ORIGINAL ARTICLE

Stature Estimation from Foot Anthropometry in Individuals Above 18 Years Belonging to Indian Demography

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ABSTRACT

Background: Personal identification is an integral part of the investigation in cases of mass disasters, where disintegrated and amputated body parts are found very frequently. The approach to personal identification does not follow the conventional course when it comes to body fragments. Anthropometry could be a useful tool that can be utilized in such circumstances. This research adopts foot anthropometry, foot length (FL) *per se* for personal identification by estimation of stature.

Materials and Methods: The FL and stature of 500 students of JSS University were recorded for the study. Collected data were analyzed using Statistical Package for Social Sciences computer software. Standard deviation, correlation coefficient, and linear regression formula were predicted.

Results: The FL was found to be significantly larger in males. Similarly, the descriptive statistics for stature among males and females showed a statistically significant correlation with each other and among both the gender.

Conclusion: A significant relationship exists between FL and stature.

KEY WORDS: Anthropometry, foot length, stature

Introduction

Identification of the unknown can be done by a variety of parameters. Identification becomes challenging when body fragments like lower limbs are the only source, which are the outcomes of a mass disaster of natural or manmade, amputation, severed, explosion, and natural calamity.[1] Though a person could be identified by head relatively easier and convenient than any other body part, the role of the foot cannot be denied, especially in the case where it is the only source for identification. No two persons can possess the same foot and, based on this principle this study was carried out. Sex and stature are the primary characters for identification. Hence, this study was attempted to estimate the stature from the foot anthropometry, i.e., foot length (FL).

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Materials and Methods

Source of data

The FL and stature of 500 healthy medical students (250 males and 250 females) were selected for the present study. The study was conducted in the Department of Forensic Medicine and Toxicology in a Medical College. These medical students belonged to various parts of India, and they were taken in uniform proportion. Hence, the study did not concentrate on a particular endogenous group since India is a country enclosing various such endogenous groups. There ages ranged between 18 and 25 years. The left foot was selected for measurement as per recommendation of the international agreement for paired measurements at Geneva (1912).[2]

The measurements were taken at a fixed time between 2.00 and 4.30 p.m. to eliminate diurnal variation and by the principal, as well as an additional investigator, to negate inter- and intra-observer error in methodology.

Materials

1. Rod compass: The rod compass was used for measuring FL (Figure 1).

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2. Stadiometer: It was used to measure vertical stature for stature estimation. The stadiometer is graduated in cm, mm, and inches (Figure 2).

Method of collection of data

1. FL: (Figure 3):
   It is the direct distance from the most prominent part of the heel backward to the hallux (second or first toe) (Figure 3). It can be the head of the first or second toe, whichever is larger. The measurement is taken on the sitting subject. The rod caliper is placed along the inner border of the "loaded" foot and measured.
2. Stature:
   It is the vertical distance between a highest point on the vertex and the platform of the stadiometer. The subject should stand erect, barefoot on a level platform against the stadiometer bar with his back and hips touching the bar, the feet should touch each other and the heels touching the bar, arms hanging by the side. The head of the subject should rest without any strain in the eye - ear plane or Frankfurt plane, i.e., tragion and the infraorbital margin of both the sides must lie in the same plane.

Statistical analysis

The data obtained were computed and analyzed using Statistical Package for Social Sciences, version 22.0 (SPSS) computer software (SPSS, Inc., Chicago, IL) and results drawn. Karl Pearson's correlation coefficient was derived. Multiplication factors were calculated from the mean values of FL for the reconstruction of the extremities for various measurements. The significance of results was tested using Student's *t*-test; *P* value was found to be significant.

Results

Descriptive statistics for FL in males and females are shown in Tables 1 and 2. The FL was found to be significantly larger in males. Similarly, the descriptive statistics for stature among males and females were tabulated, and they showed a statistically significant correlation with each other and among both the gender (Table 3) (Figures 4 and 5).

