

# Estimation of stature from foot anthropometry in Central Indian population

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## Abstract

Out of many parameters for human identification, stature is a principal anatomical variable. Stature estimation, especially in post-mortem cases where only some parts of an individual is available or cases where only footprints are available, foot anthropometry will be extremely useful. The objective of the current study is to find out interrelationship between the stature & foot length & formulating a regression equation for determination of height from foot length among individuals from Central India. This cross sectional study was conducted at the department of Forensic Medicine & Toxicology of Datta Meghe Medical College, Nagpur from June 2020 to August 2020. Collected data was entered in Microsoft Excel sheet & analysed using SPSS software. Mean stature in male was 165.8 cm with SD of 6 cm, while in female, it was 159.9 cm with SD of 6.7 cm. Gender wise difference in mean stature & foot length was statistically significant. This research found remarkable positive correlation between stature & foot-length in both sexes. Regression formula was derived which will be extremely helpful to forecast the height of an individual from known foot-length in cases of medicolegal importance.

**Keywords:** Stature, Foot length, Central India, Anthropometry, Regression equation.

## Introduction

Establishment of human identification especially in cases of decomposed bodies, mutilated remains, amputated bodies, charred bodies etc has become of paramount importance in homicidal investigation. Also identification of human remains is extremely important in mass disasters (both natural & man made) like floods, earthquakes, cyclones, aircraft accidents, wars, blast injuries & the list goes on. Persons involved in medicolegal investigation are well aware of the fact that in many such cases at the death scene or crime scene,

only some bony remains or human remains are available & they have to utilize their knowledge regarding various anthropometric techniques for human identification. In forensic anthropology, there is a long list of parameters for human identification, out of which height of an individual is of immense importance. Many researchers have done studies regarding estimation of stature from evaluation of both upper limb & lower limb but in extreme mutilated cases, even complete limbs are not available<sup>1</sup>. In such cases, it has been found that the reliability of prediction of stature from foot anthropometry has shown promising results<sup>2,3,4</sup>. Epiphyseal union & maturation in foot occurs earlier than long bones and this fact will be of immense help in cases of adolescents requiring medicolegal attention<sup>5</sup>.

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**Aims & objectives:** To find out relationship between height & foot length and to develop a regression equation for estimation of stature from foot length among Central Indian population.

### Methodology

This is a cross sectional study was conducted at the department of Forensic Medicine & Toxicology, Datta Meghe Medical College, Nagpur during the period of June 2020 to August 2020. 140 domicile individuals from Nagpur, who are born & brought up here were registered for this study. Informed written consent was taken from each individual & their participation was voluntary. Socio-demographic parameters for each individual were noted. The study participants who are having any disease, physical deformity, any history of injury or fracture or any surgical intervention were not included in the study.

The stature of an individual was measured between the vertex & floor in standing & erect position & head in Frankfurt plane. It was measured using stadiometer. As per recommendations of International agreement for paired measurements at Geneva (1912), left foot should be selected for measurements but in our study, both sides were included. Foot length was measured as a direct distance from the most prominent point of the

back of the heel to the tip of the hallux or to the tip of the second toe when second toe was longer than hallux using spreading callipers (nail extensions were excluded in the measurements). Measurements were taken during the fixed time duration of the day i.e between 11:00 AM to 2:00 PM to exclude any diurnal variation & single observer took all the measurements to avoid bias. The obtained data was entered in Excel sheet and was analysed using SPSS (statistical package for social sciences).

### Results:

**Table 1: Gender-wise distribution of study subjects:**

Sex	Number
Male	70
Female	70
Total	140

In this study, 140 healthy subjects were included with 70 males and 70 females. All subjects were grown adults with age ranging from 23 years to 50 years.

**Table 2: Descriptive statistics for foot length & stature with respect to gender (all readings are in cm):**

	Male			Female			Combined		
	Left foot length	Right foot length	Stature	Left foot length	Right foot length	Stature	Left foot length	Right foot length	Stature
Mean	24.5	24.5	165.8	23.4	23.3	159.9	24.2	23.9	162.9
SD	1.5	1.4	6.0	1.7	1.7	6.7	1.8	1.6	7.0
Minimum	22.3	22.3	155.3	20.8	20.9	148.4	20.8	22.3	148.4
Maximum	27.4	27.3	181.4	26.7	26.7	172.4	26.7	27.4	181.4

Left and Right foot length as well as height were noted for males and females. It was observed that the left foot length in males varied from 22.3cm to 27.4 cm with mean (SD) of 24.5 (1.5) cm. The mean (SD) right foot length in males was found to be 24.5 (1.4) cm varying between 22.3 cm to 27.3 cm. In females, left foot length ranged from 20.8 cm to 26.7 cm while the right foot length varied from 20.9 cm and 26.7cm with mean (SD) of 23.4 (1.7) cm and 23.3 (1.7) cm respectively. Mean (SD) combined left foot length was 24.2 (1.8) cm whereas for right foot length it was 23.9 (1.6) cm. The stature in males varied from 155.3 cm to 181.4 cm with mean (SD) stature of 165.8 (6.0)cm and for females the

reading was noted to be 159.9 (6.7) cm ranging from 148.4 cm to 172.4 cm.

