Original Article

Indian Journal of Anatomy
Volume 7 Number 1, January - February 2018
DOI: http://dx.doi.org/10.21088/ija.2320.0022.7118.5

Study of Correlation of Foot Length and Foot Breadth with Stature in Humans

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Abstract

Anthropometry helps in reconstruction of biological profile of the deceased such as age, sex, ethnicity and stature. *Aim:* The aim of the present study is to study the correlation of foot length and breadth with stature. Material and Methods: Sample size of the present study consisted of 200 students (males = 84 and females = 116) between 17–24 years of age from Government Medical College. Their stature and foot length and breadth were recorded. *Observations:* It was observed that males had higher mean, standard deviation and range for each of the parameter considered than those of females. Significant correlation was observed between height and foot length and breadth. From the regression equations derived, one can calculate height from any known parameter and vice versa. *Conclusion:* Foot length and foot breadth showed statistically significant correlation with height in total cases and also when male and female cases were evaluated separately. Foot length and foot breadth show significant positive correlation with each other. When one has to calculate height using one parameter, we recommend the use of foot length for the same as it showed highest correlation with height. This study will be useful for stature estimation from available skeleton material or parts of the deceased body that are available.

Keywords: Correlation; Stature; Foot Length; Foot Breadth.

Introduction

Stature is the height of a person in upright position [1]. Anthropometry helps in reconstruction of biological profile of the deceased such as age, sex, ethnicity and stature [2,3,4].

Rutishauser [5] estimated height from foot length in African children aged below six years with as much success as found by Trotter and Glesser [6,7] in adult American Negroes and Whites. So far few studies have been done to estimate height of an individual from measurement of foot length and foot breadth together. Also no information regarding correlation among these parameters is available.

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Received | 15.11.2017, **Accepted** | 23.11.2017

Aim

To study the correlation of foot parameters with stature.

Material and Methods

Sample size consists of 200 students (males = 84 and females = 116) from our College. Subjects known to have any significant disease, orthopaedic deformity, metabolic or developmental disorders which could have affected the general or bony growth were not included in this study. Samples were drawn randomly across the student population, after taking written valid informed consent from each of the participants. The age of the sample group ranged between 17–24 years. Stature i.e. height, foot length and foot breadth were studied in each subject. The material used for the present study is standiometer (height measuring instrument), measuring scale, paper and pencil.

All the above mentioned parameters were measured under the same conditions using the same measuring instruments in a well illuminated room at a fixed time. Before taking measurements, it was

checked that nails were trimmed. Measurements were taken on both sides in each subject by using standard anthropometric instruments in centimetre.

Height of the individual was measured as vertical distance from the vertex to the floor by using an anthropometer. Measurement was taken by making the subject stand erect on a horizontal resisting plane bare footed. The movable rod of an anthropometer is brought in contact with vertex in the mid-saggital plane [8]. No pressure was exerted since this is a contact measurement [2].

Foot Measurements

For recording foot measurements, the participant was made to stand so that both feet were slightly apart with equal pressure on both arches [2]. The outline was marked as it is done for shoe print [3]. Both feet were measured for foot length and breadth as follows (Figure 1).

Fig. 1: Showing foot tracing done

The length of the foot was measured as direct distance from most prominent point of the back of the heel to the tip of the hallux, or to the tip of second toe, when the second toe was larger than the hallux [4]. Distance between posterior most point of the heel and anterior most point of the foot was measured as the foot length [1,9] (Figure 2).

The breadth of the foot was measured as the direct distance between medial metatarsal point (metatarsaletibiale i.e. most prominent part of the head of the 1st metatarsal bone) and lateral metatarsal point (metatarsalefibulare i.e. most prominent point of the head of the 5th metatarsal bone) (Figure 2).

