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Original Article

Reconstruction of Stature by Percutaneous Measurement of Foot - An Anthropometric Study

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ABSTRACT

The study 'Reconstruction of stature by percutaneous measurement of foot' is a part of our research project 'Reconstruction of stature from the parts of upper and lower extremities,' of which regression equations and multiplication factors are derived for the estimation of height from the distal part of upper extremity (combined length of forearm and hand) and from leg. For stature from foot, standing height and length of right and left feet were measured in 100 adult male and female medical students of 19–25 years and analysed statistically to establish relation between height and length of foot them. Regression equations are derived separately for male and female and these are 3.35X+82.6 and 3.42X+75.8, respectively, where X stands for length of foot. By taking the foot length value of different subjects their stature is calculated and compared with the corresponding real standing height and these were close (±3 cm) in most of the cases. Multiplication factor is also calculated, which is 6.49 for male and 6.65 for female. By using these factors the calculated stature is more than ±5 cm in nearly one-third of the cases, suggesting it less reliable than regression equation.

Keywords: Stature; Foot; Dismembered remains; Regression equation; Multiplication factor

INTRODUCTION

Estimation of stature is an essential part of identification process of unknown individuals, especially when body is in mutilated condition or skeletonised. A number of multiplication factors and regression equations has been derived to reconstruct stature from long bones and dismembered parts of upper and lower extremities[1–6] but very few from foot length[7–8.]

The study 'Reconstruction of stature by percutaneous measurements of foot' is an effort to establish correlation between length of foot and stature and thus helps in estimation of stature from foot length especially when other parts of extremities are damaged.

MATERIALS AND METHODS

Two hundred healthy students (100 males and 100 females) of Subharti Medical College, Meerut, between 19 and 25 years of age were selected for this study irrespective of their caste, religion, dietary habits and socio-economic status. Students having significant growth disorders, deformities, bony anomalies, fracture/amputation of foot are excluded to rule out any abnormal result in reconstruction of stature.

For reconstruction of stature from foot, standing height of all the selected students is measured on stadiometre without shoes, as distance between standing surface to the highest point on the head in mid-sagital plane. The length of both right and left feet is measured, for which subject is requested to put his/her foot on plane white paper and most prominent point of heel and great toe is marked with pencil and the distance between the two points is measured as length of foot.

These measurements are compiled in master chart on excel format in computer. Regression equation is derived by using the formula:

$$y = \pi \frac{\delta y}{\delta x} (X - \overline{X}) + \bar{y}$$

Where,

y = standing height (stature)

$\bar{y}$ = average (mean) of standing heights

X = length of foot

$\overline{X}$ = Average (mean) of length of feet

δy = Standard deviation of standing height

δx = Standard deviation of length of feet

π = Correlation coefficient between standing height and length of leg

The mean and standard deviation of standing height, mean and standard deviation of length of right and left feet and average of both feet are calculated, from which their correlation coefficient with standing height are derived. The regression equations for reconstruction of stature are derived separately from right and left feet and the average of both feet in both male and female.

Multiplication factors are also derived in both the sexes as an average of ratio of stature and length of foot.

OBSERVATION AND RESULTS

Stature

The standing height of males varied from 158.5 to 184 cm with mean value of 170.9 cm and standard deviation (SD) of 6.00673. The stature of females varied from 147.5 to 167.5 cm with mean value of 156.6 cm and standard deviation of 4.73963 (Table 1).

Table 1: Stature of the study group

Stature	Total males (100)	Total females (100)
Minimum	158.5	147.5
Maximum	184	167.5
Mean	170.9	156.6
Standard deviation	6.00673	4.73963

Length of Foot

A. Males:

The length of right foot varied from 22.5 to 29.8 cm in males with mean value of 26.428 cm, standard deviation of 1.657068 and correlation coefficient with standing height of 0.914327. The length of left foot varied from 22.2 to 30 cm with mean value of 26.366 cm, standard deviation of 1.639242 and correlation coefficient with standing height of 0.906656. The average lengths of right and left feet varied from 22.35 to 29.9 cm with mean value of 26.397 cm, standard deviation of 1.64135 and correlation coefficient with stature of 0.914287 (Table 2).

Table 2: Length of foot in males

Measurement	Length of foot (in cm)		
	Right	Left	Average
Minimum	22.5	22.2	22.35
Maximum	29.8	30.0	29.9
Mean	26.428	26.366	26.397
Standard deviation	1.657068	1.639242	1.64135
Correlation coefficient with stature	0.914327	0.906656	0.914287

B. Females:

The length of right foot varied from 21.2 to 26.2 cm in females with mean value of 23.613 cm, standard deviation of 1.134104 and correlation coefficient with standing height of 0.8423. The length of left foot varied from 21.1 to 26.1 cm with mean value of 23.522 cm, standard deviation of 1.156499 and correlation coefficient with standing height of 0.81063. The average lengths of both the legs varied from 21.3 to 26.1 cm with mean value of 23.5775 cm, standard deviation of 1.146434 and correlation coefficient with stature of 0.829467 (Table 3).

