

Estimation of Stature by Measuring Foot Length in Adult Females in a Tertiary Care Centre in Kanpur

Ankita Kakkar¹, Sushil Kumar², Pooja Rastogi³, Alok Kumar⁴

¹Associate Professor, Forensic Medicine & Toxicology, School of Medical Sciences & Research, Sharda University, Greater Noida (U.P.), ²Professor & Head, Forensic Medicine & Toxicology, Rama Medical College, Kanpur (U.P.), ³Professor & Head, Forensic Medicine & Toxicology, School of Medical Sciences & Research, Sharda University, Greater Noida (U.P.), ⁴Professor & Head, Forensic Medicine & Toxicology, Uttar Pradesh University of Medical Sciences, Saifai, Etawah. (U.P.)

Abstract

Background: Identification of an individual is the core element in forensic investigations. Accurate estimation of height is of paramount importance which has been carried out by several researchers by the measurement of various long bones. However, foot measurement has not been frequently used for this purpose, particularly in females of our region.

Method: Present study was performed in the department of Forensic Medicine at Rama Medical College, Hospital and Research Institute, Kanpur. The material comprised of 88 young and healthy female medical students of Rama medical College, Mandhana, Kanpur.

Results and Conclusion: A statistically significant correlation was established between height and foot lengths (Right and Left). The regression equation for height and foot length was also developed.

The correlation between stature and foot measurements was found to be positive and statistically significant (p -value < 0.001). Linear regression models and multiple regression models were derived for estimation of stature from the measurements of the foot. The results also indicated significant differences between left and right foot length measurements.

The present study indicates that anthropometric measurements of foot are extremely valuable in the estimation of stature. This is a meaningful tool to estimate stature with greater accuracy.

Conclusion: Prediction of stature was found to be most accurate by linear regression analysis. Present study has established definite correlation between stature and foot length. It will help in medico-legal cases; particularly in establishing identity of an individual when only a few body remains are available as in mass disasters, bomb explosions, accidents etc. This study will be of immense value for Doctors, Police and other concerned authorities, investigating these cases.

Key words: Forensic; Anthropometry; Stature; Foot Length; Female; India.

Corresponding Author:

Dr. Alok Kumar,
Professor & Head (Forensic Medicine & Toxicology).
Uttar Pradesh University of Medical Sciences,
Saifai, Etawah. -206130 (U.P.), India. Contact:
Tel. +91-9456995036;
E mail - drsalok@rediffmail.com

Introduction

In medico-legal practice, establishing personal identity is of prime importance and often required. In forensic anthropology, estimation of stature from feet dimensions plays a significant role in establishing personal identity. There is a scarcity of literature on the estimation of stature from foot length and foot breadth

among various Indian populations.¹ Accurate stature estimation plays an important role for this purpose and is necessary for reconstructing living body mass, skeletal rigidity and activity levels. Different body parts, long bones and appendages have been used for the estimation of stature.

Stature is the height of the person in the upright posture and it refers to the distance from the vertex, the highest point on the head in the Frankfurt horizontal plane, to the sole of the foot in an upright position. Stature is an important measure of physical identity. Establishing the identity of an individual from mutilated, decomposed and amputated body fragments has become an important necessity in recent times due to natural or manmade catastrophes e.g. earthquakes, floods, accidents, bomb explosions, war victims etc.

At times, the mutilation of dead body can also be done by the criminals who want to destroy all traces of identity to facilitate the easy disposal of the victim. Various studies have shown the correlation of stature with different body parts eg. Face, upper limb, lower limb and long bones.

Most studies utilized the long bones for estimation of stature, a very few studies have been conducted so far to find out the stature with the help of foot measurements. The reliability of prediction of stature from foot length is as high as that from long bones.

The relationships of stature to length of bones differ among populations, and different regression equations are required for individuals belonging to different populations. So, there are inter-racial & inter-geographical differences in measurements & their correlation with stature which may be true for the other.

