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Personal height of an individual person from measuring foot length

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Abstract
Determination of stature of a person plays an important role in identification of a person which is necessary in criminal cases and as well as in mass disasters where only a portion or a part of body may be seen. The present study was carried out on the measurement of foot length and body height of 184 medical students (91 males and 93 females) of 19 to 25 years of age. The study was carried out in department of Anatomy, Katihar Medical College & Hospital, Katihar, Bihar state, India. Anthropometric measurements were taken by using anthropometric instruments in centimetres to the nearest millimeter. All the measurements were taken in a well-lighted room. Obtained data was analysed for correlation coefficient and to derive a regression formula between foot length and height of an individual. A medium correlation of height was observed with foot length and it was statistically significant. The present study would be useful for anthropologists and forensic experts.

Keywords: Forensic Anthropology, Stature, Foot Length, Co-relation coefficient, Regression Equation

1. Introduction
Forensic expert report the estimation of stature of the deceased from a few skeletal remains may become an important part of evidence in court of law. Determination of stature of a person plays an important role in identification of a person which is necessary in criminal cases and as well as in mass disasters where only a portion or a part of body may be seen. The orthodox method for estimating stature from skeletal remains is correlation that exists between living stature and long bone length. Consequently various workers derived many sets of regression equations for this purpose. The better known are karl- Pearson's [1], Dupertius & Hadden's [2] and Trotter & Gleser's [3]. However these methods are limited to long bones. Consequently some authors have attempted to find suitable alternatives when no limb bone is recovered completely for its length to be measured accurately. Methods are developed for use in cases of fragmentary remains with identifiable bony land marks by steel's formula. Relationship that exists between different parts of the body and height has been of great interest to anthropologists, for many years. This is because of increase in the number of catastrophic events causing mass deaths which requires the identification of a victims from dismembered human remains. Foot length reflects the internal structure of feet [4] they can yield the information about the size and shape of the bones in the feet. Ruttihauser's first time showed the reliability of prediction of height from simple measurements like foot length was as high as that of long bones. Ossification and maturation of foot occurs earlier than in long bones, and therefore during the adolescent period height could be more accurately predicted from foot measurements than from the long bones [5]. The personal identification from foot length becomes more important in case of mass disasters, where there is always likelihood of recovering feet often enclosed in shoes, separate from the body. Footprints are also of immense value in establishing personal identity of the criminals in forensic examinations[4]. Present study was therefore conducted to find out correlation between foot length and body height in the population of Bihar, India.

2. Material and Methods
The present study was carried out in the department of anatomy. Katihar Medical College & Hospital, Katihar, Bihar. A total of 185 subjects were included in the study, out of which 92 males and 93 females within age group of 19 to 25 years. The subjects included in study were healthy individuals free from any apparent skeletal deformity. Anthropometric measurement of foot length were taken independently on left and right side of each individual. Besides the above measurements, stature of each subject was also recorded. All measurements were taken in well lighted room. The measurements were taken by using standard anthropometric instruments in centimetres to the nearest millimeter in following manner [6].

3. Anthropometric Measurement
- **Foot length:** It is the distance from the most prominent part of the heel backward to the most distal part of the longest toe (2nd or 1st).
- **Instrument:** Vernier Calliper.
- **Technique:** The measurement was made on standing subject. The caliper was horizontally placed along the medial boarder of the foot. The fixed part of the outer jaw of the calliper was applied to the pternion and the mobile part of the outer was approximated to the acropodian and measurement were taken. In the same way measurement of the other side were taken.
- **Stature:** It is the vertical distance between the point vertex and the heel touching the floor (ground surface).
- **Technique:** The subject was made to stand in erect posture against the wall with the feet axis parallel or slightly divergent and the head balance on neck and the measurement was taken. The data was collected, analysed and subjected to statistical analysis using statistical

package for social sciences (SPSS) to know the correlation of the stature with the length of feet and simple linear regression formulae were derived for various combinations. The reliability of estimation of stature from the lengths of feet was determined with the help of standard error of estimation (SEE).

4. Results

Table 1 shows the standard deviation and mean of foot length of both foot and height of subjects. Table 2 exhibits standard error of estimation and correlation coefficient in male and female subjects, it ranges from 5.3 in males and 4.12 in females. Estimation of height from female subjects exhibits lower values of standard error of estimation than from foot length of males. It means the reliability of estimation of stature from foot length of females is more as compared to males.

The present study focused on estimation of stature from the length of the feet. Table 3 is showing regression equation, for estimation of stature from measurements of feet of males and females.

Regression Equation:

Stature = Vale of Constant (a) + Regression Coefficient (b) x Foot Length.

For males: Y= 88.39+3.27 RFL.
Y=92.81+3.10LFL.

For Female: Y=81.29+3.32 RFL.
Y=80.90+3.34 LFL

Where; Y= Total height, RFL is right foot length and LFL is for left foot length.

