Original Article

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Estimation of Stature from Foot Length in Population of Rajkot Region, Gujarat

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Abstract

Context: The use of anthropology has increased day by day by forensic experts for identification. With increasing frequency of mass disasters due to nature and man, the numbers of deaths are increasing which pose a threat for identification due to mutilation. Similar situation is encountered in cases of murder, where there is destruction of identity. Such situations give rise to studies which estimate the stature from different body parts. *Aims:* The present study was carried out with the aim to evaluate the anthropometric relationship of foot length with the stature of an individual in study population and to derive regression formulae and multiplication factor to estimate stature from these dimensions. *Settings and Design:* The present is an observational study wherein total of 208 individuals were selected for study, 105 males and 103 females, from 10 to 60 years of age. The measurements were carried out in the department for a fixed duration to avoid diurnal variation. *Methods and Material:* The parameters were measured after excluding any disease or deformity. Stature was measured with the subjects barefoot, standing erect, the feet pointed outward at 60 degree angle and head oriented in the Frankfurt plane. Foot length (FL) was taken on left foot as a straight distance between the most posteriorly projecting points of the heel (Pternion) to the most anteriorly projecting point (Acropodion) of the first or second toe whichever was bigger when the foot was fully stretched. After proper positioning measurements was taken. *Statistical Analysis used:* Statistical programme for social science and Microsoft excel. *Results:* The measured foot length showed significant correlation ($p<0.05$) with the stature of the individual. *Conclusion:* Linear regression equation and multiplication factor for estimating stature from foot length was derived for males, females and either sex. The regression equation gives more accurate results than multiplication factor for estimation of stature.

Keywords: Stature; Foot Length; Regression Equation.

Introduction

For medicolegal studies, examination of human skeleton has an utmost importance for the identification purpose, which is the prime component of *Corpus Delicti*. Personal identification is an integral part of the investigation and the stature estimation occupies relatively a central position in the identification necessitated by the medico-legal experts [1].

Mass disasters like earthquake, cyclone, landslide, floods, high impact transportation injuries, explosions etc where disintegrated and amputated parts are found very frequently, reconstruction of living stature from skeletal remains is useful to the forensic experts [1,2]. Similar scenario also applies in case of murder as the mutilation of dead body is done by a criminal who wants to destroy all traces of identity and thus facilitate the disposal of the dead [3].

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It is an established fact that stature bears a direct relation to the length of various bones, be it a child or adult. However, intact long bones may not be present in every instance. So, establishment of alternative methodologies for personal height estimation is important. In such a situation, measurements of various remains of body like torso, pelvis or available portion of limbs provide useful data to estimate the stature. With this view the present study was carried out to evaluate the anthropometric relationship of length of left sole with the stature of an individual in study population of Rajkot region and to derive regression formulae and multiplication factor to estimate stature from these dimensions.

Material and Methods

The present study was conducted in the Department of Forensic Medicine and Toxicology during the period of March, 2011 to July, 2012. This is an observational study which included total of 208 individuals, 105 males and 103 females. Age group selected for the study was 10-60 years of age. The individuals for the study were normal healthy volunteers from Rajkot region. Measurements were taken at a fixed time of the day (2:00 pm to 4:00 pm) to avoid errors in relation to diurnal variation. The aim and procedure of examination were explained before measurements. None of the individuals had any injury or deformity of the body that might have had an inûuence on the measurements of the foot length or stature. History of dietary habits and any hormonal or metabolic disorder was also taken to rule out any dietary deficiencies. Stature was measured with the subjects barefoot, standing erect, the feet pointed outward at 60 degree angle and head oriented in the Frankfurt plane. Foot length (FL) was taken on left foot [4] as a straight distance between the most posteriorly projecting points of the heel (Pternion)[5] to the most anteriorly projecting point (Acropodion)[5] of the first or second toe whichever was bigger when the foot was fully stretched. For measurement, the foot was placed on the measuring board. The foot taken for measurement was placed on this board in such a way that the heel was in contact with the surface of the board. This would confirm the position of the foot and it would not move while taking the measurement. This was further supported with the hand at the ankle region during the examination. After proper positioning measurements was taken. The data obtained was analyzed statistically to find out the mean and standard deviation for each of the above measurements in both the sexes using Microsoft Excel and Statistical programme for social science (SPSS) Version 17 to derive a linear regression equation and multiplication factor for stature estimation.

