Original Research Article

Stature estimation using foot measurements in south Indian population

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A R T I C L E I N F O

A B S T R A C T

This study was conducted in the Department of Anatomy during the period of August to September 2019 in the Department of Anatomy, MIMS Mandya. The aim of study was to find the correlation between foot measurements and standing height of both males and females and to derive the regression equation for calculating the Stature. This study included 255 subjects (105 males & 150 females) in the age group of 18 to 22 years. After obtaining the consent and recording the demographic profile, foot length and foot breadth was recorded in both sides by a single person(to avoid inter-observer error) in accordance with the directions given in manual of Physical Anthropology. The data was statistically analyzed and was found that foot length provided high correlation with stature ($p < 0.001$) and foot breadth also showed statistically significant correlation with p value < 0.05. Regression equation was derived in females as Height = 116.811 - 1.274* (FBR) + 1.827 *(FBL) -1.548 *(FLR) + 3.249 * (FLL) and in males as Height = 118.671 + 0.490* (FBR) + 1.316 *(FBL) - 0.449 *(FLR) + 1.345 * (FLL). In unknown sex as Height = 82.734 -0.306* (FBR) +0.946 *(FBL) + 1.174 *(FLR) + 2.104 * (FLL). In our study there was no statistically significant difference in stature estimation by foot length of right and left sides. This information would be in turn useful to establish partial identity and biological profile of an individual from South Indian population.

1. Introduction

Anthropometry, a traditional tool of Forensic and Physical Anthropology provides scientific methods and techniques for taking various measurements on the living man (somatometry) and the skeleton (osteometry).The origins of Anthropometry dates back to old Egypt and Greece where the Artists formulated various standard canon for the human body. The Scientific Anthropometry began with J F Blumenbach who laid foundation of Craniology in 18th century, Broca, Flower and Turner further improvised with Flower inventing a Sliding Calipers which later came to be known as Flower's Calipers. Rudolf Martin wrote a complete text book on Anthropology which is even now a lighthouse for physical Anthropology students and a laboratory manual was published by Wilder in1918.[1]

The growing field of Forensic Anthropology is now set for proper analysis of skeletal remains as a part of identification. It is the determination of species, race, sex, age and stature of a person.

Stature estimation is an important aspect especially in medico legal cases like mutilated dead bodies, aeroplane accidents, deaths from terrorist bombings, mass disasters etc. On many occasions the exhumed available remains are in fragmented and mutilated state. The Forensic investigators thus have an uphill task to analyse whatever remains have found and draw inferences of medico legal importance to promote legal justice.[2]

The study of the human foot in forensic identification has been emphasized because of the increased likelihood of retaining the foot (often protected by the shoes) in the case of mass disasters, wars, explosion and high-impact transportation accidents.[3]

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The lower extremities have shown to be a relatively accurate biological characteristic from which identification can be made in terms of estimating sex and stature. Ossification and maturation in the foot occurs earlier than the long bones and therefore, during adolescence age, height could be more accurately predicted from foot measurements as compared to that from long bones.[4]

Quantitative analysis of foot anthropology is also important for the study of ergonometrics, orthotics designing of foot devices.[5]

Present study was, therefore conducted to find out correlation between foot measurements and body height and evaluate the reliability of estimation of height from foot measurements in the South Indian Population.

2. Aims and Objectives

The aim of this study was to find the correlation between foot measurements and standing height of both males and females and to derive the regression equation for calculating the Stature.

3. Materials and Methods

The present study was conducted on 255 MBBS students(107 males and 150 females) belonging to South India aged between 18 to 22 years. Ethical clearance was obtained from Institutional Ethics Committee, informed consent was taken in the prescribed format and the demographic profile was recorded. The instruments needed were Anthropometer rod and Sliding Calipers available in the Research lab, Department of Anatomy.

