International Journal of Biomedical and Advance Research
ISSN: 2229-3809 (Online); 2455-0558 (Print)
Journal DOI: https://doi.org/10.7439/ijbar
CODEN: IJBABN **Original Research Article**

Estimation of stature from hand length and foot length in Nagpur region of Maharashtra State

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***Article History:**
Received: 18/10/2017
Revised: 24/10/2017
Accepted: 02/11/2017
DOI: https://doi.org/10.7439/ijbar.v8i10.4455

Abstract

Aim and Objectives: Stature (body height) is an important and useful anthropometric parameter for identification of an individual. The present study was undertaken to set up a standard formulae to estimate stature from hand length and foot length in medical students of Nagpur region of Maharashtra state.

Method: Four hundred healthy and normal adult medical students comprising of 200 males and 200 females in 18-25 years age group were included in the study. The hand length and foot length were measured independently on left and right side of each individual using a Sliding caliper and spreading calipers respectively. Stature of individuals was measured with the help of a Stadiometer.

Results: The paired sample 't' test showed that the statistical difference between males and females on both sides was highly significant for all the measurements ($p < 0.0001$). The correlation between stature and various parameters studied in both the sexes were found to be positive and statistically highly significant ($p < 0.0001$). The correlation coefficient of foot length in both males and females together depicts higher correlation with stature than hand length with highest correlation coefficient 0.87. The correlation between stature and hand length as well as stature and foot length was higher in females than males. Linear and multiple regression equations for stature estimation were calculated separately for males and females as well as for both sexes together.

Conclusion: The significant positive correlations between the explanatory variables and stature indicate that these variables can be successfully used to predict stature.

Keywords: Hand length, Foot length, Stature, Sliding callipers, Spreading callipers, Stadiometer, Correlation coefficient.

1. Introduction

Personal identification is one of the main tasks of forensic research. Estimation of stature has been considered as one of the parameters of forensic anthropology and will assist in establishing the biological profile of a person [1]. Stature prediction occupies relatively a central position in anthropometric research. Anthropometry as 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 [2]. Dimensional relationship between body segments and the whole body has been the focus of anatomists, scientists, and anthropologists for many years [3]. 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 [4].

Stature is the height of the person in upright posture and this parameter determine the physical identity of an individual. Before estimating stature, one must determine the race, sex, and age of the individual as stature varies with these variables. Potential stature refers to the stature of an individual who has not undergone skeletal

changes associated with the aging process. These changes do not occur in most people who are 30 years of age or less at the time of death [5]. Living stature refers to the stature of an individual who has undergone degenerative changes associated with the aging process which results in a decrease in stature. Most people who are 30 years old or older at the time of death have undergone some of these changes [5].

Regression analysis is one of the most heavily used statistical methods in physical anthropology. This is largely as a result of its ubiquity and wide availability in statistical packages. Many previous studies have been done to estimate the stature from length of different long bones using either multiplication factors or regression formulae [6-8]. Others have tried to estimate the stature using different body parts such as length of hand and foot; head length and arm span [9-11]. Here, we have made an attempt to find out correlation between hand length and foot length with stature and also to derive regression equations for the calculation of stature from hand length and foot length.

2. Material and Method

The study design was a cross-sectional one, total 400 healthy and normal adult medical students of either sex (200 Male and 200 Female), age between 18-25 years and those having no obvious deformities or previous history of trauma to the hands or feet were selected for the study. Permission was obtained from the Head of Departments of medical colleges to conduct this study. After getting approval letter from Independent Ethics Committee, the study was started. Exclusion criteria included students with any musculoskeletal deformity like kyphosis, scoliosis, poliomyelitis, trauma etc. which will affect the normal measurements of hand and foot length, measurements excluded if any nail extending over the end of toe and other fingers, patients with pedal deformity or injury, abnormal heights like gigantism, dwarfism etc.

The subjects were measured for the following parameters after obtaining written informed consent.