Results

Table 1: Sex wise distribution of subjects

Sex	No. of Subjects
Male	105 (50.49%)
Female	103(49.51%)
Total	208 (100%)

Table 2: Stature and sex wise Mean and Standard Deviation (SD) of Foot length (FL)

Stature (cm)	Foot length (cm)		
	Either sex*	Male	Female
120-130	16.45 ± 0.36	16.53±0.50	16.40±0.28
130-140	16.88 ± 0.40	17.02±0.29	16.60±0.57
140-150	21.12 ± 1.03	21.56±0.35	21.05±1.08
150-160	21.58 ± 0.79	22.02±0.64	21.53±0.80
160-170	23.35 ± 1.07	23.69±1.06	22.62±0.63
170-180	25.10 ± 1.23	25.20±1.23	23.96±0.15

* → Both male and female

The difference between stature and foot length among male and female is evident from the Table 2. The foot length increases as the stature increases but the foot length in case of male is always more than in female.

Table 3: Descriptive statistics of the study sample according to sex

Parameter	Either sex Mean ± SD	Male Mean ± SD	Female Mean ± SD
Age (years)	33.04 ± 14.37	32.84 ± 14.02	33.25 ± 14.78
Stature (cm)	159.88 ± 11.60	165.01 ± 11.21	154.65 ± 9.50
FL (cm)	22.54 ± 2.25	23.57 ± 2.30	21.49 ± 1.63

The average stature and foot length for male are greater than female subjects as evident form Table 3. The average foot length is more in male than that of female.

Dig. 1 shows scatter distribution of Stature v/s Foot length. Maximum number of subjects are within 95% confidence interval indicating significant correlation between the two parameters (r^2=0.806).

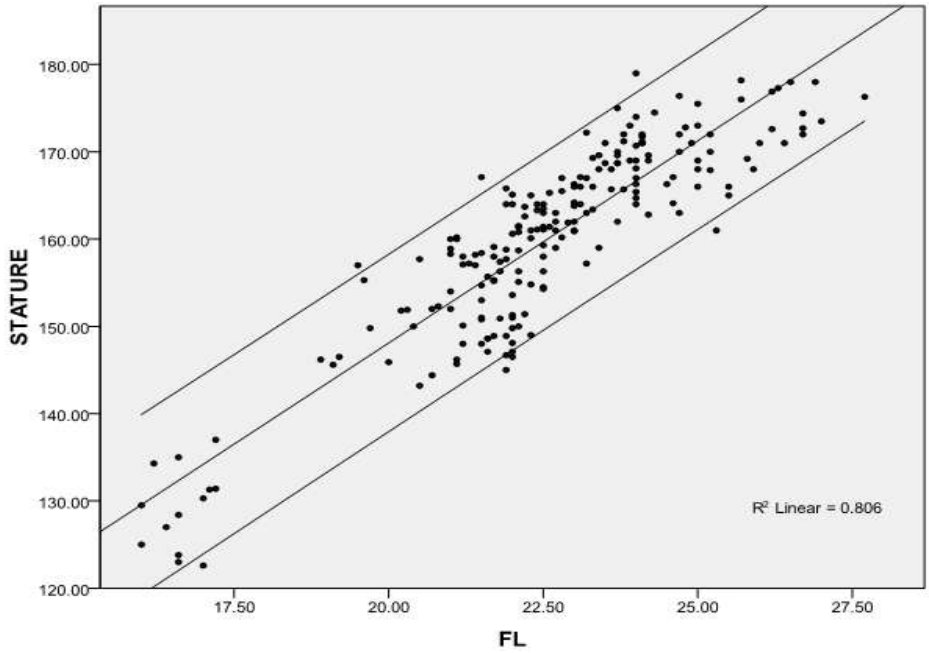

Diagram 1: Scatter distribution of Stature v/s Foot length

Table 4: Level of significance of different measurements of foot length and linear regression formula for estimation of stature

Parameter	N	PCC	R^2	SEE	Regression formula
Either sex	208	0.898	0.806	5.126	S = 55.427 + 4.633 x FL
Male	105	0.893	0.798	5.060	S = 62.170 + 4.363 x FL
Female	103	0.848	0.719	5.113	S = 49.356 + 4.906 x FL

N – Number of cases
PCC – Pearson's correlation coefficient
SEE = Standard Error of Estimate

Table 5: Mean multiplication factor for estimating stature from foot length

Parameter	Mean multiplication factor		
	Either sex	Male	Female
Foot length	7.118	7.028	7.210

The mean multiplication factor for estimation stature for either sex as well as male and female separately is given in Table 5. It is calculated as the ratio of the stature to foot length.