The Somatometric landmarks were Vertex, Pternion, Acropodian, Metatarsale fibulare, Metatarsale tibiale. Measurements were done independently on the left and right sides of each individual. The measurements were taken by one observer in order to avoid inter-observer error. Individuals were made to stand in Frankfurt eye-ear plane.[6] The height vertex or stature was measured in centimeters with the help of an anthropometer from vertex (The highest point in the head which is not an anatomically determined point and is dependent on the orientation of the skull in Frankfurt plane) to floor. Foot length was measured using Sliding Calipers from pternion (Hindmost point on the heel of stretched foot) to Acropodian (Most distally placed point on toe-cap of 1st or 2nd toe whichever is longer when foot is stretched on the ground). Foot breadth was measured using Sliding Calipers from metatarsale fibulare (The most laterally placed point on the head of the fifth metatarsal) to metatarsale tibiale (The most laterally placed point on first metatarsal).[6]

The data was entered in excel sheet and analyzed using SPSS Software.

4. Observations and Results

In the present study foot measurements were taken on 255 subjects(105 males &150 females) and the results were recorded as follows.

Table 3 shows the mean and standard deviation according to gender. Stature in males varied from 152 -184 cm with a mean value of 170.76 cm and standard deviation of 6.34 cm. Stature in female varied from 144-180 cm with a mean value of 159.19 cm and standard deviation of 6.16 cm. This difference in mean stature between males and females was statistically highly significant ($p<0.001$). Foot length of both sexes showed highest correlation with stature. Foot breadth of both sexes also showed correlation with a p value <0.05

Table 4 shows Karl Pearson's correlation of height and among all study subjects. It is observed that all parameters showed statistically significant correlation with height.

Graph 01: Scatter diagram showing relation between Height and Right Foot Length Females
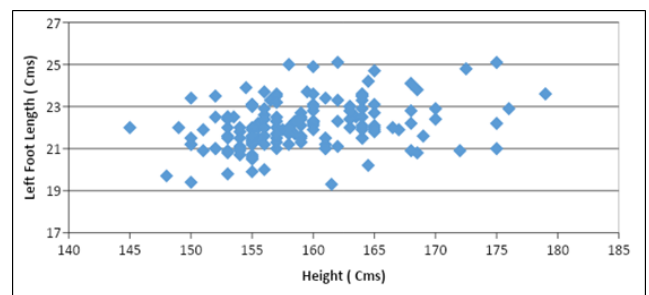
Fig. 1: Scatter diagram showing relation between Height and Left Foot Length in females
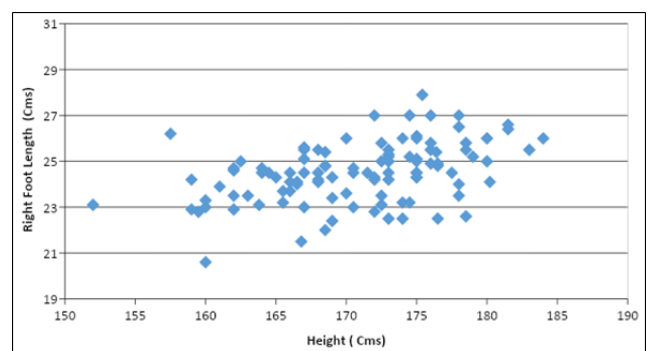
Fig. 2: Scatter diagram showing relation between Height and Right Foot Length males

Table 7 shows Regression equation which was derived as related to height and sex of the study subjects based on individual parameters and Table 8 shows the same in separate sexes combining all the four variables.

Table 1: Distribution according to age and sex of the study subjects

Age in Years	Males	Females	Total
18-20	74	49	123
20-22	31	101	132
Total	105	150	255

Table 2: Descriptive statistics of the study subjects(cm)

Variable	Mean + SD	Minimum	Maximum
Height	163.96 + 8.439	145	184
Right Foot Breadth	8.80 + 0.94	5.5	12.1
Left Foot Breadth	8.76 + 1.05	0.8	12.0
Right Foot Length	23.11 + 1.68	19.0	27.9
Left Foot Length	23.06 + 1.66	19.3	27.5

Table 3: Mean & SD according to gender of the study subjects

Variable	Males (105)Mean + SD	Females (150)Mean + SD	t-test Value	P-Value
Height	170.76 + 6.34	159.19 + 6.16	14.58	<0.001
Right Foot Breadth	9.04 + 1.02	8.64 + 0.84	3.39	0.001
Left Foot Breadth	8.96 + 1.27	8.62 + 0.84	2.61	0.009
Right Foot Length	24.49 + 1.29	22.13 + 1.16	15.25	<0.001
Left Foot Length	24.39 + 1.36	22.13 + 1.13	14.02	<0.001