2.1 Stature

Measured as vertical distance from vertex (the highest point on the top of head) to the floor in mid-sagital plane with subject standing barefooted, on an even floor and the head being oriented in the Frankfurt's plane. It is measured with the help of Stadiometer (Anthropometer) [12]. Frankfurt's plane: The plane determined by the lowest points on the infra orbital margins and the tragion (the notch immediately above the tragus of the ear). This corresponds almost exactly to the plane of visual axis, which is obtained when the individual is looking straight in front of him.

2.2 Hand Length

Measured as straight distance from mid-point of a line connecting the styloid processes of radius and ulna to the most anterior projection of the skin of the middle finger. The hand is laid flat on a table. It was measured with the help of sliding calipers [13].

2.3 Foot Length

Measured as straight distance from the most posterior projecting point on the heel to the tip of the most anterior projecting point of toe. With the subject standing erect, it was measured with the help of spreading calipers [13]. Before measuring the foot lengths, it was ensured that both the feet were firmly placed on a flat surface and ensuring that both feet bears the body weight evenly. Footrest was used for ensuring flat surface. The length is measured between most backward and prominent part of the heel and the most distal part of the longest toe of the foot. Second toe was considered as most prominent while measuring the foot length; wherever it was longer than the great toe.

The measurements of hand length and foot length were taken from the limbs of both sides of the body. The measurements were taken in centimeters. The results were analyzed statistically.

2.4 Statistical Analysis

Statistical analyses were done using descriptive analytical methods which included Mean and Standard deviation, Pearson Correlation coefficient (r) Regression equation, students paired 't' test with and usage of graph pad software system.

3. Observations and Results

Table 1 represents the mean values ± standard deviations (S.D), maximum, minimum values and ranges for the measured parameters. In male subjects, the mean stature was 172.10 ± 6.479 cm and ranged between 159 cm to 186 cm. The average hand length of right side and left side were 18.96±1.189 cm and 19.01±1.091cms respectively whereas average foot length of right side and left side were 25.60±1.335 cm and 25.96±1.327 cm respectively. Similarly in female subjects, the mean stature was 158.58±12.268 cm and ranged between 147 cm to 171 cm. The average hand length of right side and left side in female subjects were 17.64±0.834 cm and 17.59±0.874 cm respectively while the average foot length of left side and right side were 23.26±1.179 cm and 23.20±1.167 cm respectively. Hence the mean values of stature, hand length and foot length were found to be greater for males than females.

Table 1: Descriptive statistics of parameters studied in total sample

	Hand Length		Foot Length		Stature
	Right	Left	Right	Left	
Minimum	15.8	16	20.3	20.7	147
Maximum	21.5	21.6	29.2	29.0	186
Range	5.7	5.6	9.2	8.3	39
Mean	18.30±1.219	18.33±1.239	24.42±1.717	24.38±1.716	164.93±4.986

All the parameters in the total sample exhibited statistically significant ($P < 0.0001$) positive correlations with the stature on both sides but the correlation coefficient of foot length depicts higher correlation with stature than hand length with highest correlation coefficient of 0.87. The correlation between stature and hand length as well as stature and foot length was higher in females than males, (Table 2).

Table 2: Correlation coefficient (r) between dependant variable (stature) and explanatory variables (LHL, RHL, LFL and RFL) in the total sample, in males and in females

Sex	Parameters	r	'P' value
In Males	Left Hand Length	0.66	< 0.0001
	Right Hand Length	0.72	
	Left Foot Length	0.69	
	Right Foot Length	0.66	
In Females	Left Hand Length	0.74	< 0.0001
	Right Hand Length	0.71	
	Left Foot Length	0.79	
	Right Foot Length	0.76	
In Both	Left Hand Length	0.81	< 0.0001
	Right Hand Length	0.80	
	Left Foot Length	0.87	
	Right Foot Length	0.85	

The linear regression analysis of the data has provided the regression equations for each parameter to predict the height in both males and females together and in either male or female (Table 3). While multiple linear regression equation for the estimation of stature from combination of the dimensions of foot and hand in males, females and in both sexes, (Table 4). The multiple regression equations shows multiple correlation coefficients for RHL-RFL and LHL-LFL in males, females and both as 0.75 and 0.74 , 0.79 and 0.82 , 0.87 and 0.89 respectively which were greater than the correlation coefficients of simple regression equations. Therefore the interpretation of these results suggested that the multiple regression equations were better indicators of stature estimation from hand lengths and foot lengths as compared to the simple linear regression equations.

