Original Article

Stature Estimation using Foot Parameters of Andhra Pradesh Tribal Children

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Abstract

Introduction: Stature estimation has an important role in forensic medicine, anthropology, and shoe wear industry. Personal identification using individual body parts forms the basis for this study. Koya and Konda Reddy tribal children are considered for this study because of their endogamous origin. The primitive nature of their origin is well preserved due to the lack of exposure to the developing world. They can be true representatives of people of that region. Height estimation using foot parameters is an essential parameter for personal identification. **Material and Methods:** A study on foot parameters was conducted on 360 Koya and Konda Reddy tribal children of Andhra Pradesh. Standing height was measured from vertex to the heel with the head held in Frankfurt's plane. Foot length (FL) and breadth were measured using an osteometric board. Foot index was calculated. **Results:** Mean height was noted as 129 cm in male and 124 cm in female children. Paired differences of FL and foot breadth between the right and left sides were not significant. Average values of foot parameters were considered for further analysis. Gender differences in foot parameters were significant. Correlation was noted high between foot parameters and stature. Therefore, regression equations were derived using FL and foot breadth for both genders separately. **Discussion and Conclusion:** Out of FL, foot breadth, and foot index, high correlation was noted between stature and FL. Hence, it is one of the best parameters in personal identification when only a part of the body such as foot is found.

Keywords: *Anthropometry, foot length, foot width, Konda Reddy, Koya, stature*

Introduction

Anthropometric study conducted for specific region or population group is useful in forensic investigations. Height is one of such anthropometric parameters which is gender specific, age specific, and racial specific. In countries like India where natural calamities are common, there is necessity for the identification of individual with the help of available minimal body parts. Previous studies established correlation between foot measurements and stature. The current study is conducted on children belonging to Koya and Konda Reddy tribes. These two tribes belong to Australoid ethnic group, residing mostly in the Eastern Ghats of Andhra Pradesh, India. There is no literature available reporting the correlation of foot measurements with stature in this study population. The study participants live in tribal habitat with preferable barefoot walking habit.

Material and Methods

A total of 360 tribal children comprising 180 males and 180 females of Andhra Pradesh state were included in this study. Children of 3–15 years' age group were considered. Standing height of participants was measured using flexible metallic tape. Participants were made to stand with the feet together and the heels, buttocks, and upper part of the back touching the tape. The head was placed in the Frankfurt plane. Then, a ruler was firmly drawn down on the vertex, crushing the hair as much as possible. Care was taken to watch that the feet did not come off the floor and that the position of the head was maintained in the Frankfurt plane [Figure 1].[1-3]

Foot length (FL) and foot width (FW) were measured using the osteometric board [Figure 1]. Readings of both feet were taken with the participant in standing position. FL was measured as the distance from acropodion (it is the most forwardly projecting point on the tip of the first or second toe whichever is longer, when the participant stands erect) to pternion (it is the most backwardly projecting point on

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the heel, when the participant stands upright with equal pressure on both feet). Foot-breadth was the distance between the medial metatarsal point (the most prominent part of the head of the first metatarsal bone) and the lateral metatarsal point (the most prominent point of the head of the fifth metatarsal bone).[4] Using FL and breadth, foot index was calculated.

Foot index = (FW × 100)/FL

Data were analyzed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, New York: USA) for all analyses. Stature was derived from foot parameters using simple and multiple linear regression equations. Simple linear regression equations were derived using individual parameters of FL, width, and index. Multiple linear regression equations were derived using a combination of all three parameters.

Results

Paired *t*-test revealed no significant bilateral differences in FL and FW parameters for both genders. Hence, linear regression equations to estimate height were derived using average FL and FW [Table 1].