Table 4: Karl Pearson's correlation of Height and among all study subjects

Variable	Height Correlation	P-Value
Right Foot Breadth	0.279	0.001
Left Foot Breadth	0.287	< 0.001
Right Foot Length	0.655	< 0.001
Left Foot Length	0.662	< 0.001

Table 5: Karl Pearson's Correlation of Height in female subjects

Variable	Height Correlation	P-Value
Right Foot Breadth	0.106	0.197
Left Foot Breadth	0.125	0.128
Right Foot Length	0.285	<0.001
Left Foot Length	0.328	0.001

Table 6: Karl Pearson's correlation of Height in male subjects

Variable	Height Correlation	P-Value
Right Foot Breadth	0.291	0.003
Left Foot Breadth	0.362	< 0.001
Right Foot Length	0.435	<0.001
Left Foot Length	0.444	0.001

5. Discussion

The main characteristics for identification of an individual are age, sex and stature. In medico legal cases where only part(s) of body is available establishing stature as a part of partial identification is very much required. In a study at Gulbarga, in male students gave the stature formula using the regression equation of the right foot as Ht = 86.9 + 3.40 (RFPL) and for left foot as Ht = 112 + 2.41 (LFPL).[7] A study conducted in 2014 on 200 Medical students (116 males and 84 females) aged between 17 to 21 years at Gujarat gave the regression equation as Y=a+bX, where Y is Stature and X is Foot length, for males] it is $Y_m = 74.75 + 3.42 \times X_m$ and for females it is $Y_f = 63.62 + 3.61 \times X_f$.[8] A similar study done at Rajasthan in 2015 involved 500 subjects (291 male and 209 female of age group 18 to 72 years) gave a regression equation as $Y = 169.09 + 0.0944 \times FL$ for male and $Y = 149.61 + 0.168 \times FL$ for female (Y=stature, FL=foot length).[9] A Study in 2015

**Table 7:** Regression equation in individualgender involving all parameters

		Regression Equation	Error	Value of r
Females	Right Foot Breadth	Height = 125.759 + 1.511* (FLR)	0.417	0.285
	Left Foot Breadth	Height = 119.625 + 1.788* (FLL)	0.423	0.328
	Right Foot Length	Height = 152.528 + 0.771* (FBR)	0.596	0.106
	Left Foot Length	Height = 151.360 + 0.594* (FBL)	0.594	0.125
Males	Right Foot Breadth	Height = 118.552 + 2.131* (FLR)	0.435	0.435
	Left Foot Breadth	Height = 120.353 + 2.067* (FLL)	0.411	0.444
	Right Foot Length	Height = 154.485 + 1.801* (FBR)	0.584	0.291
	Left Foot Length	Height = 154.600 + 1.803* (FBL)	0.458	0.362
Combined (Females & Males)	Right Foot Breadth	Height = 88.183 + 3.279* (FBL)	0.238	0.655
	Left Foot Breadth	Height = 86.265 + 3.369* (FBL)	0.240	0.662
	Right Foot Length	Height = 141.959 + 2.499* (FBL)	0.541	0.279
	Left Foot Length	Height = 143.845 + 2.296* (FBL)	0.482	0.287

Table 8: Derivation of regression equation as related to height and gender of the study subjects based (Combined four variables)