It was observed that there was no significant bilateral difference in foot length. So either of the two foot can give an idea of stature of a person. In present study the value of correlation between foot length and stature in males was 0.37 and 0.34 for right and left foot respectively, and for females 0.47 for both sides, according to above findings there is stronger correlation of foot length with respect to stature in females as compared to males. So if any one parameter is available the other can be calculated.

Table 1: showing standard deviation for both right and left foot and height in males and females.

Parameters	Males		Females	
	Mean	SD	Mean	SD
Right foot length	22.55	1.24	23.33	1.17
Left foot length	25.59	1.26	23.30	1.17
Avg foot length	25.57	1.25	23.30	1.17
Height	172.14	6.64	158.98	5.71

Table 2: Showing correlation coefficient and standard error of estimation separately in each foot and average of two in both males and females

	Males		Females	
Parameter	Correlation coefficient	SE of the estimate	Correlation coefficient	SE of the estimate
Right Foot Length	0.37	5.27	0.47	4.15
Left Foot Length	0.34	5.4	0.47	4.13
Avg Footlenth	0.36	5.33	0.48	4.12

Table 3: depicting regression equation in both males and females on from each foot and as an average.

	Males	Females
Parameter	Regression equation	Regression equation
Right Foot Length	Height=88.39+3.27 (Right foot length)	Height=81.29+3.32 (Right foot length)
Left Foot Length	Height=92.81+3.10 (Left foot length)	Height=80.90+3.34(Left foot length)
Avg Footlenth	Height=90.16+3.20 (Average foot length)	Height=80.07+3.37 (Average foot length)

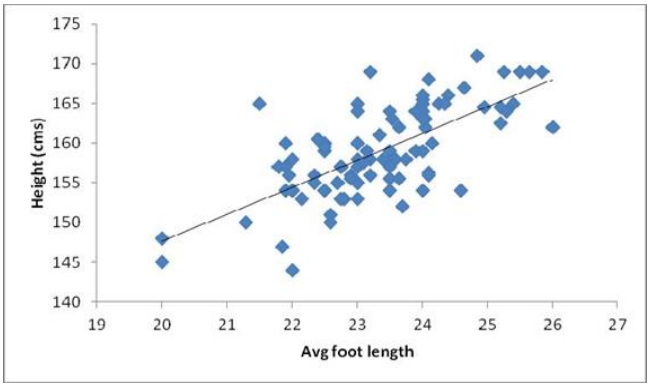

Fig 1: Scatter diagram showing correlation between height and average foot length in females.

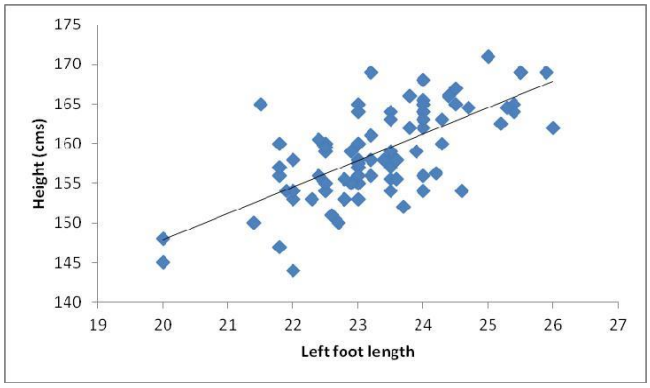

Fig 2: Scatter diagram showing correlation between height and left foot length in females.

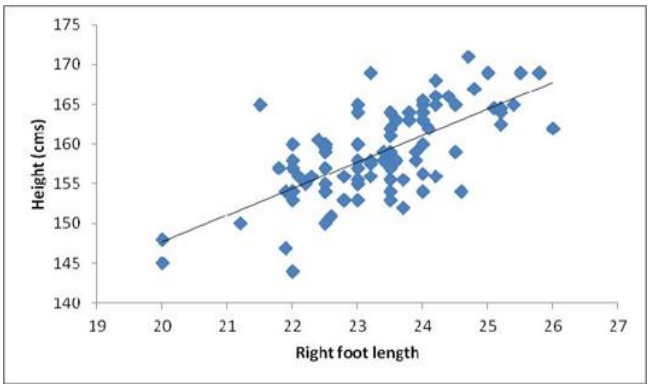

Fig 3: Scatter diagram showing correlation between height and right foot length in females.

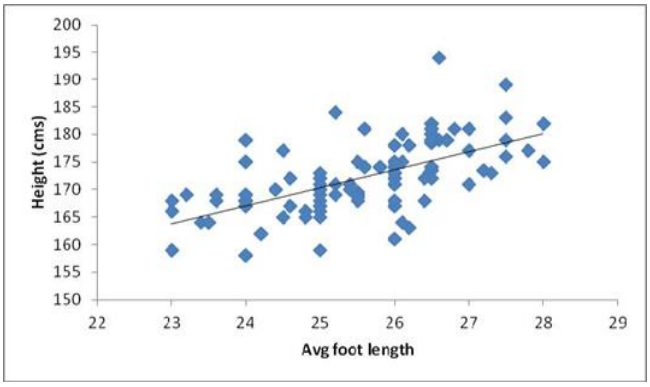

Fig 4: Scatter diagram showing correlation between height and average foot length in males.