Figure 1: Somatometric measurements

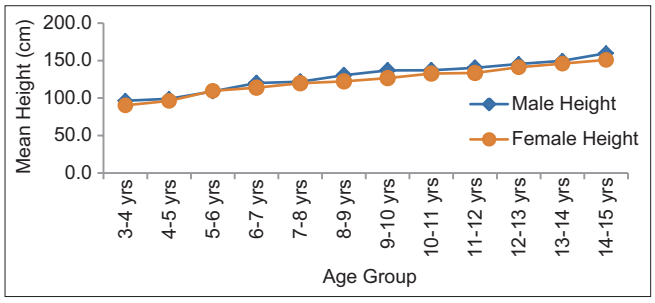

Figure 3: Line graph showing mean foot length for different age groups of both genders

Independent *t*-test revealed significant gender differences in average FL and FW at $P < 0.05$. Hence, linear regression equations to estimate stature were generated separately for both males and females [Table 2].

The overall mean height was 128.8 cm and 123.6 cm for male and female children, respectively. Mean height varied from 96.3 cm to 159.9 cm in males and 90.3 cm to 151 cm in females from 3: <4 years to 14: <15 years [Table 3 and Figure 2].

Overall mean FL was 20 cm and 19.3 cm for male and female children, respectively. Mean FL varied from 15.7 cm to 24.2 cm in males and 14.8 cm to 22.2 cm in females from 3: <4 years to 14: <15 years [Table 3 and Figure 3].

Range of FL was 14.4 cm to 27.2 cm in males and 13.5 cm to 23.8 cm in females.

Overall mean FL was 8.1 cm and 7.6 cm for male and female children, respectively. Mean FW varied from 6.5 cm to 9.5 cm in males and 6 cm to 8.4 cm in females from 3: <4 years to 14: <15 years [Table 3 and Figure 4].

FW in case of males ranged from 6 cm to 10.3 cm, whereas in females from 5.3 cm to 9.5 cm.

R value shows high positive correlation between FL and height measurements [Table 4].

R value showed high positive correlation between FW and height measurements [Table 5].

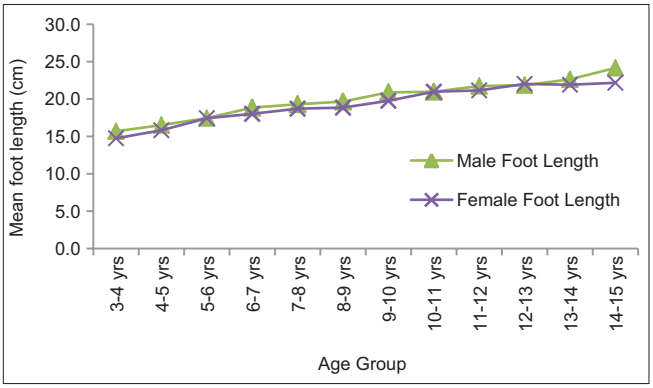

Figure 2: Line graph showing mean height for different age groups of both genders

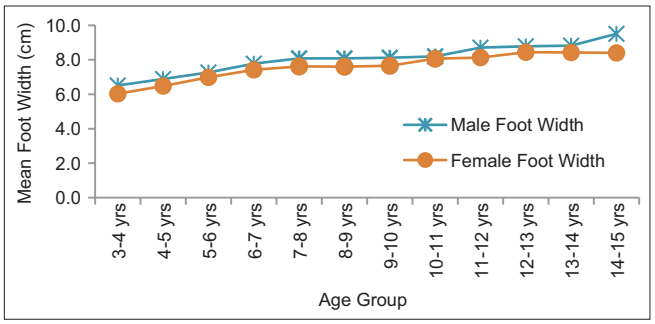

Figure 4: Line graph showing mean foot width for different age groups of both genders

Table 1: Descriptive statistics for foot length and foot width, paired *t*-test value and its significance

Gender	Parameters	Mean	SD	Paired *t*-test	
				t	Significance (two-tailed)
Male	FLR	19.98	2.7	−0.904	0.367
	FLL	19.98	2.7		
	FWR	8.06	0.95	−0.517	0.606
	FWL	8.06	0.95		
Female	FLR	19.28	2.5	−1.119	0.265
	FLL	19.28	2.5		
	FWR	7.61	0.85	−1.613	0.108
	FWL	7.62	0.85		

