Estimation of human stature by measurements of foot

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Abstract

Introduction: Stature is the height of the person in upright posture. It is an important physical identity. Assessing the height of an individual, from measurements of different parts, has always been of immense interest to the anatomists, anthropologists and forensic medicine experts.

Material and Methods: This cross sectional analytic study was carried out on 196 medical student of first year MBBS of two medical colleges of Uttar Pradesh,of age group of 18-23years having no foot deformity, spinal or bony injuries or surgeries. Following parameters were recorded: age, residence, gender, weight, height, foot length and foot breadth. The obtained data was statistically analyzed; Correlation coefficient has been calculated and Regression equations for estimation of height from foot length and foot breadth were derived.

Results: The mean age (year) was 19.76±1.95, Stature (cm) mean of male and female was 164.90±14.50, weight (kg) was 65.13±12.80, Left Foot Breadth (cm) was 10.1±0.72, Right Foot Breadth (cm) was 10.30±0.72, Left Foot length (cm) was 25.68±1.66 and Right Foot length (cm) was 25.62±1.58. Males having significantly higher values than females. **Correlation** by comparing the Pearson correlation coefficient, foot length(FL) showed the highest relationship in males (FLR:r = 0.188, FLL: r=0.194) and females (FLR: r = 0.698, FLL: r=0.703). Regression for women, prediction accuracy was the highest when the regression equation involved foot length.

Conclusion: It is concluded that males have greater mean value of stature as compared to that of females. It was also observed that there is direct relationship between foot length and foot breadth with the stature in both sexes.

Keywords: Stature, Foot length, Food breadth.

Introduction

Age, sex and stature are the primary characteristics of identification. Personal identification means determination of individuality of a person. It may be complete (absolute) or incomplete (partial). Absolute fixation of individuality of a person means complete identification and partial identification means ascertainment of only some facts about the identity of the person while others still remain unknown.[1]Like other parts of the body such as head, trunk, lengths of upper and lower limb, the foot size also displays a definite biological correlation with stature. On the basis of this relationship, it is possible to predict the stature from the foot and its segments.[2]

In medico-legal cases height estimation is as important as other parameters like age, sex and race.[3]The stature of an individual is an inherent characteristic which varies with race and is determined by genetic constitution of a person, geographical location, environment and climatic conditions.[4]In mass disasters, it is essential to find out correlations between stature, age and sex of an individual with variable information collected from different systems, organs or its parts which is of great importance. Many Researchers established correlation between hand and foot measurements with stature.[5-7]

Morphology and morphometry of human feet is greatly affected by the combined effects of heredity and living style of man and that determines the sizeand shape of the feet or footprints and makes them unique parameter to establish human identity.[8,9] Clinicians, anthropologists, anatomists and forensic scientists have studied the various aspects of foot, over a long period of time.[9] Primarily, Rutishauser et al find foot length as a reliable predictor for estimation of body height.[10] Since then, many authors discover other predicting factors to determine height with higher accuracy and reliability. Because maturation and ossification of small bones of foot occur earlier than the long bones so the body height can be predicted earlier by measuring foot parameters than by long bones indices so the application of foot bones indices can be more valuable.[11]As foot ossification and maturation is earlier than long bones in adolescent age group, foot length can be used to predict stature of an individual.[12] The foot length has been correlated with weight and height even in dead fetuses thereby making possible the estimation of foetal age and body dimensions with precision.[13]

So the aim of the present study was to consider the following measurements in a population sample from North India- foot length and foot breadth and correlate them with stature. To calculate the height from hand and foot measurements, regression formulae were

established in the whole sample (combined population), in male and female samples separately (sexual dimorphism). Such formula will be of great use in medicolegal cases.

Material and Methods

This cross sectional analytic study was carried out on 200 medical student of first year MBBS of two medical colleges of Uttar Pradesh. Participants were of age group 18-23years, having no foot deformity, spinal or bony injuries or surgeries. Prior ethical clearance (from IERC) and consent from participantswas taken.

Following parameters were recorded: age, residence, gender, weight, height, foot length and foot breadth. Age and residence was confirmed by documents of students submitted in records.

Height was measured on stadiometer. They were made to stand bare foot against wall and height was measured in centimeters, at a fixed time to eliminate diurnal variation and by same person to avoid personal error in methodology.

Foot length& Foot Breadth: Toe nails were trimmed and measurements were taken on ruled paper in standing position. Foot Length: measured as distance between proximal and distal point on both right and left foot. Proximal point is the point of maximum curvature on outline of heel. Distal point is the point of maximum curvature on outline of great toe or of second toe, which one was bigger. It was measured by measuring scale in centimeters.Foot Breadth: was measured as a direct distance between the most prominent point on the medial aspect of head of first metatarsal and most prominent point on the lateral aspect of head of fifth metatarsal by measuring scale in centimeters.