**Table 3: Paired t-test for left & right foot length comparison:**

	Left foot length (cm)	Right foot length (cm)	p – value
Male	24.5 ± 1.5	24.5 ± 1.4	>0.05
Female	23.4 ± 1.7	23.3 ± 1.7	>0.05

There was no significant difference observed between left and right foot length in males as well as females. Hence, regression equations for estimation of stature were obtained with left foot length only.

**Table 4: Regression statistics:**

Stature (Dependent variable - DV)	Left Foot length (Independent variable-IV)		
	Male	Female	Combined
Intercept	73.37	77.3	74.43
Regression coefficient	3.71	3.52	3.66
Correlation coefficient	0.91	0.92	0.93
R <sup>2</sup> (coefficient of determination)	0.83	0.85	0.87
Significance	<0.01	<0.01	<0.01

It is observed that there is a strong positive correlation between dependent variable stature and independent variable foot length. The correlation coefficient for foot length of male and stature is 0.91, foot length of female and stature is 0.92 and correlation of foot length with stature of any person irrespective of gender is 0.93. The R<sup>2</sup> (coefficient of determination) shows how good fit is the linear regression between the independent and dependent variable. In this study it is noted that the foot length of male explains 83% of variability in male stature while for females it explains 85% of stature variability. R<sup>2</sup> is maximum for foot length irrespective of gender, it explains 87% of variability in stature.

**Linear regression equation is expressed as:**

$$DV = \text{Intercept} + \text{Regression coefficient} \times IV$$

In this study, stature is DV and foot length is IV, thus the estimation of stature can be done by following equations.

**1. Estimated stature of males**

$$\text{Est. Stature (M)} = 73.37 + 3.71 (\text{Length of left foot print})$$

**2. Estimated stature of females**

$$\text{Est. Stature (F)} = 77.3 + 3.52 (\text{Length of left foot print})$$

**3. Estimated stature irrespective of gender**

$$\text{Est. Stature} = 74.43 + 3.66 (\text{Length of left foot print})$$

**Discussion**

Sr. No.	Author	Region	Year	Mean foot length(cm)		Mean Stature(cm)		Correlation Coefficient		R <sup>2</sup> (coefficient of determination)	
				Male	Female	Male	Female	Male	Female	Male	Female
1	SanliS et al <sup>1</sup>	Turkey	2005	26.25	23.47	175.05	159.96	0.716	0.699	0.512	0.488
2	Krishan K et al <sup>2</sup>	Himachal Pradesh	2007	24.7	22.6	168.24	155.72	0.741	0.734	0.549	0.538
3	Kanchan T et al <sup>3</sup>	Punjab	2010	26.01	23.78	166.39	159.56	0.704	0.536	0.496	0.287
4	Rajesh D et al <sup>4</sup>	Puducherry	2011	22.05	20.89	166.03	157.24	0.787	0.876	0.619	0.767
5	Kanchan T et al <sup>5</sup>	New Delhi	2013	24.89	-	167.08	-	0.575	-	0.33	-
6	Khairulmazidah M et al <sup>6</sup>	Malaysia	2013	24.8	22.3	166.56	156.08	0.659	0.662	0.434	0.438
7	Atal D et al <sup>7</sup>	Uttarakhand	2015-2016	26.51	23.83	172.85	158.2	0.525	0.65	0.276	0.422
8	Jat et al <sup>8</sup>	Rajasthan	2016-2017	25.47	24.05	162.1	150.5	0.94	0.93	0.88	0.86
9	Lalwani R et al <sup>9</sup>	Central India	2019	25.99	23.23	169.52	154.75	0.731	0.686	0.534	0.47
10	Karan Jain	Central India	2020	24.5	23.4	165.8	159.9	0.91	0.92	0.83	0.85

Current study was done to find out the correlation between foot length & stature and in turn to formulate a regression equation for the population of Central India. It will be of immense help in medicolegal cases requiring anthropometric assessment. When we compare our study with the other studies done in the past we found out that, our study is in total agreement with study conducted by Jat et al<sup>8</sup> in Ajmer region (Rajasthan). Like our study which is from Central India, Lalwani et al<sup>9</sup> conducted similar study in this region in 2019, where the researchers concluded that, mean foot length (25.99 cm) in males & (23.23 cm) in females along with that, height in males (169.52 cm) & in females (154.75 cm) are similar to our findings. Also in the same study, the correlation is positive (high) but in our study, it is 0.91 (for males) & 0.92 (for females) which indicates strong correlation. Similar study was conducted in Puducherry<sup>4</sup> which is in Southern part of India in 2011. When we compare our study with this study, it is in agreement with correlation between height & stature. Studies conducted by Kanchan et al<sup>3</sup>, Atal et al<sup>7</sup> & SanliS et al<sup>1</sup> showed low degree of correlation between height & stature, hence the estimate for stature would be poor.

### Conclusion

Our study found significant positive correlation between height & foot length in both genders. Regression equation was formulated for Central Indian population, which will be of tremendous help in determining the height of an individual from foot length especially in medicolegal cases. When we go through all the studies which we have taken into consideration, there is a lot of variation in correlation coefficients between height & foot length which may be due to improper sampling or sampling error. So to study this discrepancy in correlation more & more studies from different regions of India must be conducted to check whether it is sampling fluctuation or the difference is actually variable for the different regions. Also the studies must include larger sample size which will result in reduction of sampling variability & will provide stronger estimates.

**Ethical Clearance:** Taken from institutional ethics committee.

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**Conflict of Interest:** Nil.

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