. However, both foot length and foot breadth shows highly reliable estimated value for stature in case of simple regression method, but in case of multiple regressions method, foot length shows closer value than foot breadth.

Conclusion

Due to diversity, Indian population shows different correlation between height and foot dimensions. Hence separate studies are required for different population in respect of geographical location or race or caste. This study will help the forensic anthropologists, anatomists or medico-legal experts to determine stature among the studied community from the area considered for present study.

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Conflict of Interest: None to be declared.

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Table 3: Comparative Table of stature estimation from foot dimensions for present study with different International and Indian studies

	Studies	Age (years)	Sample (N)	Mean HT (cm)	Mean FL (cm)		Mean FB (cm)		Correlation (r)				Regression equation
					LFL	RFL	LFB	RFB	LFL	RFL	LFB	RFB	
International	Malik et al., 2015 Pakistan	>20	146	159.02±5.00	24.1±1.06	-	-	-	0.63	-	-	-	HT= 88.210+2.93*LFL
International	Phang et al., 2017 Malaysia	20-30	75	157.80±5.63	23.20±9.42		9.10±0.49		0.697		0.265		H= 60.99+4.167*FL
International	Oghenemavwe & Egwede, 2022 Nigeria	18-50	81	164.86±7.61	24.23±1.80		7.61±0.72		0.54		0.23		H= 109.3+2.29*(FL) H= 146.7+2.38*(FB)
Indian	Narde & Dongre,2013 Medical Students, Nagpur	18-23	297	156.28±6.15	24.32±1.43	24.25±1.43	9.39±0.53	9.33±0.53	0.984	0.986	0.977	0.985	H= 53.3+4.23*LFL; H= 53.0+4.26*RFL H= 51.5+11.1*LFB; H= 51.3+11.2*RFB
Indian	Moitra et al., 2017 West Bengal	18-35	200	157.44±5.55	-	-	-	-	0.283		-	-	H= 135+0.920*FL
Indian	Agarwal et al., 2018 Medical Students, UP	18-23	80	159.93±6.97	24.38±1.33	24.34±1.18	9.62±0.55	9.88±0.64	0.394	0.698	0.298	0.252	H= 72.37+3.59*LFL; H= 62.35+4.01*RFL H= 94+6.86*LFB; H= 108+5.26*RFB H= 64.54+2.03*LFL+1.88*RFL H= 89.31+5.08*LFB+2.20*RFB

	Shetty et al., 2020 Medical Students, South India	17-30	149	152.5±4.9	-	-	-	-	-	-	-	-	H= 152.83-0.02*LFL; H= 158.14-0.23*RFL H= 148.02+0.50*LFB; H=152.12+0.04*RFB H= 148.63+0.51*LFB-0.03*LFL H= 183.60-0.05*RFL-1.54*RFB
	Sharma et al., 2021 Rajasthan	20-60	52	155.68±6.32	22.54±1.09	22.04±1.21	-	-	0.65	0.69	-	-	-
	Present study Murshidabad, West Bengal	18-70	381	149.38±5.21	22.37 ±1.28	22.40±1.33	8.86 ±0.59	8.91 ±0.61	0.504	0.508	0.305	0.283	H=103.52+2.05*LFL; H=104.95+1.98*RFL H=125.71+2.67*LFB; H=128.00+2.39*RFB H= 103.90+2.09*LFL-0.16*LFB H= 104.36+1.94*RFL+0.17*RFB