FLR: Foot length right, FLL: Foot length left, FWR: Foot width right, FWL: Foot width left, SD: Standard deviation

Table 2: Descriptive statistics and independent *t*-test for average foot length and foot width for both genders

Parameters	Mean	SD	Independent *t*-test	
			t-value	Significance (two-tailed)
FL				
Male average	19.98	2.69	2.567	0.011
Female average	19.27	2.5		
FW				
Male average	8.06	0.95	4.674	0.000
Female average	7.61	0.85		

SD: Standard deviation, FL: Foot length, FW: Foot width

R value indicated high positive correlation between FL and FW and height [Table 6].

R value indicated weak positive correlation between foot index and height [Table 7].

Discussion

Sociocultural characteristics bring about difference in foot size. Mongoloids including Japanese have wider feet compared to the Caucasoid and Australoid population.[5] It shows the importance of region-specific data.[6] Previously length of long bones was used as a criterion for stature estimation.[4] Plethora of study was conducted on stature estimation using hand and foot measurements. This study focused on stature estimation using foot parameters. Foot parameters play a crucial role in footwear design as well as in personal identification.

In this study, FL and FW measurements revealed no significant bilateral differences. Bari *et al*., in 2010, conducted a study on 5–6 years' age group Malaysian children where bilateral differences in FL and width were not significant.[7] Jakhar *et al*.[8] had reported similar findings in both genders of the Haryanavi population. Chavan *et al*., in 2012, observed significant bilateral differences for different foot parameters in 6–8-year and 12–14-year age children of Maharashtra.[9] No significant differences among the right and left FL and width were noticed by Singh *et al*. in female participants of 18–23 years' age group.[10] A study conducted to estimate stature in male children of Gulbarga, Karnataka, by Karaddi *et al*. in 2013, inferred no significant differences in bilateral FLs.[11] Pandey *et al*. did not find any significant differences in FL of both sides.[12] Another study by Parekh *et al*.,[13] conducted, in 2014, on 200 participants of 17–21 years' age group Gujarat population, showed no significant difference in bilateral FLs. Ewunonu *et al*.[14] measured foot dimensions using sliding caliper and a meter ruler in 18–30-year age Igbo people of Nigeria. They observed longer and broader right foot in comparison to left in case of both male and female participants. This difference was found significant only in females. Reason for this was attributed to genetic factors and cerebral dominance on lateral preference for the right foot. Banik *et al*., in 2015, studied asymmetry of hand and foot parameters in 18–22-year girl students of Bilaspur, Chhattisgarh, India. Except for handbreadth, their study showed no significant difference in hand length, FL, and foot breadth of the right and left sides.[15] They explained bilateral developmental stability as the cause for insignificant differences in foot parameters. The minor bilateral differences noted were due to stochastic variations in the developmental process.

Significant gender differences in FL and FW measurements were noted as mentioned previously.[16] Hence, regression equations were derived separately for male and female children. Reliability of stature estimation using regression analysis was established earlier.[17,18]

Stature derived from FL had a higher correlation than that of FW [Tables 4 and 5]. This study noted a highly significant correlation coefficient between height and FL as $R = +0.935$ in male and $R = +0.959$ in female. Karaddi *et al*. noticed +0.82 correlation coefficient between FL and stature in male students of Karnataka.[11] Mansur *et al*.[6] observed correlation of height with FL among students of Kathmandu university school of sciences as +0.688 in male and +0.587 in female children. Mohanty *et al*. found that the correlation coefficient between height and FL was +0.65 in male and +0.80 in female population of Odisha.[19] Qamra *et al*.[20] noted a correlation coefficient for foot breadth and stature as +0.42 in male and +0.70 in female children,