The obtained data was statistically analyzed; Correlation coefficient between Height and right foot breadth, between Height and left foot breadth, between right Foot length and right Foot breadth in combined male and female respondents, for male respondents and for female respondents separately has been calculated. Regression equations for estimation of height from foot length and foot breadth were derived.

Results

The mean age (year) was 19.76±1.95, Stature (cm) mean of male and female was 164.90±14.50, weight(kg) was 65.13±12.80, Left Foot Breadth (cm) was 10.1±0.72, Right Foot Breadth (cm) was 10.30±0.72, Left Foot length (cm) was 25.68±1.66 and Right Foot length (cm) was 25.62±1.58 (Table 1). In females, stature varied from 149 to 187 cm with a mean value of 159.93±6.79 cm, mean weight was 59.28±12.43kg mean right foot length was 24.34±1.18 cm, left foot length was 24.38±1.33 cm, right foot breadth was 9.88±0.64 and left foot breadth was 9.62±0.55 but males having significantly higher value. All parameters having significanthigher values in male than female. (Table 1& 2)

Table 1: Mean, minimum and maximum values of measured parameter (N=194)

	Mean	Std. Dev.	Minimum	Maximum
Age (years)	19.76	1.95	17.40	28.80
Weight (Kg)	65.13	12.8	42	95
Height (cm)	164.90	14.50	106	199
FLR (cm)	25.62	1.58	22	29
FLL (cm)	25.68	1.66	21.9	29.2
FBR (cm)	10.30	0.72	8.9	12.2
FBL (cm)	10.1	0.72	8.3	11.5

Table 2: Measured value of different parameters in Male and Female participants

	Male (N=114)			Female (N=80)			t-value	p-value
	Mean+ SD	Minimum	Maximum	Mean+Sd	Minimum	Maximum		
Age	19.81±1.85	17.70	27.10	19.68±2.10	17.40	28.80	0.46	0.65
Weight	69.25±11.41	45	95	59.28±12.43	42	94	5.77	0.000
Height	168.39±17.24	106	199	159.93±6.79	149	187	4.17	0.000
FLR	26.52±1.14	23.7	29	24.34±1.18	22	27	12.94	0.000
FLL	26.59±1.20	23.3	29.2	24.38±1.33	21.9	28.2	12.06	0.000
FBR	10.60±0.63	9.3	12.2	9.88±0.64	8.9	11.9	7.75	0.000
FBL	10.35±0.66	9	11.5	9.62±0.55	8.3	11.4	8.12	0.000

Correlation between subjects' height and measurement values were analyzed by comparingthe Pearson correlation coefficient (Table 3). Among all of the variables, foot length(FL) showed the highest relationship in males (FLR:r = 0.188, FLL: r=0.194) and females (FLR: r = 0.698, FLL: r=0.703).

Table 3: Correlation between stature and foot length and foot breadth

	Total(N=194)				Male(N=114)				Female(N=80)			
	FLR	**FLL**	**FBR**	**FBL**	**FLR**	**FLL**	**FBR**	**FBL**	**FLR**	**FLL**	**FBR**	**FBL**
R	0.391	0.394	0.252	0.298	0.188	0.194	0.046	0.108	0.698	0.394	0.252	0.298
p-value	0.000	0.000	0.000	0.000	0.022	0.019	0.312	0.126	0.000	0.000	0.000	0.000
R^2	0.153	0.156	0.064	0.089	.036	.038	0.002	0.012	0.153	0.156	0.064	0.089
SEE	13.383	13.362	14.07	13.882	17.01	16.99	17.301	17.22	13.38	13.36	14.07	13.88

Regression; Tables 4 and 5 show correlation coefficients for foot length, for men and women. Formen, prediction accuracy was the highest when the regression equation involved footlength (Fig. 1).

Table 4: Linear Regression formulas of height (prediction of Height from FLR, FLL, FBR and FBL in Total participants)

		FLR	**FLL**	**FBR**	**FBL**
Linear regression Y=a+bX	Total	H=72.77+3.6 (FLR)	H=76.61+3.44 (FLL)	H=112.88=5.1 (FBR)	H=104.22+6 (FBL)
	Male	H=92.67+2.86 (FLR)	H=94.65+2.77 (FLL)	H=154.9+1.27 (FBR)	H=139.16+2.82 (FBL)
	Female	H=62.35+4.01(FLR)	H=72.37+3.59(FLL)	H=108+5.26(FBR)	H=94+6.86(FBL)
Multiple regression Y=a+bX	Total	H=72.40+1.59(FLR)+ 2 (FLL)		H=100+1.44(FBR) + 4.97 (FBL)	
	Male	H=89.15+1.2(FLR)+1.8(FLL)		H=143.5+1(FBR)+3.4(FBL)	
	Female	H=64.54+1.88(FLR)+2.03(FLL)		H=89.31+2.2(FBR)+5.08(FBL)	

