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Establishment of Relation between Stature and Right Foot Length

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Abstract
Anthropometric measurements can be used for identification which is required in many situations like in civil and criminal disputes. It can be done by multiple methods like examination of human skeletons or portions to evaluate height. Establishing the living height of an individual from skeletal remains is a routine and straightforward practice in forensic anthropology that leads to derivation of the regression equations and multiplication factors to estimate stature. In this study 200 cadavers (100 males and 100 females) were selected for anthropometric measurements to find out relation between stature and right foot length with development of regression equations and multiplication factors. The foot length showed significant positive correlation with stature as well significant bisexual variation.
Keywords: *Anthropometry, Identification, Stature, Right foot length.*

INTRODUCTION

French criminologist Alphonse Bertillon in 1882 developed the first classification and identification system to identify criminals based on anthropometry that leads to genesis of forensic anthropology. Since then, forensic examinations of unknown commingled human remains had been done with the help of anthropometry.[1]

Forensic anthropology is the application of standard techniques employed by many physical anthropologists to identification of unknown human remains. This involves the examination of human skeletons or portions thereof that have been recovered under circumstances suggesting the need for proper identification.[2]

Mass disasters either natural such as earthquakes, flood, tsunamis, and cyclones or man-made such as terror attacks, bomb blast, wars, fire explosions and railway or aircraft accidents are increasing in present era. It imposes grave problem for forensic experts as there is intermixing of bodies and body parts. Identification is difficult but also important for these mutilated & commingled remains and hence requires special attention in these settings.[3]

Height, like other phenotypic traits, is determined by a combination of genetic and environmental factors. Estimation of stature from measurements of upper limb and lower limb bones has been attempted by many scientists with varying degree of accuracy.

Anthropometric calculations depend on the fact that limbs exhibit consistent ratios relative to the total height of a person. These ratios are linked to age, sex and race. Characteristic variations in

proportions were shown to appear between major races and furthermore even among smaller ethnic groups.[4]

There are methods like anatomical method and the mathematical method for stature estimation.[5] The anatomical method, more commonly referred to as the "Fully method" (George Fully 1956), has recently been re-examined in detail by Raxter et al (2006-07), involves the summation of superoinferior measurements of contributory skeletal elements to determine stature as directly as possible; but it cannot be applied to incomplete remains. In such circumstances mathematical method allow estimates of living stature from the length of skeletal elements, which is related to derivation of formulae that can be applied directly to estimate stature from a given bone/part of the body. Some other methods of stature estimation are FORDISC 3 and revised Fully method.[6]

Establishing the living height of an individual from skeletal remains is a routine and straightfor-ward practice in forensic anthropology. Bones and teeth survive much longer than soft tissue hence used for identification in anthropometry.[7]

Estimation of stature in mutilated bodies especially from their bones is a tedious and time consuming process and gives erroneous results due to considerable statistical differences between the lengths of fresh and dry bones.[8] Another problem is that the whole process of collection of bones from cadaver, cleaning by treating these bones with chemicals and drying may lead to considerable difference in actual bone length meanwhile fragment of bone may be detached from the bone which make measurement difficult from intact dry bones.

Trotter and Gleser, Dupertuis and Hadden described firstly the regression equations to estimate stature.[9] Of all the mathematical methods used, regression formulae based on long bones measurements yield the most accurate result.

This research work was aimed and concentrated on anthropometric measurement of lower limb parameter i.e. right foot length of both side in cadavers and to develop its correlation with supine length and to find out multiplication factors and regression equations for the adult population of Delhi.

AIM AND OBJECTIVES

AIM: Determination of correlation between supine length and percutaneous measurements of right foot length in cadavers.

OBJECTIVES

1. Correlation between supine length and percutaneous measurements of lower limb parameter i.e. right foot length in male and female independently.
2. Derivation of multiplication factor and regression equation to be subsequently used for determination of supine length in dead bodies.
3. To find bisexual variation.

MATERIAL AND METHODS

Material for the present study comprised of measurements taken from the dead bodies brought for medico legal autopsies to the Mortuary of the Department of Forensic Medicine, University College of Medical Sciences and Guru Teg Bahadur Hospital, Delhi.