Present study has established definite correlation between stature and foot-length and also developed regression equations. It will help in establishing an individual's identity particularly when only some body remains are found as in mass disasters, bomb explosions, accidents etc. If either of the measurement (foot length or total height) is known, the other can be calculated and this would be useful for anthropologists and forensic experts.

Material & Method

Present study was conducted in the department of Forensic Medicine at Rama Medical College, Kanpur.

88 young and healthy female medical students of 17 to 25 years had been selected for this study. Apart from taking detailed medical history clinical examination of all subjects was done and cases having any disease or orthopedic deformities, metabolic or developmental disorders which could have affected the general or bony growth were excluded from this study.

Measurement of foot length (Right & Left) and measurement of height were taken as maximum height of an individual is attained during this period. We have observed the correlation of height (in anatomical position) with foot length of subjects. .

Equipments Required

- Vernier caliper
- Measuring tape.
- Stadio meter

Method

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 second toe (when the second toe was longer) by spreading caliper when the subject was sitting in a relaxed position putting same weight on both feet after taking off the shoes and the stockings. The foot length of both right and left foot were measured.

For Height measurement, the subject was requested to stand barefoot on the foot place of the stadio meter with the head held in the Frankfurt horizontal plane. The heels were kept together and hands hanged down on each side with the palm facing the thighs. The subject inhaled deeply and maintained this upright posture during measurement and the wooden plate was gently placed on the centimeter scale keeping the eye on the same level where the vertex was in touch with the wooden plate. The measurement was carried out at a particular period of time between 10 am to 2 pm to avoid diurnal variation.

In Vernier caliper, Length = reading of the main scale + Vernier coincidence x Vernier constant + mechanical error (Here Vernier constant = 0.01 and Mechanical error = 0)

Calculation of stature using regression equation:

Stature = value of constant + regression coefficient x foot length.

Value of the constant and the regression coefficient were calculated using SPSS version 16.0 program. Present study was done exclusively for estimation of stature by forming the regression equations using percutaneous length of foot length. Total numbers of cases were subjected to statistical computations.

Table-1 Distribution of Subjects

Age (in yrs.)	Frequency
17	1
18	2
19	16
20	27
21	17
22	7
23	4
24	6
25	8
Total	88

Table-2 Measurement of Height in females

Total Number	88
Height Range (in cm)	148-174
Mean Height	157.78
Standard Deviation of height	5.906

Table-3 Right Foot indices of females

	Female
Right foot length Range	10-23
Mean foot length	15.40
Standard Deviation of right Foot length	2.39
Correlation coefficient(r) between height & right foot length	0.3608
Regression coefficient (b) of right foot	0.8905
Value of constant (a)	144.07

Table-4 Left Foot indices of females:

	Female
Left foot length Range	9.4 – 22.6
Mean left foot length	15.10
Standard deviation of left foot length	2.38
Correlation coefficient (r) between height & left foot length	0.347
Regression coefficient (b) of left foot	0.8506
Value of constant (a)	144.936

Regression Equation:

Stature (Y) = Value of constant (a) + Regression coefficient (b) * foot length

Table -5 {table (3) & (4)} Showing Regression equation of foot length

	Female
Right	Stature (Y) = 144.07+ 0.8905* foot length
Left	Stature (Y) = 144.936+0.8506* foot length

Results

The data was collected, analyzed and subjected to statistical package for social sciences (SPSS) -21.0 version to know the correlation of stature with the length of foot and simple linear regression were derived for various combinations.

There was a significant correlation between height p & Right foot length (r = 0.329, p< 0.01 for male and r = 0.3608, p < 0.01 for female) and height and entire subjects mean foot length (r = 0.5964, p< 0.01). It means that there is a positive correlation between height and right foot length.

There was a significant correlation between height p and Left-foot length(r= 0.343, p< 0.01 for male and r = 0.347, p < 0.01 for female) and height and entire subjects mean foot length (r = 0.5960, p < 0.01). It means that there is a positive correlation between height and left foot length.