Table 5: Estimated values of height of participants by regression equation & their Comparison

	Total			**Male**			**Female**		
	Mean	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**mean**	**Min**	**Max.**
Measured Height[cm]	164.90	106	199	168.39	106	199	159.93	149	187
Estimated Height By FLR[cm]	164.90	151.88	177.05	168.39	160.34	175.47	159.93	150.55	173.01
Estimated Height by FLL[cm]	164.90	151.91	177.01	168.39	159.26	175.62	159.93	151.03	173.65
Estimated Height by FBR[cm]	164.90	157.84	174.52	168.39	166.75	170.43	159.93	154.80	170.57
Estimated Height by FBL[cm]	164.90	154.35	173.68	168.39	164.58	171.64	159.93	150.91	172.16

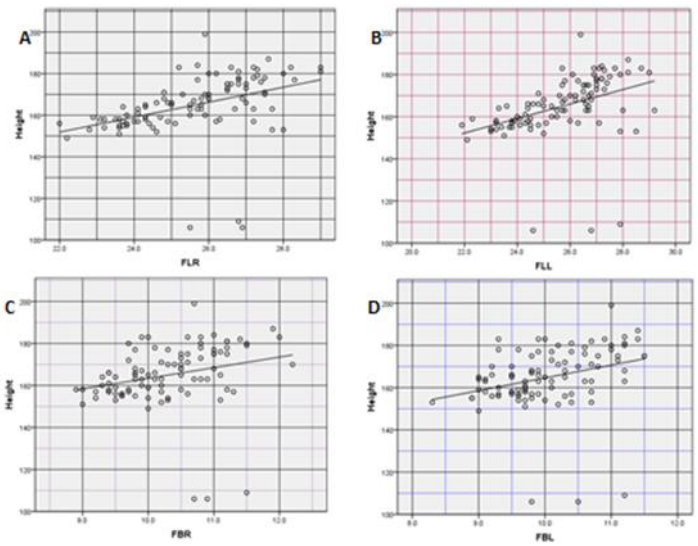

Fig. 1: Showing linear regression graph for estimation of height by FLR[A], FLL[B], FBR[C] & FBL[D]

Discussion

Body morphology and height changes influence bymany internal and external factors, like mechanicaleffects of use and wear and physical stress during the life of aperson, different cultures and life style.[14]The purpose of this study is to develop a estimation model for stature by using measurementsof foot length and foot breadth.

In present study the mean bodyweight among male subjects was found to be 69.25±11.41 kg and that among females was 59.28±12.43 kg. The difference in body weight among male and female subjects was found to be statistically significant (p value <0.000). Our finding is similar to Ozden H et al.[15]

The mean stature of male was 168.39±17.24 cm and in female 159.93±6.79 cm.Mean foot length on both sides in male was larger than female. The difference in these measurements was found to be statistically significant in male and female, and findings are similar to Ozdan et al,[15] Santi et al[16] and Krishan and Sharma.[17]

In present study Male stature was found to be significantly correlated with right foot length (r=0.188, p< 0.05) and left foot length (r= 0.194, p<0.05). Similar correlation was seen in female stature and right foot length (r=0.698, p<0.000) and left foot length (r=0.703, p=0.000).

RameswarapuSumanBabuet al[18] studiedHeight (in anatomical position) with foot lengthshows that the height ranges from 154 to 182 cm in male and 140 to 174 cm in female with a significant correlation between them. Left foot length from 23- 27cm in male and 21 to 27cm in female and right foot length from 22- 27cm in male and 21 to 27cm in female from and shows the positivecorrelation coefficients between parameters as height and foot length which was significant. It indicates that the foot length provides highest reliability and accuracy in Estimating stature of an unknown individual.

Mohanty&Agrawal et al[19]conducted a study on population of Odisha (India), developed a regression equation that could calculate the height of an individual from his foot length and shows as height increases foot length of both male and female also increases.

NatarajamoorthyTharmas et al[20]developed a regression equation for stature estimation from foot length obtained from foot impressions as well as foot using a simple linear regression statistical method and Patel S M et al[12]conducted the study on 500 asymptomatic healthy medical students of Gujarat region(India) in the age group of 14 to 25 years andconcluded that fairly good estimation of height can be made using regression equations in either sex.Qamras et.al[21]made a study on height and foot length and derived a correlation coefficient for foot breadth(Male 0.42 and Female 0.70) and footlength(Male 0.69 and Female 0.70). Jaydipsen et al[22] estimated the stature from footlength and foot breadth among population of North Bengal. The higher correlation coefficient found between stature and footlength over that of stature and foot breadth, suggested that footlength is more accurate in estimating statusrather than foot breadth. In present study also there is higher correlation between stature and foot length rather than foot breadth.