Total number of 200 (100 Males and 100 Females) dead bodies brought to the mortuary of GTB hospital from November 2012 to February 2014 were be studied for taking the various measurements.

INCLUSION CRITERIA

- All adult cases brought to mortuary for medico legal autopsy.
- Only those individuals in whom there was no anatomical distortion of the portion of body in relation to stature were included in the study.

EXCLUSION CRITERIA

- Cases with disease or defect affecting the growth in general or of bones.
- Cases with deformity and disease affecting the bones of lower extremity.

STUDY DESIGN: Analytical cross sectional study which includes all adult cases. Total number of cases, both males and females were divided according to age in four groups and were subjected to statistical computations. Total numbers of 200 (100 male and 100 female) cases were studied. (Table- 1)

TABLE1: Showing Distribution of Both Sexes in Various Age Groups.

Age group (years)	Males (n_1 = 100)	Females (n_2 =100)	Total(N = 200)
18-28	25	25	50
29-38	25	25	50
39-48	25	25	50
>48	25	25	50

MATERIALS USED

The following instruments and documents were used for the study:

- Standard Autopsy equipments.
- Scientifically standardized graduated Anthropometer.
- Documentary evidence, information from relative etc. for assessment of accurate or near accurate age.

METHODS OF COLLECTING THE DATA:

- The necessary informed consent obtained from next of kin/relative before taking the measurements.
- Before taking the measurements rigor mortis was broken by standard technique of treating the dead body thoroughly with warm water and then breaking it manually if required.
- The measurements were taken with dead body lying in supine position using scientifically standardized graduated instruments.
- All the measurements were taken three times in centimeters and mean value was used for computation of data.
- All the measurements were recorded in predesigned proforma.
- Measurements were taken for following parameters.[10]

SUPINE LENGTH

Dead body was placed in supine position on the flat hard surfaced autopsy table, with the knee and hip joints extended, and the neck and feet in a same plane and thus supine length was measured from vertex of head to heel of foot using graduations on side of autopsy table.

FOOT LENGTH

Foot length was measured as the maximum distance between most anterior & posterior points of foot.

All the above measurements were tabulated and statistical computation of data was done for each group in both the genders to find out the correlation between supine length and percutaneous measurement of lower limb parameters and to derive independent linear regression equations and independent multiplication factor for each parameter.

OBSERVATION AND RESULTS

Anthropometric measurements of 100 male and 100 female adult cadavers were taken. For statistical computation & understanding and also for uniform & fair comparisons total number of cases, both males and females were divided in to four age groups of 10 year intervals with 25 individuals in each age group. Linear regression equations were formulated independently for male & female and separately for each age group in relation with parameters included in the present study.

The regression equations were also derived for male and female combined together. This was done with the intention to find out whether a single equation can be used effectively for both genders in all the age groups or an independent equation will be required separately for an individual age group for best prediction of stature.

SUPINE LENGTH

The supine length of the dead body was measured while body was lying in supine position on standardized graduated autopsy table from vertex of skull to heel of foot.

The supine length in males varied from 150 cm to 191 cm with mean value of 165.90 cm and standard deviation being 6.9497 cm. The supine length in females varied from 133 cm to 175 cm with mean value of 153.68 cm and standard deviation being 6.8071 cm, this suggest that average supine length are more in males as compared to females as shown in Table – 2.

TABLE – 2: Descriptives of Supine Length

Sex	Min	Max	Mean	SD
Male (n = 100)	150	191	165.90	6.9497
Female (n = 100)	133	175	153.68	6.8071

SUPINE LENGTH IN MALES: The minimum supine length of 150 cm observed in two age groups i.e. 29-38yr and more than 48 yr age groups and maximum supine length also found in 29-38 yr age group as 191cm as shown in Table – 3.

TABLE – 3: Descriptives of Supine Length in Males

Age groups	No. of cases	Min	Max	Mean	SD
18 –28 years	25	157	180	167.220	6.4389
29– 38 years	25	150	191	165.880	8.7480
39 – 48 years	25	154	178	166.920	6.4091
>48 years	25	150	174	163.580	5.6267

SUPINE LENGTH IN FEMALES: Among females minimum value of supine length as 133 cm observed in 39-48 yr age group and maximum value of 175 cm seen in 18-28 age group as described in Table – 4.