The regression equations for height and foot length were found to be as follows:

Stature (Y) = 144.936 + 0.8506* foot length (for left foot of female)

Stature (Y) = 144.07+0.8905 * foot length (for right foot of female)

Discussion

In day to day medico legal practice, difficulties are being experienced in the estimation of stature particularly in dismembered bodies in mass destruction. To overcome these problems, new methods are being developed for calculation of stature. This study was dedicated to the derivation of regression formulae for estimating stature from length of foot whenever needed. In addition multiplication factors devised in this study would be of importance for calculating stature thus minimizing erroneous estimation.

Present study deals with observations on the correlation of standing height with right and left foot lengths. Our study was conducted on a population group where students belonging to various regions of Uttar Pradesh were studied to predict the stature by percutaneous measurement of foot (Right & Left) and height. A positive correlation between height and foot was established and the stature is determined by applying linear regression equations. There is no statistically significant difference in the lengths of right foot and left foot (Z=0.83, P>0.05).

We devised the linear regression equations as well as multiplication factors for estimation of stature. There was bilateral variation in left and right foot dimensions, with left side preponderance. In this study foot length is found to be good parameter for predicting stature compared to foot breadth in both the genders. The linear regression equation derived from foot length for estimation of stature showed a statistically significant relationship. However, foot breadth was not found to be a good parameter for estimation of stature.

Vidya CS in her study concluded that left foot is slightly lengthier than that of right foot in both the sexes.² In the present study even though there is no statistically significant difference in right and left footprint lengths.

Theodoros B Grivas (2008) stated that right foot length and left foot length is independent predictor of

stature.³ These findings are supported by the present study.

Abraham Philip⁴ estimated stature from known foot size by regression method. In the present study regression equations are derived to predict stature separately for right foot length and left foot length.

Agnihotri A K⁵ in his study found general multiple linear regression model was highly significant (P<0.001) and multiple correlation coefficient was (r) 0.877. In present study correlation coefficient of +0.82 and +0.80 respectively obtained for right and left footprint lengths.

Our results are in consistent with the study of Qamra et al⁶ who computed linear regression equations for estimating stature from either foot length or foot breadth and found that foot length was found to be more suitable .he suggested that a true relationship existed only between foot length and stature.

Giles et al⁷ also suggested that foot length displays a biological correlation with height and the latter can be estimated from foot length. Gordon et al⁸ estimated stature from foot dimensions and models containing both foot length and foot breadth were found to be significantly better than those containing only foot length. In this study, strong relationship was established between foot/boot lengths.

Singh and Phookan⁹ examined Thai male population of Assam and suggested foot length to be a better indicator of stature than foot breadth.

Nath et al¹⁰ formulated multiplication factors for reconstruction of stature from foot length of Rajputs and Brahmins of Srinagar, Garhwal (U.K.) with reasonable accuracy.

Jain et al¹¹ formulated multiplication factor as 6.59 for reconstructing stature among Jats females of Delhi between 17-20 years whereas in our study these were 7.76 and 7.71 for right and left foot length for females. Again the differences could be due to variations in the study group belonging to different regions.

Agnihotri et al⁵ developed a relationship between foot length and stature using linear and curvilinear regression analyses 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<0.001)

and validated with highest values for the coefficients of determination $R^2=0.769$ and multiple correlation coefficient $r=0.877$.

Krishan and Sharma¹² examined the relationship between stature and dimensions of hands and feet among Rajputs of Himachal Pradesh on a group of 246 subjects (123 males and 123 females) 17 to 20 years old. In their study also the highest correlation coefficient existed between stature and foot length. Their lowest standard error of estimate indicated that the foot length provides highest reliability and accuracy in estimating stature.

Kanchan et al¹³ examined the relationship between stature and foot dimensions among 200 (100 males and 100 females) Gujjars (North Indian community). They devised linear and multiple regression equations for estimating stature using foot dimensions. Their results are similar to our study.

