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ESTIMATION OF STATURE BASED ON FOOT LENGTH

Vidyullatha V. Shetty¹

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ABSTRACT: BACKGROUND: Stature is the height of the person in the upright posture. It is an important measure of physical identity. Estimation of body height from its segments or dismember parts has important considerations for identifications of living or dead human body or remains recovered from disasters or other similar conditions. **OBJECTIVE:** Stature is an important indicator for identification. There are numerous means to establish stature and their significance lies in the simplicity of measurement, applicability and accuracy in prediction. Our aim of the study was to review the relationship between foot length and body height. **METHODS:** The present study reviews various prospective studies which were done to estimate the stature. All the measurements were taken by using standard measuring devices and standard anthropometric techniques. **RESULTS:** This review shows there is a correlation between stature and foot dimensions it is found to be positive and statistically highly significant. Prediction of stature was found to be most accurate by multiple regression analysis. **CONCLUSIONS:** Stature and gender estimation can be done by using foot measurements and study will help in medico-legal cases in establishing identity of an individual and this would be useful for Anatomists and Anthropologists to calculate stature based on foot length.

KEYWORDS: Stature, Foot length, Foot dimensions, Regression, Correlation, Anthropometry.

INTRODUCTION: Stature is the height of the person in the upright posture. It is an important measure of physical identity. Dimensional relationships between the body segments and the whole body have been of interest to artists, scientists, anatomists, anthropologists and medicolegistics for long time.¹ Anthropometry as defined by Wilbur A.K² is adopted by medical scientist is described as a technique of expressing the form of human body quantitatively as it is the systematic collection and correlation of measurement of the human body. Telkka² further explains body proportions and the dimensions of various body segments, including the long bones of their limbs and the bones of the foot and hand have been used to estimate stature. Charnalia³ further showed the dimensional relationship between body segments and the whole body has been the focus of anatomists, scientists, and anthropologists for many years.

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 measurement as compared to that from long bones.

Examination of skeletal remains recovered from a scene of crime, have often been used by the forensic anthropologists to extract relevant information about the victim. One such aspect pertains to reconstruction of living stature from such skeletal remains.⁴

In medico-legal autopsies, establishing personal identity of the victims is often required. Estimation of stature from extremities and their parts plays an important role in identifying the dead body in forensic examinations.⁵

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MATERIAL AND METHODS: A prospective study of age group 17 to 25 years medical students were the subject for a study. Ethical clearance was obtained from Institute Ethical Review Committee before starting the study. Informed consent of participants was taken and socio-demographic indices like age and sex was noted. Each student was studied for the measurements of stature and foot length. The measurements were taken by using standard anthropometric instruments.

Sample size was taken as 440 (258 male and 182 female) asymptomatic, healthy medical students of the age group ranging between 17 – 25 years. The subject having any disease or deformity was not included in this study.

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 second toe when the second toe was longer than hallux by spreading caliper in centimeter.

Height of the individual was measured in standing erect anatomical position with standing height measuring instrument in centimeter.

Students having any disease, deformity, injury, fracture, amputation or record of any surgical procedures of either hand or foot were disqualified from the study. The measurements were taken at a fixed time between 2.00 to 4.00pm to eliminate the possibility of diurnal variation and by only one observer in order to avoid inter-observer error.

The data obtained were computed and analyzed using SPSS (Statistical Package for Social Sciences) computer and results drawn. The linear and multiple regression models with the explanatory variables or regressors, foot length and hand length was used as a statistical model to explain the relation or the variation in stature, the response or dependent variable.

RESULTS: There is significant correlation coefficient between height and right foot length($r = 0.688$, $p < 0.01$ for male and $r = 0.587$, $p < 0.01$ for female), height and left foot length ($r = 0.689$, $p < 0.01$ for male and $r = 0.589$, $p < 0.01$ for female) and height of entire subjects and mean foot length ($r = 0.703$, $p < 0.01$). It means that there is strong positive correlation between height and foot length of people. The regression equation for height and foot length was found to be $y = 2.738x + 100.2$ (for left foot of male), $y = 2.74x + 100.1$ (for right foot of male), $y = 2.66x + 96.40$ (for left foot of female), $y = 2.66x + 96.31$ (for right foot of female), $Y = 3.179 X + 87.65$ (for both male and female and mean foot length), where X is the foot length and Y is the height.

DISCUSSION: Myriad 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 easiest and the reliable method is by regression analysis. All the study conducted most often have chosen medical students as in this study also, because easy availability of the study population and also easy for obtaining highest co-operation.

Table-I shows that the age ranges from 17 to 25 years, foot length from 18- 28.5 cm in male and 19 to 27 cm in female and total height from 134 to 183 cm in male and 140 to 185 cm in female with a significant correlation between them.