Table 3: Linear regression equations obtained for various parameters studied in males and females as well as in total sample were as follows:-

Sex	Measured parameters	Linear regression equations
In Males	Left Hand Length	Stature = 97.557+ 3.907
	Right Hand Length	Stature = 98.108 +3.903
	Left Foot Length	Stature = 86.001 + 3.369
	Right Foot Length	Stature = 89.963 + 3.210
In Females	Left Hand Length	Stature = 84.572 + 4.208
	Right Hand Length	Stature = 83.260 + 4.269
	Left Foot Length	Stature = 80.275 + 3.375
	Right Foot Length	Stature = 84.155 + 3.200
In Both	Left Hand Length	Stature = 57.926 + 5.859
	Right Hand Length	Stature = 58.310 + 5.849
	Left Foot Length	Stature = 55.849+ 4.491
	Right Foot Length	Stature = 57.778 + 4.404

Table 4: Multiple regression equations for various parameters studied in males and females as well as in total sample were as follows

Sex	Linear regression equations
In Males	Stature = 81.086 + 2.707 (RHL) + 1.551 (RFL)
	Stature = 75.404 + 2.110 (LHL) + 2.208 (LFL)
In Females	Stature = 72.470 + 2.075 (RHL) + 2.128 (RFL)
	Stature = 70.456 + 1.978 (LHL) + 2.299 (LFL)
In Both	Stature = 46.780 + 2.474 (RHL) + 3.001 (RFL)
	Stature = 46.536 + 2.337 (LHL) + 3.115 (LFL)

The equations also exhibit standard error of estimate (SEE). The SEE predicts the deviations of estimated stature from the actual stature. Table 5 shows the SEE values of all possible simple and multiple linear regression equations with respect to males, females and total sample. A low value indicates greater reliability in the estimated stature.

Table 5: R, R^2, Adjusted R^2 and SEE values of all possible (simple and multiple) linear regression equations with respect to males, females and total sample

Sex	DV	EV(s)	R (r)	$R^2(r^2)$	Adjusted R^2	SEE
Male	Stature	RHL	0.72	0.51	0.51	5.124
		LHL	0.66	0.43	0.43	6.075
		RFL	0.66	0.43	0.43	6.629
		LFL	0.69	0.47	0.47	6.429
		RHL&RFL	0.75	0.57	0.56	5.937
		LHL&LFL	0.74	0.55	0.54	6.303
Female	Stature	RHL	0.71	0.51	0.51	5.250
		LHL	0.74	0.54	0.54	4.824
		RFL	0.76	0.57	0.57	4.579
		LFL	0.79	0.62	0.62	4.328
		RHL&RFL	0.79	0.63	0.62	4.782
		LHL&LFL	0.82	0.68	0.67	4.330
Both (M+F)	Stature	RHL	0.80	0.64	0.64	4.010
		LHL	0.81	0.66	0.66	3.832
		RFL	0.85	0.72	0,72	3.351
		LFL	0.86	0.75	0.75	3.175
		RHL&RFL	0.87	0.76	0.77	3.361
		LHL&LFL	0.89	0.79	0.78	3.161

4. Discussion

The results of the present study demonstrated that the length of the hands and feet show statistically significant positive correlation with stature of an individual. The presence of a positive linearity between the study variables and stature facilitates formulation of regression equations which can be successfully utilized for stature estimation in study population.