Sen and Ghosh¹ established the relationship between stature and feet dimensions among Rajbanshi male and females of North Bengal. Stature, foot length and foot breadth are positively and significantly correlated with each other. Contrary to our study, they found foot breadth to be more accurate in estimating stature. They concluded that their study provided equations to estimate stature from the feet dimensions among the Rajbanshis. It would be unwise to use the same equations for stature estimation for different Indian populations.

Present study illustrates that foot measurements have a strong relationship with stature in the young female population of North India. Hence, the stature of an individual can be successfully estimated from the foot using different regression models derived in the study. It was observed that the regression models derived from foot length measurements were more reliable than those from foot breadth measurements in the prediction of stature in forensic examinations. Stepwise multiple regression models tend to estimate stature more accurately than linear regression models in female sub-adults. Similar studies on a male population are proposed. It is highlighted here that the findings of the present research apply to a very specific population (North Indian females) and hence, should not be generalized. Researchers are encouraged to conduct similar studies in different population groups to look into the generation of additional standards which can further be used in the identification of individuals from human remains.

Conclusion

Foot dimensions give better prediction of stature than the other measurements as they are strongly correlated with stature. It is further concluded that the reliability and prediction of stature by the regression method is better than that of the division factor method. There are lot of variations in estimating stature from limb measurements among people of different region & race. It is, therefore, studies are required to collect the data from the different part of globe as the stature is the inherent characteristic of the individual, though influenced environmentally, therefore regional, simple and multiple regression equations can be of great value and quite handy for use by a lay public like police etc, also.

Conflict of Interest: None

Ethical Clearance: Taken from the Ethical Committee from the Institute

Source of Support: Nil

References

1. Sen J and Ghosh S. Estimation of stature from foot length and foot breadth among the Rajbanhsi: An indigenous population of North Bengal. *Forensic Science International* 181 (2008) 55.e1–55.e6
2. Vidya CS, ShamasundarNM, Manjunatha, Nitin MD. Study of footprints for sex determination in the South Indian population. *Journal of South IndiaMedicolegal Association* 2009 Sept; 1(2): 49-52.
3. Theodoros B G, Mihas. Correlation of foot length with height in school age children. *J Forensic and Legal Medicine*. 2008 Feb; 15(2): 89-95.
4. Abraham Philip. Formulae for estimating stature from foot size by regression method. *J IndAcadFor Med*, 1990; 12 (2):57-62.
5. Agnihotri AK, Purwar B. Estimation of stature by foot length. *J Forens and Legal Med*, 2007 July; 14(5): 279-283.
6. Qamra SR, Jit I, Deodhar SD. A model for reconstruction of height from foot measurements in an adult population of North West India. *Indian J Med Res*. 1980; 71: 77 – 83.
7. Giles E, Vallaneligham PH. Height estimation from

- foot and shoe print length. *J Forensic Sci.* Jul 1991; 36(4): 134-1151.
8. Gordon CC, Buikstra JE. Linear models for the prediction of stature from foot and boot dimension. *J Forensic Med Sci.* 1992; 37(3): 771 –782.
 9. Singh TS, Phookan MN. Stature and foot size in four Thai communities of Assam, India. *Anthropol ANZ.* 1993; 51(4): 349 – 355.
 10. Nath S, Kaur S, Jain P, Joshi PC. Reconstruction of stature among Rajputs and Brahmins of Srinagar Garhwal (U.P.). *South Asian Anthropologist.* 1999;20(2): 63-66
 11. Jain P, Roy S, Nath S. Estimation of stature through measurements of hand and foot among female Jats of Delhi. *Anthropologists.* 1999;1(3):171-173.
 12. Krishnan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. *J Forensic Leg Med.* 2007; 14(6):327-32.
 13. Kanchan T, Menezes RG, Moudgil R, Kaur R, Kotian MS, Garg RK. Stature estimation from foot dimensions. *Forensic Sci Int.* 2008; 179(2-3):241.e 1-5.