Variable	Regression Equation	Error	Value of r
Females	Height = 116.811 - 1.274* (FBR) + 1.827 *(FBL) -1.548 *(FLR) + 3.249 * (FLL)	10.416	0.353
Males	Height = 118.671 + 0.490* (FBR) + 1.316 *(FBL) - 0.449 *(FLR) + 1.345 * (FLL)	10.640	0.496
Together (Females & Males)	Height = 82.734 -0.306* (FBR) +0.946 *(FBL) + 1.174 *(FLR) + 2.104 * (FLL)	5.895	0.672
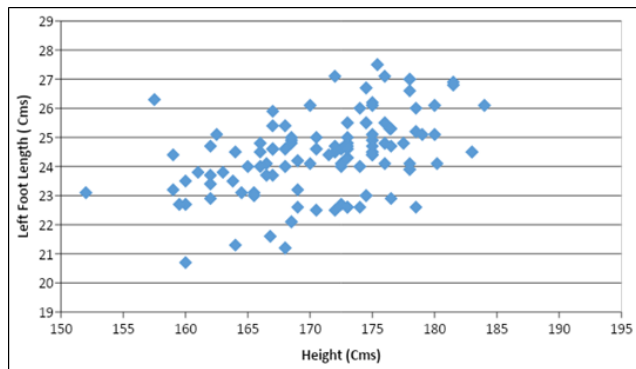
Fig. 3: Scatter diagram showing relation between Height and Left Foot Length males
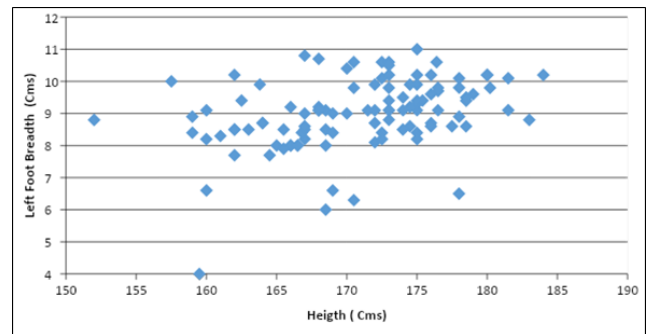
Fig. 4: Scatter diagram showing relation between Height and Left Foot Breadth males

on 308 students aged between 18 to 20 years at Tumkur gave the regression equation as Ht=155.6+0.708×FL for males and Ht=136.43+1.095×FL for females (Ht=height, FL=Foot length).[10] In all the above studies there was no statistically significant difference in stature estimation by foot length of right and left sides.

The data derived from different population cannot be used for all types hence the baseline data needs to be derived from local population which can be used for height

estimation. Earlier multiple factor method was used but now world wide regression formulae are accepted as of at-most importance.[11]

In our study, Foot length of both sides in both gender showed statistically high significance with stature. Foot breadth also showed significance with p value <0.05. If the foot measurements are known in South Indian population, stature can be estimated using the regression equation as shown in the Tables 7 and 8.

6. Conclusion

It is concluded that the foot length in males and females show highest correlation with stature and minimum standard error in estimation of stature. So the foot length provided the highest reliability and accuracy in estimating stature. In population similar to our study, stature estimation can be done by using foot measurements. This study serves as useful tool for Forensic Experts, Anatomists, Archaeologists, Anthropologists and Legal experts to aid in stature calculation based on foot measurements.

7. Summary

This study was conducted in the Department of Anatomy during the period of August to September 2019 in the Department of Anatomy, MIMS Mandya. The aim of study was to find the correlation between foot measurements and standing height of both males and females and to derive the regression equation for calculating the Stature. This study included 255 subjects (105 males & 150 females) in the age group of 18 to 22 years. After obtaining the consent and recording the demographic profile, foot length and foot breadth was recorded in both sides by a single person(to avoid inter-observer error) in accordance with the directions given in manual of Physical Anthropology. The data was statistically analyzed and was found that foot length provided high correlation with stature (p<0.001) and foot breadth also showed statistically significant correlation with p value <0.05. Regression equation was derived in females as Height = 116.811-1.274* (FBR) + 1.827 *(FBL) -1.548 *(FLR) + 3.249 * (FLL) and in males as Height = 118.671 + 0.490* (FBR) + 1.316 *(FBL) - 0.449 *(FLR) + 1.345 * (FLL). In unknown sex as Height = 82.734 -0.306* (FBR) +0.946 *(FBL) + 1.174 *(FLR) + 2.104 * (FLL). In our study there was no statistically significant difference in stature estimation by foot length of right and left sides. This information would be in turn useful to establish partial identity and biological profile of an individual from South Indian population.

8. Acknowledgement

9. Source of Funding

10. Conflict of Interest

Nil.

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