TABLE – 4: Descriptives of Supine Length in Females

Age groups	No. of cases	Min	Max	Mean	SD
18 –28 years	25	140	175	153.680	7.7229
29– 38 years	25	141	165	153.840	6.1079
39 – 48 years	25	133	164	153.840	7.6468
>48 years	25	141	165	153.360	5.9626

FOOT LENGTH:

Foot length measured as maximum distance between most anterior & posterior points of foot.

In males the right foot length varied from 21.0 cm to 27.1 cm with mean value of 23.231 cm and standard deviation being 1.0651 cm. In females it varied from 19.1 cm to 23.1 cm with mean value of 20.937 cm and standard deviation of 0.8360 cm as depicted in Table – 5.

TABLE – 5: Comparison of Foot Length

Sex	Side	Min	Max	Mean	SD
Male(n =100)	R	21.0	27.1	23.231	1.0651
Female(n=100)	R	19.1	23.1	20.937	0.8360

Significant bisexual differences were seen in right foot length. The length is observed to be less in females as compared to males.

RIGHT FOOT LENGTH IN MALES: The maximum value was observed in 29-38yr age group while the minimum value was observed in

more than 48 yr age group with least mean value. The standard deviation was minimum in the age group of 18- 28 years and maximum in age group of 39-48 years as illustrated in Table – 6.

TABLE – 6: Descriptive of Right Foot Length

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	21.9	24.1	23.420	0.5635
29 – 38 years	25	21.5	27.1	23.340	1.0901
39 – 48 years	25	21.8	26.5	23.284	1.2502
>48 years	25	21.0	26.5	22.880	1.1958

Linear regression equation derived from foot length for estimation of supine length in males in each age group is depicted in Table – 7. (Figure 1)

TABLE – 7: Regression Equation in Males

Age groups	Regression equation	SEE(+/-) cms	'r' value	p-value
18 – 28 years	200.905-1.438×RFtL	6.5251	0.126	0.549
29 – 38 years	107.759+2.490×RFtL	8.4950	0.310	0.131
39 – 48 years	134.851+1.377×RFtL	6.3062	0.269	0.194
>48 years	170.053-0.283×RFtL	5.7373	0.060	0.775
Combined	139.029+1.157×RFtL	6.8744	0.177	0.078

Linear regression equation derived from foot length for estimation of supine length in males show positive 'r' value for all age groups with highest in 29-38 yr age groups. But the p- value in all age groups is >0.05. So right foot length in males from this study do not provide better correlation of stature.

RIGHT FOOT LENGTH IN FEMALES: The maximum value was observed in 29-38yr age group while the minimum value was observed in 39-48 yr age group however least mean value observed in more than 48 yr age group having also the least standard deviation as described in Table – 8.

TABLE – 8: Descriptive of Right Foot Length

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	20.0	22.9	21.040	0.8000
29 – 38 years	25	19.3	23.1	21.004	0.8839
39 – 48 years	25	19.1	22.8	20.908	0.9604
>48 years	25	19.3	22.7	20.796	0.7086

Linear regression equation derived from foot length for estimation of supine length in females in each age group is depicted in Table – 9. (Figure 2)

TABLE – 9: Regression Equation in Females

Age groups	Regression equation	SEE(+/-) cms	'r' value	p-value
18 – 28 years	71.739+3.895×RFtL	7.2185	0.403	0.046
29 – 38 years	99.491+2.588×RFtL	5.7854	0.374	0.065
39 – 48 years	69.567+4.013×RFtL	6.7363	0.506	0.010
>48 years	53.629+4.796×RFtL	5.0049	0.570	0.003
Combined	76.026+3.709×RFtL	6.0907	0.456	0.001

Best correlation observed in more than 48 year age group, however regression equation derived from combined age groups also yield good results. In 29-38 year age group p-value observed to be >0.05