Nivedita et al[23]found that male stature is significantly correlated with rightfoot length (r=0.451, p<0.001) and left footlength (r=0.452, p<0.001). Similarstatistically significant correlation was seenbetween stature and right (r=0.421) and left(r=0.506) foot dimensions of females. Similar findings were also recordedbyKrishan and Sharma[17] inthe North Indian population (Rajputs), Sen andGhosh,[24]Patel SM et al[12] and Mansur DI et. al[25]that if either of the measurement(foot length or total height) is known theother can be calculated and this fact maybe of practical use in Medico-legalinvestigations and in Anthropometry.

Agnihotri et al[7] correlated foot length and stature in Mauritians (125 males and 125 females) and derived regression equations to calculate height and they used right foot for analysis. Sen et al[24]studied the foot measurements and stature of 350 Rajbanshis of West Bengal (175 males and 175 females) and derived several formulae to reconstruct height from the measurements of foot. Kanchan et al[26] studied the relationship between stature and foot dimensions among Gujjars, a North Indian endogamous group. They measured stature, foot length and foot breadth of 200 subjects comprising of 100 males and 100 females. They derived multiplication factors and regression equations from foot dimensions to estimate stature. The foot was used to determine the sex of an individual by Gulsah et al[27] and Danbarno et al.[28] Dhaneria V et al[29]was noted the foot type and an attempt was made to find the relation between stature and foot dimensions (foot breadth and foot length). As per the recommendation of the International agreement for paired measurements, left foot is to be used for measurements. But studies conducted by Das et al,[30] Anadi Pal,[31] Robbins LM,[32] Gulsah et al[27] have not shown any statistically significant interside difference. Robbins in her study concluded that either of the foot could be used for estimation of height.[32]

Stature estimated by Arti L et al[33]in males varied from 150.00 cm to 198.00 cm (Mean =170.75 cm and S.D. =7.13 cm) whereas in females stature varied from 140.00 cm to 178.00 cm (Mean =156.28 cm and S.D. =6.15 cm) in a total of 640 (343 males and 297 females) healthy individuals of age group 18-23 years. It is also observed that males have greater mean value of stature as compared to that of females. Similar age group studies were carried out by Rani M et al[34] and Nath S et al.[35]

The stature obtained by different researchers such as Duyar I et al,[36] Nath S et al,[35] Qamara SR et al,[21] and

Ozaslan A et al[37] varies due to geographical variations and variations in the morphology of different population group, however they had also noticed that males have greater mean value of stature as compared to females.

Arti L et al[33] derived linear regression equations for estimation of stature from foot length and foot breadth. High positive value of 'r' i.e. correlation coefficient suggests that there exists a direct relationship between these parameters and stature.

Foot length and breadth for estimation of stature by use of regression formula have been explored by Qamra SR et al[21] and he reported that foot length appeared to be a suitable measurement than foot breadth for stature estimation. Giles E et al[38] presented linear regressions for determining height from foot length for males and females and it was found that foot length displays a biological correlation with height. In present study also foot length is better predictor for height of an individual than the foot breadth. However in study by Arti L et al[33]and Gordon CC et al[11]both foot length and foot breath are found good predictor for estimation of the stature in both sexes. Singh TS and Phookan MN[39] studied the correlation between stature, foot length and foot breadth among four Thai population of Assam, but in their study only male population was studied and it was suggested that estimation of stature from foot length is preferable than from foot breadth.

The similarities and variations in the values in different population is the direct outcome of the variation in the morphology of different population group. All measurements exhibit high value of correlation in both sexes and thus any of these lengths would offer a reliable estimate of the stature forboth males and females of this region. Therefore depending upon the availability of the body parts, stature may be estimated using linear regression equations with reasonable accuracy. Present study is done on medical students of private Medical College, which are from middle to higher socioeconomic class so the anthropometricmeasurements can be on higher side. The ideal study to formulate regressionequation for all population should be a community basedstudy. Moreover, these equationscannot be applied for giants and dwarfs. A similar study should be done in all regions to formulate simple regressionequation specific for each region.

Conclusion

It is concluded that males have greater mean value of stature as compared to that of females. It was also observed that there is direct relationship between foot length and foot breadth with the stature in both sexes. These regression equations are specific for this region only because of geographical variations in the morphology of different population group. The stature can be accurately and satisfactorily estimated for medico-legal and forensic purposes since bilateral and bisexual differences have been taken into account while devising the linear regression equations.

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