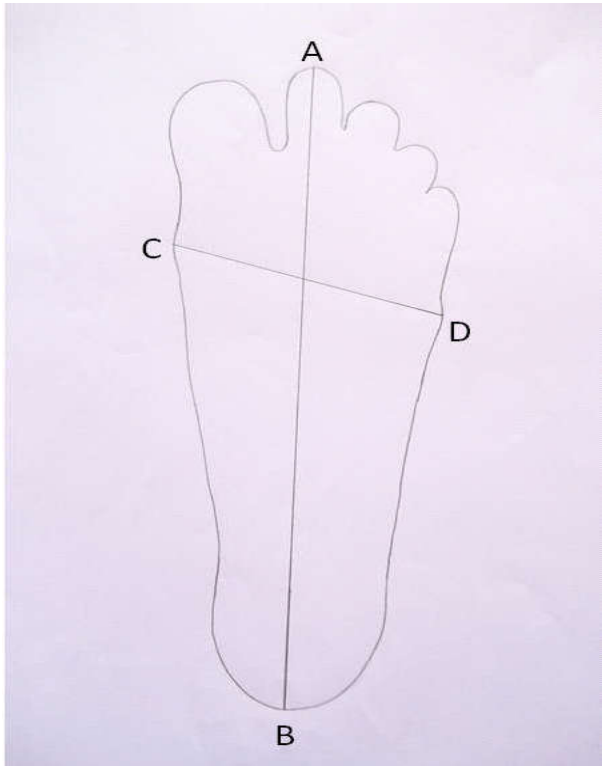


Fig. 2: Landmarks for foot measurements:
Distance between A and B = Foot length
Distance between C and D = Foot Breadth

Results

The data was analysed using SPSS software version 20.

The data was analysed for pooled sample as well as for males and females separately.

As there was no significant difference between the measurements of right and left sides, we have taken the average of the right and left sides of each parameter into consideration for further study.

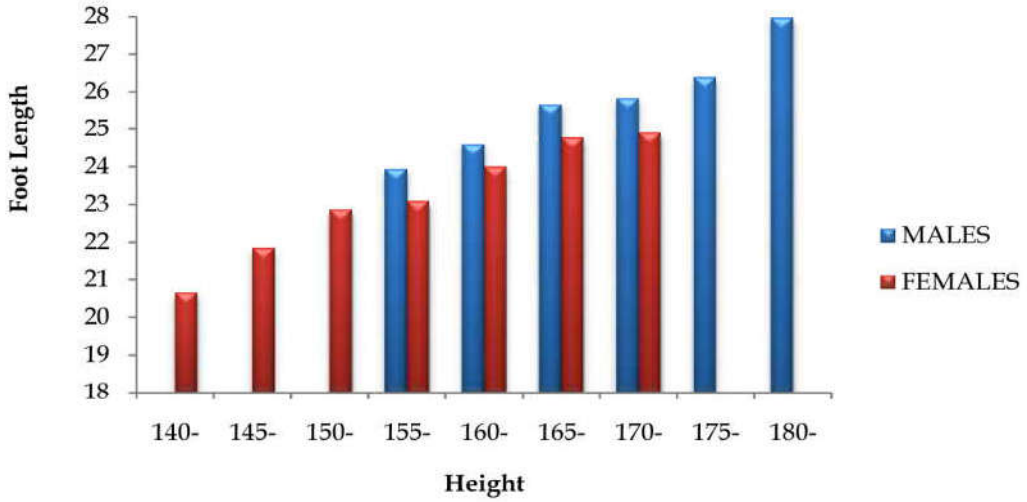
From the Table 1, we observe that the mean value for each parameter is higher for the male population than total cases, which is still higher than the female population. By using Student's t-test of significance, this difference among the male and female parameters is found to be highly significant. $P < 0.01$ indicates that the probability of difference being due to chance is less than 1% [12].

In graph 1 and 2, we arranged the observations of foot lengths and foot breadths of male and female population separately for a defined height range.

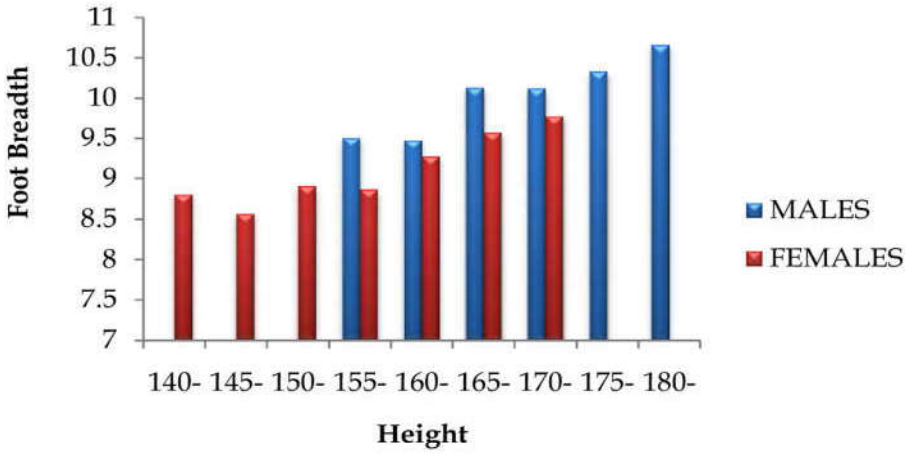
Table 1: Distribution of various parameters in study population with 't' values indicating the difference in male and female parameters