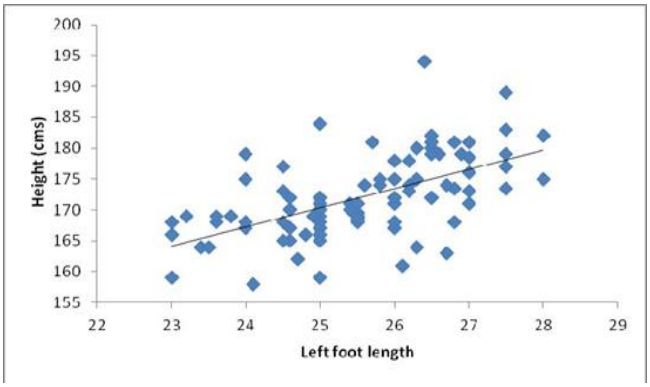

Fig 5: Scatter diagram showing correlation between height and left foot length in males.

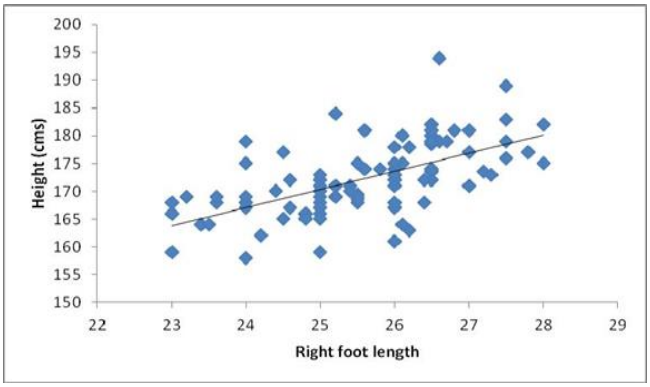

Fig 6: Scatter diagram showing correlation between height and right foot length in males.

5. Discussion

Pearson was the first to set regression equation to estimate stature from long bone measurements and he concluded that these formulae are population specific and should not be applied to individuals of different populations [9]. Various studies have been conducted on the estimation of stature from the human skeleton. There are various methods to estimate stature from the bones but the earliest and the reliable method is by regression analysis [4, 5]. Martin [10] was probably first to have developed a ratio index of foot length to estimate stature, concluded that foot length relative to stature shows no great variation within the human races, on an average amounting to 15%. Studies using hands and feet measurement for stature estimation are scarce. These studies indicate that bilateral variations was insignificant for all measurements in both the sexes. Robbins also did not find significant bilateral symmetry in various measurements of the feet of a U.S. Sample. Sanli *et al*; (2005) established the relationship between hand length, foot length and stature using multiple linear regression analyses. Their study sample included 155 adults (80 male, 75 female) Turks residing In Adana. They found multiple linear regression model for both genders together to be the best model with the highest values coefficients of determination R2 = 0.861 and R2 adjusted = 0.859, and multiple correlation coefficient R = 0.928. Agnihotri *et al*, (2007) developed a relationship between the foot length and stature using linear and curvilinear regression analysis on a study group comprising of 250 medical students (125 males and 125 females) aged 18 – 30 years. It was concluded that general multiple linear regression model was highly significant ($p < 0.01$) and validated with highest value for the coefficient of determination R 2 = 0.769 and multiple correlation coefficient r = 0.877. Krishnan (2008) examined the relationship of stature to foot size of 1040 adult males Gujjars of north India (age 18 to 30 years). The highest correlation coefficient were shown by the toe length measurements (0.79 – 0.86).

As per above mentioned studies our study show a medium correlation coefficient with stature and foot length in 185 medical students (92 males and 93 females) age group of 18 – 25 years. It was concluded that the value of correlation coefficient has medium value but with stronger correlation with females as compared to males, and there is no gross asymmetry on both sides. Standard deviation for right foot is 4.07, left foot is 3.90 in case of males and in case of females it is for right foot 3.91 and left foot 3.93. Similar views are expressed by Philip that either of the feet can be used for the estimation of stature as no significant asymmetry was observed by him while working on the footprints of south Indian population [9]. The present study similarly did not find any bilateral asymmetry in measurement of foot length in an individual. The correlation coefficients between stature and all the measurements of feet were found to be positive and statistically significant. Similar results were observed by kanchan *et al* in north Indian endogamous group [10]. It was observed that the foot length in males and females show medium correlation with stature and minimum standard error in estimation of stature.

6. Conclusion

The present study has been taken to fix the actual height of both males and females by measuring foot length both right and left. Which shows that there is medium correlation with actual

height and foot length. Moreover the estimation of stature from foot length is easy, economical and convenient no specialized equipment or training is required to use this method.
Anthropologists, forensic experts and investigating officers should be able to use this method to their added advantage. Thus this study has been able to add another method to estimate stature from foot length. It is concluded that the foot length in males and females show medium correlation with stature and minimum standard error in estimation of stature. So foot length provides the medium reliability and accuracy in estimating stature.

7. References

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