Multiplication factor = Actual Stature / Foot length

Discussion

Table 6: Comparison of mean stature and foot length in either sex

	Stature (cm)		Foot length (cm)	
	Male (Mean ± SD)	Female (Mean ± SD)	Male (Mean ± SD)	Female (Mean ± SD)
Krishan et al[5]	168.20 ± 6.50	155.70 ± 5.20	24.7 ± 1.20	22.60 ± 1.10
Patel et al[4]	170.96 ± 5.13	156.14 ± 5.15	24.44 ± 0.99	22.34 ± 1.12
Nachiket et al[7]	172.82 ± 5.65	156.70 ± 6.24	25.67 ± 3.62	23.27 ± 1.04
Present study	165.01 ± 11.21	154.65 ± 9.50	23.57 ± 2.30	21.49 ± 1.63

In present study, the mean stature and foot length for male subjects is 165.01 cm (±11.21) and 23.57 cm (±2.30) respectively and for female subjects it is 154.65 cm (±9.50) and 21.49 cm (±1.63). Mean stature and foot length in male subjects are more than female subjects in present study which is comparable with other studies. The findings in present study are comparable with the findings of Krishan et al.

Table 7: Comparison of multiplication factor in either sex

	Mean multiplication factor	
	Male	Female
Krishan et al[5]	06.82	06.89
Rani et al[3]	7.227	7.710
Jasuja et al[8]	6.44	-
Jain (brahmin) et al[9]	7.23	-
Nath (rajput) et al[10]	6.87	6.73
Nath (brahmin) et al[10]	6.64	6.68
Jain (jats) et al[11]	-	6.59
Present study	07.03	07.21

The mean multiplication factor for estimation of stature is compared with the studies conducted by different workers. In present study, mean multiplication factor is 7.03 for males and 7.21 for females. The value of factor is more in female than in males in the studies conducted in both male and female.

Table 8a: Comparison of Actual stature from mean multiplication factor and regression formula in either sex

Parameter	Male (Reg)			Male (M.F.)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
			n=105			
Stature (cm)	122.60	179.00	165.01 ± 11.21	122.60	179.00	165.01 ±11.21
FL (ES)	131.98	183.03	165.02 ± 10.02	112.48	194.73	165.71 ±16.14

Table 8b: Comparison of actual stature with estimated stature from mean multiplication factor and regression formula in male

Parameter	Either Sex (Reg.)			Either Sex (M.F.)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
			n = 208			
Stature (cm)	122.60	179.00	159.88 ± 11.60	122.60	179.00	159.88 ± 11.60
FL (ES)	129.56	183.76	159.87 ± 10.41	113.92	197.22	160.51 ± 16.00

Table 8c: Comparison of actual stature with estimated stature from mean multiplication factor and regression formula in female

Parameter	Female (Reg.)			Female (M.F.)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
			n=103			
Stature (cm)	123.00	171.20	154.65 ± 9.50	123.00	171.20	154.65 ± 9.50
FL (ES)	127.85	167.59	154.81 ± 8.02	115.36	173.76	154.97 ± 11.79

$n \rightarrow$ Number of subjects
FL (ES) $\rightarrow$ Estimated Stature from foot length in cm.
M.F. $\rightarrow$ Mean Multiplication Factor
Reg $\rightarrow$ Regression Equation

Actual stature and stature estimated from multiplication factor and regression analysis are compared in Table 9A, 9B and 9C. Mean actual stature and stature derived from multiplication factor and regression equation did not show significant differences between them. However, the standard deviation of estimated stature from the multiplication factor exceeds the standard deviation of actual stature, whereas the estimates from regression equation have standard deviation lower than the actual stature.

The above data shows that stature can be estimated from the foot length with the help of regression equation and multiplication factor. However, regional, ethnic, dietary and other variations exist and different data set is required to derive equations for different study population. The other parameters like percutaneous tibial length, hand length etc can also be studied for estimation of stature, either singular or in conjunction with foot length for more accurate results.

Conclusion

- Mean foot length in male was 23.57 cm with SD of 2.30 while that of female was 21.49 cm with SD of 1.63 and for either sex, it is 22.54 cm with SD of 2.25.
- Regression equation derived for either sex "Stature=55.427 + 4.633 x FL", with Standard Error → 5.126 cm and strength of association → 0.806.
- Regression equation derived for male sex "Stature=62.170 + (4.363 x FL)", with Standard Error → 5.060 cm and strength of association → 0.798.
- Regression equation derived for female sex "Stature=49.356 + (4.906 x FL)", with Standard Error → 5.113 cm and strength of association → 0.719.
- Mean multiplication factor for estimation of stature from foot length for either sex, male and female is 7.118, 7.028 and 7.210 respectively.
- In case of mean multiplication factor, the standard deviation of estimation of stature is more than that of regression equation, hence giving less accurate results than regression equation.

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