Sr. No.	Parameter		Total Cases	Males	Females	t	P Value
1	Height	Mean ± SD	163.08 ± 8.36	169.76 ± 6.42	158.23 ± 5.90	13.149**	
		Range	142-185	155-185	142-171		0.001
2	Average Foot Length	Mean ± SD	24.45 ± 1.62	25.76 ± 1.23	23.51 ± 1.15	13.268**	
		Range	20.45 - 29.3	23.4 - 29.3	20.45 - 26.4		0.001
3	Average Foot Breadth	Mean ± SD	9.51 ± 0.79	10.09 ± 0.68	9.10 ± 0.57	11.255**	
		Range	7.75 -12.1	8.8 - 12.1	7.75 - 10.5		0.001

If P ≤ 0.01 or 0.001 Highly Significant
** - Highly Significant



Graph 1: Showing mean foot length for various height groups in males and females



Graph 2: Showing mean foot breadth for various height groups in males and females

Comparing this data, we observed that for a specific height, foot length and breadth in males is always higher than the foot length and breadth in females and the difference is statistically highly significant (t = 13.268; P = 0.001 and t = 11.255; P = 0.001 for foot length and foot breadth respectively) (Table 1).

For finding out the strength of correlation, we calculated the Pearson's correlation coefficient (r). Pearson's correlation coefficient (r) for height and foot length is 0.841, 0.655 and 0.730 for total cases, males and females respectively. Pearson's correlation coefficient (r) for height and foot breadth is 0.675, 0.388 and 0.482 for total cases, males and females respectively. Pearson's correlation coefficient (r) for foot length and foot breadth is 0.801, 0.679 and 0.634 for total cases, males and females respectively. All values are significant at 0.01 level (P = 0.001).

The correlation of height with foot length and foot breadth is highly significant; foot length showing stronger correlation than foot breadth. Also foot length and foot breadth show highly significant correlation among them.

Linear regression equations are used to calculate an unknown variable from known variable. Linear regression model is given by: $y = a + bx$

where y = dependent variable (which is height in our case)

x = independent variable (FL/FB)

b = regression coefficient

a =intercept (a constant)

The linear equations for calculating height from foot length are:

For total cases: Height = 57.283 + 4.326 FL

R^2= 0.707 and f value = 477.16, P = 0.001

For males: Height = 80.49 + 3.466 FL

R^2= 0.442 and f value = 64.96, P = 0.001

For females: Height = 70.169 + 3.746 FL

R^2= 0.533 and f value = 130.19, P = 0.001

The linear equations for calculating height from foot breadth are:

For total cases: Height = 94.993 + 7.156 FB

R^2= 0.456 and f value = 166.03, P = 0.001

For males: Height = 133 + 3.682 FB

R^2= 0.15 and f value = 14.51, P = 0.001

For females: Height = 70.169 + 3.746 FL

R^2= 0.232 and f value = 34.48, P = 0.001

The high 'F' value with low 'P' value indicates significant functional relationship between dependent variable and independent variable. R square is the square of the correlation coefficient. In equation of deriving height from foot length in total cases, it is 0.707 which indicates that 70.7% of variation in height is due to variation in foot length. Foot length shows stronger correlation with height, hence predicting height better.

Multiple regression equations calculate unknown parameter using multiple known variables. Multiple regression model is given by: $y = \beta_0 + \beta_1(FL) + \beta_2(FB)$

where y = dependant variable (height in our case)

β_0= regression coefficient

β_1 = regression coefficient for FL

β_2 = regression coefficient for FB

For total cases: Height = 57.28 + 4.30FL+ 0.068FB

R= 0.84 R^2= 0.71 and f value = 237.39, P = 0.000

For males: Height = 81.03 + 3.89FL- 1.13FB

R= 0.67 R^2= 0.45 and f value = 33.08, P = 0.000

For females: Height = 69.62 + 3.64FL+ 0.33FB

R= 0.73 R^2= 0.53 and f value = 64.68, P = 0.000

In the multiple regression equations, the dependant variable is height and explanatory variables are foot length and foot breadth. The multiple correlation coefficient (R) is highly significant at P = 0.001.