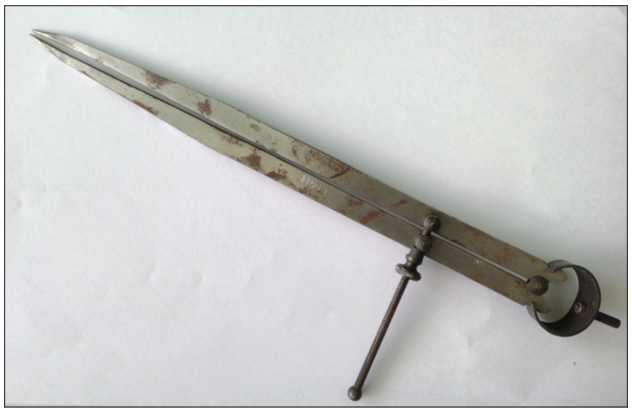

Figure 1: Rod Compass

Figure 2: Stadiometer

Table 1: Descriptive statistics: Foot length in males and females

Variables	Male (n=250)				Female (n=250)				*t*-value
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	
FL	21	29	25.81	1.50	20	27	23.52	1.15	19.15

SD: Standard deviation, FL: Foot length, n: Number of participants, $P<0.001$

Table 2: Descriptive statistics: Stature in males and females

Variable	Male (n=250)				Female (n=250)				*t*-value
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	
S	149	189	169.11	5.42	142	173	158.80	5.59	20.93

SD: Standard deviation, S: Stature, n: Number of participants, $P<0.001$

Table 3: Pearson correlation in stature and foot length in left foot

Variable	Males (n=250)		Females (n=250)		Pooled	
	S	FL	S	FL	S	FL
S	1.000	0.720	1.000	0.545	1.000	0.798
FL	0.720	1.000	0.545	1.000	0.798	1.000
P value	<0.001		<0.001		<0.001	

S: Stature, FL: Foot length, n: Number of participants

Reconstruction of stature using the regression equation:

Linear regression equation for stature estimation from FL:

Regression equation for male - Stature = 101.95+2.6 × (left foot length in cm)

$Y = a + b(x)$

Where, Y = Stature of male, a = Constant for male, b = ˇ Coefficient, x = Left foot length.

Eg:

Y = 101.95+2.6(25)

Y= 166.95 cm

Height of male = 166.95 cm.

Regression equation for female - Stature = 134.5+3.6 × (left foot length in cm)

$Y = a + b\ (x)$

Where Y = s of female, a = Constant for female, b =ˇ Coefficient, x = Left foot length.

Eg: Y = 89.63+3.6 (21)

Y = 165.23 cm.

Height of female = 165.23 cm.

Discussion

Often forensic experts have to deal with unidentified deceased or mutilated remains. Many factors need to be studied and considered in order to make a positive identification. Determination of sex and stature play a very important role in establishing identity. Thus, when sex and stature are known, half the identity is known. The present study is aimed at estimation of stature from per-cutaneous measurements of left FL and breadth by formulating linear regression equations.

In Pondicherry, 541 subjects were measured for the FL, foot breadth and correlated with stature. It was observed that the hallux (Big toe) is the longest digit in the majority. Correlation between FL and foot breadth from the pooled values was high

Figure 3: Measurement of Foot Length (FL)

