

Determination of Gender from the Foot Measurements of Telanganite Adults: A Cross Sectional Study

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Abstract

Background: Dimensions of foot provide valuable information in determining the sex and stature of the individual based on various statistical formulae and equations. There were many physical anthropometric studies show the gender difference.

Objectives: 1. To determine the correlation of various measurements of the feet with gender. 2. To derive logistic regression equations for gender determination from foot dimensions among Telanganite adults.

Material and Methods: The present study was conducted in Prathima Institute of Medical Sciences, Karimnagar, Telangana State, India, amongst 436 students from Telangana state, aged between 18-22 years. After obtaining Institutional Ethics Committee clearance and informed consent from the participants, foot length, foot breadth and Bi-malleolar breadth were recorded and foot index was also calculated. The data was then subjected for statistical analysis using SPSS version 21.

Results: The mean values of Foot length, Foot breadth, and Bi-malleolar breadth were found to be significantly higher in males than females. The average foot index in males and females were 43.465 and 41.595 respectively. Prediction of gender with logistic regression equations using multiple parameters was found to be better than that with individual parameters.

Conclusion: The higher values of foot dimensions in males as compared to females proves the sexual dimorphism of foot dimensions.

Key words: Bi-malleolar breadth, Foot breadth, Foot dimensions, Foot length, Foot index.

Introduction

The determination of gender is an initial and essential component of any medicolegal investigations

and in forensic anthropology casework, and requires foremost consideration in the examination of skeletal remains. Forensic anthropologists frequently

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employ morphologic and metric methods for sex determination of human remains [1,2].

The human foot is a basic unit of bipedal locomotion and it is formed by a complex multi bone structure involving different 26 bones and numerous articulations [3]. Dimensions of foot provide valuable information in determining the sex and stature of the individual based on various statistical formulae and equations [4]. Many physical anthropometric studies show the gender difference [5,6,7].

The identification of human remains from the different anthropometric parameters is the main domain of forensic anthropometry and forensic podiatry. The recognition of a deceased individual is the mainstay of forensic analysis. So, the forensic anthropologists construct an osteo-biography consisting of a set of biological attributes like sex, stature, and age [8].

The average male is ten centimeters taller than the average female and this difference will also be translated in an overall trend that males will have greater foot length as compared to females [9]. The size, shape and morphology of human feet and foot-prints is greatly influenced by combined effects of heredity and living style and environmental factors, there by making those unique data to establish human identity [10].

For designing of various foot devices also the quantitative analysis of foot anthropometry is very important [11]. Different studies on foot dimensions have found significant clinical application of such studies. Rodier et al observed that children with autism had smaller feet compared with the control group [12]. Schultz et al reported that many girls with Rett Syndrome had small feet for their height [13].

The likelihood of retaining the foot mainly by the shoes in terrorist attacks, wars, mass disasters, high-impact transportation accidents and explosions, the detailed anthropometric analysis of the human foot has been emphasized in forensic identification [14]. In view of very few studies, the present study was an attempt to determine the correlation of various measurements of the feet with sex and to formulate the logistic regression equations to predict sex of a person by using dimensions of feet. It is expected to be useful for legal experts, forensic science researchers

and different investigators in the person's gender determination.

Materials and Methods

The present study was conducted from August 2023 to November 2023 in Prathima Institute of Medical Sciences, Karimnagar, Telangana State, India, amongst 436 students from Telangana state, aged between 18-22 years. After obtaining Institutional Ethics Committee clearance, the informed consent was obtained from all the subjects willing to take part in the study. A structured, predesigned, pretested questionnaire was used to get the basic socio-demographic information like age, sex, native state, etc. The study subjects with any apparent physical foot anomalies, trauma, orthopedic deformities, inflammation, history of foot surgery in the past, metabolic or developmental disorders were not included. The participants were made to stand erect in anatomical position bare-footed on a horizontal flat surface to measure the foot dimensions.

The study included only the students above 18 years of age as most people attain their maximum growth and maximum foot length and breadth above this age. The following foot measurements were undertaken [8].

Foot Length (FL): It was measured as a direct distance from the most posterior point of the back of the heel (pternion) to the most distal part of longest toe (acropodian). Along the medial border of the foot, caliper was horizontally placed. The mobile part of the outer jaw was approximated to the acropodian and the fixed part of the outer jaw of the caliper was placed at pternion and then the measurements were taken on both sides.