In our study, the mean value of stature was higher in males as compared to females. Thus the mean values of all male parameters studied were higher when compared with mean values of female parameters; this result was correlated with other studies [14-16]. These statistically significances between males and females were due to the fact that fusion of epiphysis of bones occurs earlier in males than females. Males have about two more years of bone growth than females [14]. The present study showed bilateral symmetry for all the parameters studied in males and females. Studies conducted by Jasuja *et al* [17] reported significant asymmetry for foot length and Krishan *et al* [1] reported significant asymmetry for hand length. All the parameters of our study showed positive correlation with stature by Pearson correlation coefficient and thus results can be applied for stature estimation. The Correlation coefficients for right and left hand length in both sexes were 0.80 and 0.81 respectively. Also for right and left foot lengths were 0.85 and 0.87 respectively. Therefore foot length was the best parameter for the estimation of stature in total subjects. This supports the findings of Khanapurkar *et al* [18].

The value of correlation coefficient for males hand length was 0.72 and for females hand length was 0.74. Female hand length parameter showed statistically significant and highly positive correlation with stature than male hand length parameter. This was similar with the previous studies [14,18,19]. Similarly the value of

correlation coefficient for males foot length was 0.69 and for female foot length was 0.79. The difference in the correlation coefficients in males and females may be attributed to environmental, social and genetic factors. Female foot length showed statistically significant highly positive correlation with the stature than male foot length. This finding was similar with the study of Philip *et al* [20] and IIaperuma *et al* [21].

The presence of positive correlations between stature and other study parameters hand length and foot length facilitates formulation of regression equations which can be successfully utilized for stature estimation in the population. In the present study height was estimated using simple and multiple linear regression models, we compared the results of these models and found that the multiple linear regression models was better than simple linear regression model for estimating stature. The coefficient of determination (R^2) values for RHL-RFL and LHL-LFL in male were 0.57 and 0.55 respectively which indicates 57% and 55% of the prediction of the height can be attributed to hand length and foot length of right side and left side respectively. Similarly the coefficient of determination (R^2) values for RHL-RFL and LHL-LFL in female were 0.62 and 0.68 respectively which indicates 63% and 68% of the prediction of the height can be attributed to hand length and foot length of right side and left side respectively. For both male and female the coefficient of determination (R^2) values for RHL-RFL and LHL-LFL were 0.76 and 0.79 respectively which indicates 76% and 79% of the prediction of the height can be attributed to hand length and foot length of right side and left side respectively.

The multiple correlation coefficients 'R' in both males and females together was 0.89, also R^2 was 0.79. This means 79% of prediction of height can be done by hand length and foot length together while 75% of prediction of height could be attributed to foot length alone and 66% to hand length alone i.e. more accurate prediction of height can be done by multiple regression equation than simple linear regression equation. Similar to our results Krishnan *et al* [1] and Sanli *et al* [22] also stated that multiple linear regression model is best fitted than simple linear regression model for estimating height from hand length and foot length. It was observed that multiple regression equations were with highest values of R, R^2, and adjusted R^2 and with lowest values of SEE. Therefore the interpretation of these results suggests that multiple regression equations were the best indicators of stature estimation compared to linear regression equations.

The result of present study shows that the dimensions of hand lengths and foot lengths can be successfully used for estimation of stature by law enforcement agencies forensic experts and anatomists. The only precaution which must be taken into consideration is that these formulae are applicable to the population from which the data have been collected. It is due to inherent population variations in these dimensions, which may be attributed to genetic and environmental factors like climate, nutrition etc.

5. Conclusion

In the present study, all the parameters correlated significantly with stature but foot length in both males and females together depicts higher correlation with stature than hand length. This significant positive correlation between the explanatory variables and stature indicate that these variables can be successfully used to predict stature. Also, study concluded that multiple linear regression analysis is better over simple linear regression analysis in accurately estimating stature.