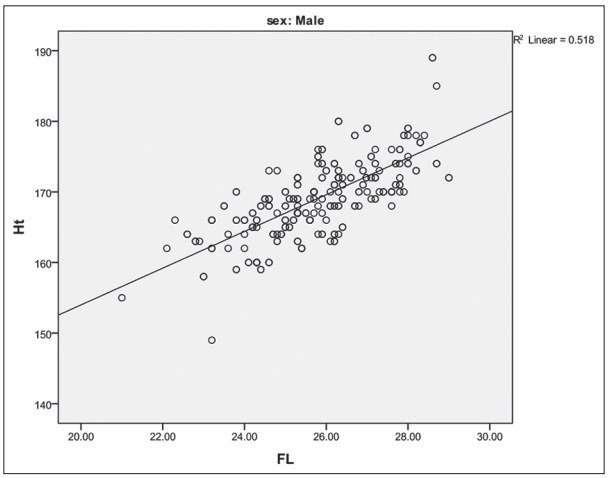

Figure 4: Scatter diagram showing relation of stature with foot length in males

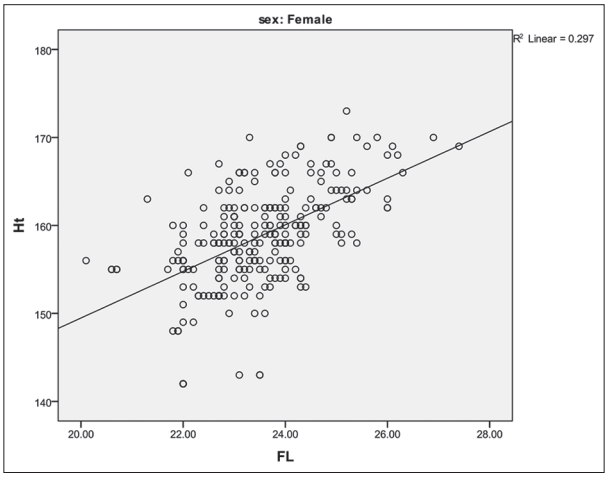

Figure 5: Scatter diagram showing relation of stature with foot length in females

and statistically significant. Stature had a higher correlation with FL than with foot breadth.[3]

A model for reconstruction of stature based on the measurement of FL was proposed by Ilayperuma *et al*. The difference of the FL between the genders was found to be highly significant. A positive correlation between stature and FL was observed in both sexes, and it was statistically significant. A study was carried out on a cross-sectional sample of 400 students. The relationship between hand and FL and stature was strongly significant.[4]

The present study is not entirely different than studies done by Agnihotri *et al*., Kanchan *et al*. and other researchers, which stated that the mean FL of males is observed to be higher than the females [5-7] Although our findings are identical to those reported earlier, there exists differences in the mean value of FL, a stature, which significantly altered the regression equation.

A study conducted on urban Japanese populace documented that women had smaller feet than men in relation to their respective stature. This observation was in total contrast with another study from the same geographic locale, where men had smaller feet. [8] Thus, two researches, from relatively homogenous study samples differing in sexual dimorphism of FL proportionate to stature were observed. This may be construed as an indication of the extent to which such correlations are in need of further scrutiny. However, the present study had documented smaller foot in females than in males, proportionate to stature, which is similar to the former study in Japan and other studies conducted in India.

In the present study, to predict stature from left FL among males, the formula derived is S = 101.95 ± 2.6 (FL). A similar study was done on 246 subjects (123 males and 123 females) considering only the left foot. Linear regression equations were derived was S = 69.544 ± 3.995 (FL). In a study done on Gujjars population of north India, the equation derived was S = 90.275 ±2.9 (FL).[6]

Another study was done on growing foot of children below 18 years of age, considering individual digits with different age groups.[8] The linear regression equations were given with respect to individual toes and the specific age group as it was growing toes. The current study stands different as it involves samples from the age group of above 18 years, with the fully developed foot.

In the present study, to predict stature from left FL among females, the formula derived is S*W* = 89.63± 3.6 (FL). Similarly, linear regression equations were derived by Indian workers working on Indian female endogenous population.[9,10]

Conclusion

The result of the present study reveals a strong correlation exists between the FL and stature. FL serve as a reliable tool in stature estimation when gender is known thus aiding establishment in the primary characteristic of identification. However, the calculated stature could be a near possible, and the precise stature is almost practically impossible.

In case of mass disasters where there is a chance of evaluating various mutilated parts of the body, DNA technology could be the most accurate procedure one can come up for identification of these body parts. However, DNA analysis lacks in terms of reasonableness and affordability in India.[11,12] Hence, identification by anthropometry like the present study, involving FL to estimate the stature could be a reasonable, convenient and a simple solution till DNA analysis takes off and has a steady course in India.

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