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Table 2 shows the correlation coefficients between various parameters. Between age and height, between age and foot length and between height and foot length. It is positive, suggesting that it is significant. The correlation coefficients between height and foot length, indicate the foot length provides highest reliability and accuracy in estimating stature of an unknown individual.

In present study the correlation coefficient between height and foot length is + 0.688 in male and + 0.587 in female which is highly significant. From the above facts, it is clear that if either of the measurement (foot length or total height) is known the other can be calculated and this fact may be of practical use in Medico-legal investigations and in Anthropometry. Our finding is similar to the study conducted by Ozden H et al (2005)⁶ conducted in Turkey in this regard.

Charnalia VM showed the significant correlation between height and foot-length, where correlation coefficient was 0.46.19 According to John G, nasion-inion length (head-length) is 1/8 of the total height of an individual.³ Shushil Kumar et.al measured length of forearm and hand of 200 male medical students age ranging 18-25 years in India and developed a formula.⁶ Bhavna et.al have been studied on 503 male Shiah Muslim of Delhi, India and reported a body dimension which correlates highly with stature.⁷ Natarajamoorthy T et.al studied on 107 randomly selected subjects in Malaysia and developed a regression equation for stature estimation from foot length obtained from foot impression.⁸ Patel SM et.al in their study on 502 medical students (278 male and 224 female) between 17 to 22 years of age belonging to various region of Gujarat, India and reported a regression formula between foot length and height of an individual.⁹ Krishna K, et al. have been studied on 252 Koli male adolescents from North India and suggested that all the cephalo-facial measurements are significantly correlated with stature.¹⁰ Krishna K, et.al reported a regression equation for stature estimation from dimension of hand and feet in a North Indian Population.^{11,12} Jadav HR, et al. took length of head of 727 (468 male and 259 female) medical students belongs to various region of Gujarat, India and established a regression equation.¹³ Saxena SK, et.al who derived a regression equation between head-length and height in Agra population. Their correlation coefficient between head-length and height was +0.2048.¹⁴ Qamra S, et al made a study on height and foot length and derived a correlation coefficient for foot breadth (Male 0.42 and Female.0.47) and foot length (Male 0.69 and Female 0.70).¹⁵ Shroff AG, et al. have also derived the height from the length of superior extremity and its segments.¹⁶ Singh B, et al. and Jit I, et al. have shown a significant correlation between height and length of clavicle.^{17,18}

CONCLUSION: This study indicates that stature can be predicted accurately by linear and multiple regression analysis even when identity is unknown from foot length - a problem frequently encountered in medico-legal investigations. Establishing identity of an individual when only some remains of the body 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 Medicine experts. It will also help in establishing identity in certain civil cases.

This study also found that foot measurements can be used to calculate stature with reasonable accuracy using statistical considerations and it is revealed that a single dimension can

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estimate the stature of a person with a great accuracy and small standard error. There are lot of variations in estimating stature from limb measurements among people of different region & race. Hence there is a need to conduct more studies among people of different regions & ethnicity so that stature estimation becomes more reliable & identity of an individual is easily established.

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Age	Mean height in cm		Mean foot length in cm	
	Male	Female	Male	Female
17	164.000	-	22.0000	-
18	165.7235	155.0300	23.4632	22.5762
19	165.0170	156.7864	23.7431	22.3679
20	165.1848	159.1478	23.5585	22.8906
21	167.7085	156.7672	24.1830	22.6923
22	166.0203	155.2982	23.5383	22.6562
23	165.6612	154.1321	24.2887	22.8556
24	166.2350	150.2510	25.2340	22.8333
25	163.1000	-	24.2100	-

Table 1: Table shows the average mean height in this prospective study

	Male	Female
Total Number	258	182
Height range (cm)	134 - 183	140 - 185
Mean height (cm)	165.66	155.70
S.D. of height	8.24	6.26
Foot length Range (cm)	18 - 28.5	19 - 27
Mean foot length (cm)	23.89	22.64
S.D. of foot length	2.19	1.46
Correlation Coefficient(r) (Height and Foot Length)	0.69	0.59
Regression Coefficient (b)	2.72	2.64
Value of Constant (a)	100.16	96.42

Table 2: Height, foot length, correlation coefficient, regression coefficient (b) and value of constant (a) in Male and Female.

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AUTHORS:

1. Vidyullatha V. Shetty

PARTICULARS OF CONTRIBUTORS:

1. Professor, Department of Forensic Medicine, Sri Muthukumaran Medical College Hospital & Research Institute, Chikkarayapuram, Mangadu, Chennai.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Vidyullatha V. Shetty,
Professor, Department of Forensic Medicine,
Sri Muthukumaran Medical College Hospital &
Research Institute, Chikkarayapuram,
Mangadu, Chennai-600069.
E-mail: vidyullatharajesh@rediffmail.com

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