Foot Breadth (FB): It was measured as a distance between metatarsal tibiale (medial margins of the head of the first metatarsal) and metatarsal fibulare, (the lateral margin of the head of the fifth metatarsal using the sliding caliper.

Bi-malleolar breadth: It was obtained as distance between the most medial projection of medial malleolus and the most lateral projection of lateral malleolus using sliding caliper [15]. All the measurements were recorded in centimeters to the nearest 1 mm. The measurements were taken by a

single observer for avoiding the inter-observer bias and at a fixed time to eliminate any diurnal variations.

(SPSS) version 21.

Foot index [4,8]: It was calculated by the formula-

$$\text{Foot Index} = (\text{Foot breadth}/\text{Foot length}) \times 100.$$

The collected data was compiled, tabulated and analyzed by Statistical Package for Social Sciences

Results

The present study included 235 (53.90% girls and 201 (46.10%) boys. The results of foot dimensions of left and right sides in both sexes of 436 students in the present study were recorded.

Table 1: Gender and side wise descriptive statistics of foot dimensions

Foot Dimensions	Gender	Mean ± SD	Minimum	Maximum	P value b/w sides	Average	P value b/w Gender
Foot Length (cm)	Male						< 0.001
	-Lt	21.86±3.66	16.9	28.5	0.29	21.865	
	-Rt	21.87±3.68	16.7	28.6			
	Female						
	-Lt	20.51±2.56	16.8	26.2	0.51	20.515	
	-Rt	20.52±2.59	16.9	26.4			
Foot Breadth (cm)	Male						< 0.001
	-Lt	9.51±0.72	6.9	11.3	0.49	9.44	
	-Rt	9.49±0.73	6.7	11.5			
	Female						
	-Lt	8.52±0.69	6.5	10.7	0.47	8.53	
	-Rt	8.54±0.70	6.4	10.9			
Bi-malleolar Breadth (cm)	Male						< 0.001
	-Lt	7.28±0.68	4.8	9.7	0.42	7.285	
	-Rt	7.29±0.71	4.6	9.6			
	Female						
	-Lt	6.41±0.74	4.7	9.5	0.49	6.415	
	-Rt	6.42±0.75	4.8	9.7			

Table 1 shows the descriptive statistics of foot dimensions in both sides among both sexes. The mean values of Foot length, Foot breadth, and Bi-malleolar breadth in males were found to be 21.865 cm, 9.44 cm, and 7.285 cm respectively, which were significantly higher than that in females (p value < 0.05). However, there was no statistically significant difference in left and right sides in all these parameters in both the genders.

Table 2: Foot index in both genders for mean foot dimensions.

Gender	Male		Female	
	Lt side	Rt Side	Lt side	Rt Side
Foot Length (cm)	21.86	21.87	20.51	20.52
Foot Breadth (cm)	9.51	9.49	8.52	8.54
Foot Index	43.50	43.40	41.54	41.62

Table 3. Descriptive statistics for the Foot index in both genders

	Male		Female	
	Lt	Rt	Lt	Rt
Mean	43.51	43.42	41.55	41.64
Standard Error	0.54	0.56	0.76	0.78
Standard Deviation	7.13	7.16	9.12	9.19
Minimum	40.83	40.12	38.69	37.87
Maximum	62.61	62.64	57.59	57.64
Average Foot Index	43.465		41.595	
P value	<0.001			

The mean Foot index in males was found to be 43.465 and in females it was 41.595 as seen in Table 2 and Table 3. This observed difference was statistically significant (p value < 0.001). The minimum and

maximum average foot index in males was observed to be 40.48 and 62.63 respectively with standard deviation of ± 7.15 while in females it was 38.28 and 57.63 respectively with standard deviation of ± 9.16 .

Table 4: Logistic regression equations for gender determination from different foot dimensions.