For total cases, R^2 is 0.71 indicating that 71% of the prediction of height is attributed to the parameters considered. Thus, height can be calculated from all the parameters with good accuracy by using multiple regression equation.

Multiple regression model fits well to the observed data than the linear regression model as the values of multiple correlation coefficient are higher than the Pearson's correlation coefficient.

Discussion

Establishing the identity of an individual from mutilated, decomposed, & amputated body fragments is an important necessity. It is important both for legal & humanitarian reasons [13]. Estimating the stature, age, sex and ancestry facilitate narrowing down of the pool of possible victim matches in the forensic investigation process and help in establishing identification of an individual [14].

When male and female population was considered separately, the mean values of all parameters including height were higher in males than those of females. This difference was statistically significant. These differences in measurements between males and females can be attributed to the fact that fusion of epiphyses of bones occurs earlier in girls in comparison to boys. Boys have about two more years of bony growth than girls [15].

We have compared the mean values of all the parameters under study with the studies conducted earlier. We observed that mean value of height in our study matches with the findings of Khanapurkar S [16] (2012) and Patel PN [17] (2012) but is lower than the findings of Sanli SG [18] (2005), Chikhalkar BG [19] (2009) and Jakhar JK [20] (2010). But height of the present study is on a lower side as compared

to the height observed by Jakhar JK [20] (2010). Jakhar JK [20] studied the Haryanvi population whereas Sanli SG [18] (2005) studied the population of Turkey. Haryanvi and Turks are known to have larger stature than the Western Indian population. Our study provides the same finding. Mean foot length and mean foot breadth are comparable with the findings of other studies.

The difference in the findings of the present study from those of the other studies may be attributed to the geographical as well as racial factors that may influence growth and stature of an individual. Hawes et al [21] (1994) studied ethnic differences in foot shape and found that besides differences between genders, ethnic origin can influence foot shape.

In the present study, we observed highly significant differences in all dimensions of males and females. Baba K [22] (1975), Anil A [23] (1997), Ashizawa [24] (1997), Jakhar JK [20](2010), Danborno B and Elukpo A [25] (2008) reported similar significant differences in males and females. Hishama S [26] (2012) estimated stature from foot anthropometry in Malaysian Chinese and found no sex difference in foot dimensions. Our findings do not match with these findings of Hishama S [26] (2012).

We observed significant moderate positive correlation of height with foot length. These findings match with those of Janardana T [27] (1963), Chikhalkar BG [19] (2009), Jakhar JK [20] (2010), Khanapurkar S [16] (2012) and Patel PN [17] (2012).

Significant moderate positive correlation was observed between stature and foot breadth in present study as well as by Chikhalkar BG [19] (2009) and Patel PN [17] (2012).

Patel SM et al [28] (2011) studied foot parameters and stature. In his study, moderate positive significant correlation between foot length and foot breadth was reported on both right and left sides. In the present study, we found similar correlation among foot length and foot breadth.

Various authors have derived the linear regression equations for deriving height from foot length as well as from foot breadth separately.

Khanapurkar S and Radke A [16] (2012) studied estimation of stature from the measurement of foot length, hand length and head length. They found that contribution of head length in estimating height was not significant. So they derived the equation taking hand length and foot length into consideration. The equation derived by them was Height = 59.451 + 2.552 FL+2.295 HL.

It must be noted that the equations are applicable to the population from which data has been collected because genetic, racial and environmental factors (climate, nutrition etc) may influence the parameters under consideration.

Summary and Conclusion

In many circumstances, stature of a deceased individual is calculated by using regression equation from available skeleton material or parts of the deceased body that are available. Present study was designed to estimate height from foot length and foot breadth. Correlation among these parameters was also studied. The difference in the measurements of males and females was found to be statistically highly significant for each parameter. Foot length and foot breadth showed statistically significant correlation with height; stronger association was shown by foot length. Foot length and foot breadth showed statistically significant correlation among them. Linear and multiple regression equations were formulated to calculate height. When one has to calculate height using one parameter, we recommend the use of foot length for the same. Multiple regression equation predicted height better than the linear regression equations.

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