Table 3: Mean height, average foot length, average foot width, and average foot index values of both genders

Age group (years)	Height (cm)		FL (cm)		FW (cm)		FI	
	Male	Female	Male	Female	Male	Female	Male	Female
3: <4	96.3	90.3	15.7	14.8	6.5	6.0	41.6	40.8
4: <5	99.0	96.2	16.5	15.8	6.9	6.5	41.7	41.0
5: <6	108.9	109.7	17.5	17.4	7.3	7.0	41.7	40.1
6: <7	120.1	113.9	18.9	18.0	7.8	7.4	41.3	41.2
7: <8	121.8	119.8	19.3	18.7	8.1	7.6	41.9	40.8
8: <9	130.5	122.3	19.7	18.9	8.1	7.6	41.1	40.4
9: <10	137.0	126.6	20.9	19.8	8.1	7.7	38.9	38.7
10: <11	137.2	132.8	21.0	21.0	8.2	8.1	39.1	38.5
11: <12	140.4	133.5	21.8	21.2	8.7	8.1	40.1	38.4
12: <13	145.5	141.2	21.8	22.0	8.8	8.4	40.3	38.3
13: <14	149.7	146.0	22.6	21.9	8.8	8.4	38.9	38.5
14: <15	159.9	151.0	24.2	22.2	9.5	8.4	39.4	37.9
Total	128.8	123.6	20.0	19.3	8.1	7.6	40.5	39.6

FL: Foot length, FW: Foot width, FI: Foot index

Table 4: Simple linear regression equations to derive stature from foot length

Gender	Regression equation	*R*	Adjusted R^2
Male	Height (cm) = 7.004 (FL) − 11.0771	0.935	0.874
Female	Height (cm) = 7.231 (FL) − 15.788	0.959	0.920

FL: Foot length

Table 5: Simple linear regression equations to derive stature from foot width

Gender	Regression equation	*R*	Adjusted R^2
Male	Height (cm) = 18.55 (FW) − 20.699	0.876	0.766
Female	Height (cm) = 19.942 (FW) − 28.29	0.903	0.815

FW: Foot width

Table 6: Multiple linear regression equations to derive stature from foot length and width

Gender	Regression equation	*R*	Adjusted R^2
Male	Height (cm) = 6.743 (FL) − 12.239	0.935	0.873
Female	Height (cm) =6.373 (FL) + 2.724 (FW) − 20.007	0.961	0.922

FL: Foot length

Table 7: Simple linear regression equations to derive stature from foot index

Gender	Regression equation	*R*	Adjusted R^2
Male	Height (cm) = 315.6−4.6 (FI)	0.465	0.211
Female	Height (cm) = 296.4−4.4 (FI)	0.468	0.215

FI: Foot index

whereas correlation coefficient for FL and stature was noted as +0.69 in male and +0.70 in female children. Rani *et al*.[21] and Sen *et al*.[22] had a similar opinion that FL was a better predictor for height. Patel *et al*.[4] noticed foot breadth as a better predictor for stature than the length of long bones. FL derived from footprints and foot outlines was also used for stature estimation.[23,24] All these studies involved adults as their study participants. The current study involved only children of 3–15 years age.

Multiple regression equations derived using both FL and FW also had higher correlation than those of simple regression equations derived separately from FL [Tables 4-6]. Khanapurkar and Radke were also of the opinion that multiple regression equations could better predict stature than individual factors.[25]

Foot index was also used to estimate stature. Correlation was weak between foot index and stature [Table 7]. Among FL, width, and index, prediction of stature using FL was found more accurate and reliable.

Conclusion

This study evolved regression equations specific for Koya and Konda Reddy tribal children of Andhra Pradesh. FL was considered as best suitable predictor for stature estimation. FL and FW are well correlated with the height of an individual, suggesting that any one of these factors available can determine the other. This region-specific data would be of great help for forensic experts, anthropologists, and shoe manufacturing industry.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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