S.No	Logistic regression equation	Percentage of average Prediction of Gender	R ²
1	$G = -18.089 + 2.0052(\text{FB})$	75.71%	0.44
2	$G = -2.36 + 0.108(\text{FL})$	63.30%	0.039
3	$G = -10.197 + 1.502(\text{BB})$	73.59%	0.288
4	$G = -16.015 + 1.76(\text{BB}) + 0.2031(\text{FL})$	77.96%	0.359
5	$G = -25.71 + 0.234(\text{FL}) + 2.36(\text{FB})$	79.39%	0.478
6	$G = -18.67 + 1.530(\text{FB}) + 0.726(\text{BB})$	77.11%	0.428
7	$G = -27.08 + 0.06(\text{FL}) + 1.77(\text{FB}) + 0.91(\text{BB})$	81.86%	0.509

FB – Foot breadth, FL - Foot length, BB – Bi-malleolar breadth, G- Gender.

R² – Percentage of variation in dependent variable (Gender). Cut off for all equations is 0.5 and the scores < 0.5 indicate male, while score > 0.5 indicate female.

As seen in Table 4, the logistic regression equations were derived to determine the gender of a person by using different parameters of foot dimensions. The accuracy in prediction of gender with multiple foot parameters was better than with regression equations of individual parameters. Foot length showed least correlation with gender at R² value of 0.039. The correlation of foot breadth with sex was best with R² of 0.44.

Discussion

Determination of gender from foot dimensions has a major role in personal identification. The normal human foot shows great individual variation in

breadth and length in males and females [16]. The human foot is the foundation for bi-pedal locomotion. It is a complex adaptation that evolved through extensive remodeling of the hind appendage of the human a boreal primate fore-bears [17]. The present study showed significantly higher mean values of foot length, foot breadth, and bi-malleolar breadth in males than in females. This sexual dimorphism in foot dimensions was also observed by other similar studies [4,8,18,19,20,21].

Males in the present study had an average foot length of 1.35 cm and foot breadth of 0.91 cm more than that in females. Females had 0.87 cm less bi-malleolar breadth than in males. Longer and broader foot in males could be due to heavier bone structure of male skeleton causing weight bearing on the male foot compared to females [8,22].

There was no any significant differences in all the foot dimensions of both sides in both sexes similar

to the findings by Bindurani MK et al [8]. However, this was in contrast with the findings of a study on Nigerian adult population which observed longer and broader right sided foot than left foot [23]. A study by Walia S et al [17] among Haryanvi jat population in India found higher foot length and foot breadth on right side in males where as these parameters were higher on left side in females. Such variations could be attributed to the differences in community, heredity, living style and environmental factors [8,10].

Foot index in the present study were 43.465 in males and 41.595 in females similar to the observations by other studies [8,19,23]. However, the studies by Agnihotri AK et al [9] and Chiroma SM et al [24] reported higher foot index in females than in males. A study by Moudgil R et al [4] observed a slightly higher foot index in females on right side and in males on left side which also concluded that gender determination cannot be made conclusively from the foot index. The findings of present study was found to be comparable to the findings of a study by Sen J on Bengali Rajbanshi population [25] and the study on Nigerian population [24].

A study by Singla R on Haryanvi and North Indian population [26] and Danborn B on Nigerian population [19] reported lower foot index than the present study. The ethnical and regional variations in genetic background, physical activities, climatic factors, nutritional conditions, socio-economic status and practice of using different footwear could be the attributed reasons for such variations [8,20,27,28].

The logistic regression equations were derived by using different parameters of foot dimensions to determine the gender of a person and were checked for their accuracy and reliability in determination of gender. Foot length showed least individual correlation with gender at prediction rate of 63.30% and R^2 0.039. The foot breadth showed highest individual correlation with gender at prediction rate of 75.71% and R^2 of 0.44 similar to the findings by Bindurani MK et al [8]. The foot length was seen to be least correlated and foot breadth at heel observed to be highest correlated with gender in a study by Koutilya [29]. However, foot length had better correlation with gender than foot width in a study by Ozden et al [30]. Prediction of gender with logistic regression equations using multiple parameters were better than with regression

equations of individual parameters in the present study as observed by Bindurani MK et al [8]. The gender was correlated best when a combination of average foot breadth, average foot length and average bi-malleolar breadth were considered which was similar to the other studies [8,29].

Conclusion

The present study observed sexual dimorphism of foot dimensions like foot length, foot breadth, bi-malleolar breadth and foot index which were higher in males as compared to females. Foot length showed least correlation and foot breadth highest correlation with gender. The gender prediction with logistic regression equations using multiple foot parameters was better than with regression equations of individual parameters. The findings of the present study provide a scientific tool in determination of the gender of a person by investigators, forensic science researchers, legal and other public health experts.

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