Table 3: Length of foot in females

Measurement	Length of foot (in cm)		
	Right	Left	Average
Minimum	21.2	21.1	21.3
Maximum	26.2	26.1	26.1
Mean	23.613	23.522	23.5775
Standard deviation	1.134104	1.156499	1.146434
Correlation coefficient with stature	0.8423	0.81063	0.829467

Regression Equations

Regression equations for estimation of stature were derived from the lengths of right foot, left foot and average of both feet separately in male and female with the formula:

$$y = \pi \frac{\delta y}{\delta x} (X - \overline{X}) + \bar{y}$$

as discussed above. These were calculated as:

1. For male

a. Height from right foot:
0.914327x6.600673/1.657068 (X-26.428)+170.9
= **3.31 X+83.4**

b. Height from left foot:
0.906656x6.600673/1.639242 (X-26.366)+170.9
= **3.32 X+83.4**

c. Height from average of right and left feet:
0.914287x6.600673/1.64135 (X-26.397)+170.9
= **3.35 X+82.6**

2. For female

a. Height from right foot:
0.8423x4.73963/1.134104 (X–23.613)+156.6
= **3.52X+73.5**

b. Height from left foot:
0.81063x4.73963/1.156499 (X-23.522)+156.6
= **3.32X+78.5**

c. Height from average of right and left feet:
0.829467´4.73963/1.146434 (X-23.5775)+156.6
= **3.42X+75.8**

Where X is the length of foot. By using the value of X in the equation, stature is calculated and compared with the corresponding real standing height and these are close (±3) in most of the cases as shown in Table 4.

Practically, there is not much difference in lengths of right and left feet and in calculated statures by using separate regression equations. So the regression equation of average of both feet, which is 3.35 X + 82.6 for male and 3.42 X + 75.8 for female are the correct answer of reconstruction of stature from the length of foot.

Multiplication Factor

To establish multiplication factor, ratio of standing height and average of combined length of right and left feet are calculated separately in both the sexes, which ranges from 6.06 to 7.09 with average of 6.49 for male and 6.18 to 7.12 with average of 6.65 for female (Table 5).

By using these multiplication factors, the error in reconstruction of stature ranges from -12.6 to +13.4 cm in male and -11.7 to +10.5 cm in female with variation of more than ±5 cm in 44% of males and 24% of female.

DISCUSSION

Estimation of stature is a crucial requirement in post-mortem examination of dead bodies especially when they are un-identified and badly decomposed, mutilated or skeletonised. In this study, a direct relationship was observed between length of foot and standing height as it was also observed by other workers[9-11]. They also have concluded that length of foot is as good as long bones for the reconstruction of height. Here regression equations and multiplication factors are derived separately for males and females.

The regression equation for stature from the measurement of foot is 3.35 X + 82.6 for male and 3.42 X + 75.8 for female and when we calculate stature by using these

Table 4: Variations in calculated stature by regression equations

Subject	Standing height	Regression equation	Length of foot (cm)	Calculated stature (cm)	Variation in cm
Male	Minimum 158.5 cm	3.31X+83.4	Rt. 22.5	157.9	-0.6
		3.32X+83.4	Lt. 22.2	157.1	-1.4
		3.35X+82.6	Av. 22.35	157.5	-1.0
	Maximum 184 cm	3.31X+83.4	Rt. 29.8	182.0	-2.0
		3.32X+83.4	Lt. 30.0	183.0	-1.0
		3.35X+82.6	Av. 29.9	182.8	-1.2
Female	Minimum 147.5 cm	3.52X+73.5	Rt. 21.2	149.2	+1.7
		3.32X+78.5	Lt. 21.1	148.6	+1.1
		3.42X+75.8	Av. 21.15	148.8	+1.3
	Maximum 167.5 cm	3.52X+73.5	Rt. 26.2	165.7	-1.8
		3.32X+78.5	Lt. 26.1	164.8	-2.7
		3.42X+75.8	Av. 26.15	165.1	-2.4

Abbreviations: AV., average; Lt., left; Rt., right.

Table 5: Multiplication factor and variation in reconstructed stature

Ratio of standing height and average of right and left feet	Male	Female
Minimum	6.06	6.18
Maximum	7.09	7.12
Average (multiplication factor)	6.49	6.65
Variation in reconstructed stature with multiplication factor	-12.6 to +13.4 > ±5 in 44%	-11.7 to +10.5 > ±5 in 24%

formulas the results are very close to actual height, i.e., less than ±3 cm in most of the cases.

The multiplication factor is also calculated and these are 6.49 and 6.65 for male and female, respectively. By this factor when statures are calculated, the errors vary from -12.6 to +13.4 cm with variation of more than ±5 cm in 44% of males and 24% of females. So multiplication factors are statistically inferior and less reliable than regression equations.

CONCLUSION

- There is a direct relationship between standing height and foot length, so it is a good criterion for reconstruction of stature.
- The difference in lengths of right and left feet is little and practically insignificant in derivation of different regression equations and multiplication factors.
- The regression equation of average of lengths of both of feet is the correct solution, which is 3.35 X + 82.6 for male and 3.42 X + 75.8 for female. Calculated statures from these equations are close to the actual height, only ±3 cm in most of the cases.
- The multiplication factor between stature and foot is also calculated and these are 6.49 and 6.65 for male and female, respectively. The calculated stature from these factors is more than ±5 cm in 44% of males and 24% of females.
- Regression equations are statistically superior and more reliable than multiplication factors.

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