Acknowledgement

The authors sincerely thank the Department of Anatomy and administration of Indira Gandhi Government Medical College and Hospital, Nagpur, Maharashtra, for permission to study and providing facility to carry out the work. As well authors would like to give thanks to all participants who participated in the study as without their help and cooperation this research work would not have been possible to conduct.

Reference

[1]. Krishan K, Sharma A. Estimation of stature from dimensions of and feet in a north Indian population. *J Forensic Leg Med* 2007; 14(6): 327-332.

[2]. Wilbur AK. The utility of hand and foot bones for the determination of sex and the estimation of stature in a prehistoric population from west central Illinois. *International Journal of Osteoarchaeology* 1998; 8:180–191.

[3]. Charnalia VM. Anthropological study of the foot and its relationship to stature in different castes and tribes of Pondicherry state. *Journal of Anatomical Society of India* 1961; 10:26-30.

[4]. Telkka A. On the prediction of human stature from the long bones. *Acta Anat.* (Basel) 1950; 9:103–317.

[5]. John DS, Denis CM and Reubin A. Longitudinal change in height of Men and Women. *American Journal of Epidemiology*, 1990; 150(9).

[6]. Nat BS. Estimation of stature from long bones in Indians of the United Province: A medicolegal inquiry in anthropometry. *Indian J Med. Res*, 1931; 18:1245-1263.

[7]. Dupertuis CW and Hadden JA. On the reconstruction of stature from long bones. *Am J Phys Anthropol*, 1951; 9:15-53.

[8]. Trotter M and Gleser GC. A re-evaluation of stature based on measurements of stature taken during life and long bones after death. *Am J Phys Anthropol*, 1958; 16:79-123.

[9]. Saxena HK *et al*. The estimation of stature from head length. *Journal of Anatomical Society of India*.1979; 28:53.

[10]. Pawar PK, Dadhich A. Study of correlation between height and hand length in residents of Mumbai. *Int. J Biol Med Res.* 2012; 3(3): 2071-2075.

[11]. Hossain S *et al*. Measurement of stature from arm span – An anthropometric study on Garo tribal Bangladeshi females. *Bang J Anat.* 2011; 9(1):5-9.

[12]. Ashley Montagu MF. A Handbook of anthropometry. USA: Charles C Thomas; 1960; 3-13.

[13]. Bansal H, Badiye A. An Estimation of Correlation between Head length and the Stature of the Children aged between 6-10 years. *Research Journal of Forensic Sciences*.2013; 1(2):1-4.

[14]. Abdel-Malek AK, Ahmed AM, El sharwaki SA, Hamid NA. Prediction of stature from hand measurements. *Forensic Sci Int.* 1990; 46:181-87.

[15]. Giles E, Vallandigham PH. Height estimation from foot and shoe print length. *JFSCA*. 1991; 36(4):1134-51.

[16]. Qamra SR, Indar J, Deodhar SD. A model for reconstruction of height from foot measurements in an adult population of Northwest India. *Indian J med Res.* 1980; 71:77-83.

[17]. Jasuja OP, Manjula. Estimation of stature from foot step length. *Forensic Sci Int.* 1993; 61:1-5.

[18]. Khanapurkar S, Radke A. "Estimation of stature from the measurement of foot length, hand length and head length in Maharashtra region." *Indian Journal of Basic & Applied Medical Research* 2012; 01:77-85.

[19]. Rastogi P. Methods of stature estimation: A review. *J Forensic Med Toxicol.* 2009; 26(1):10-13.

[20]. Philip TA. Foot size for predicting stature of males. *Ind Acad Forensic Sci.* 1988; 27(2):30-39.

[21]. Ilayperuma I, Nanayakkara BG, Palahepitiya KN. A model for reconstruction of personal stature based on measurements of foot legth. *Galle Med J*. 2008; 13(1): 6-9.

[22]. Sanli SG, Kizilkanat ED, Boyan N, Ozasahin ET, Bozikir MG, Soames R *et al*. Stature estimation based on hand length and foot length. *Clin Anatomy* (New York, N.Y.). 2005; 18:589-96.