Figure – 1: Correlation between supine length and right foot length in males

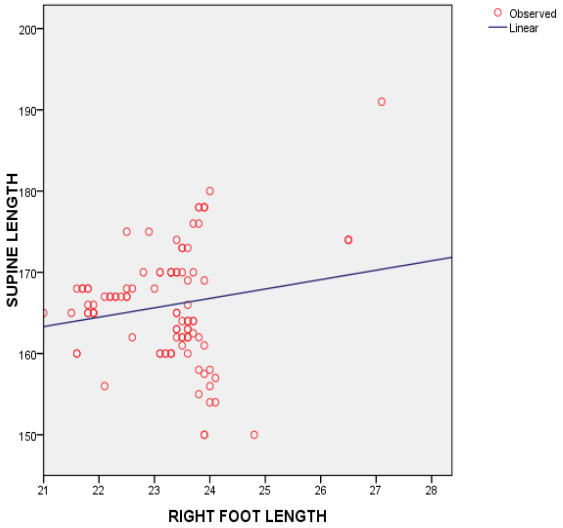
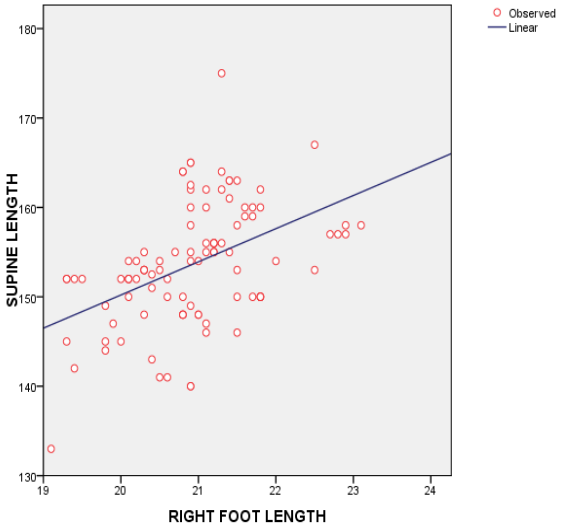


Figure – 2: Correlation between supine length and right foot length in females

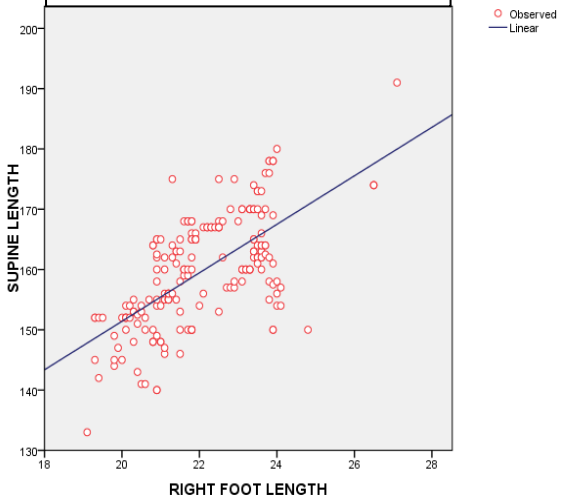


Linear regression equation derived from right foot length for estimation of supine length in combined cases (males + females)-

SL= 70.974+4.022 × RFtL, (SEE =6.9789), (r = 0.654) (figure 3)

On comparing it was observed that foot length provide better correlation of supine length in females. While for males this study does not provide better correlation of stature. However correlation was significantly positive and highest right foot length when total cases were combined together (p=0.001).

Figure – 3: Correlation between supine length and right foot length in total cases



DISCUSSION

In the present study the average age of an individual ranges from 18 years and above which has been done on the cosmopolitan population of Delhi region of india. The study was aimed at and concentrated on finding the correlation between supine length and anthropometric measurements of right foot length in males and females for subsequent determination of stature.

STATURE: The mean stature for males in the present study is 165.90 cm and for females is 153.68 cm. Minimum and maximum stature in males is 150 cm and 191 cm, while in females it is 133cm and 175cm respectively. In the present study mean stature was less in females than males, which is consistent on comparing with other studies so it can be inferred that females are smaller than males. This was seen even true when in this study age group wise comparisons made among females and males as described in Table – 3 and 4.

FOOT LENGTH: The mean right foot length in males in the present study is 23.231 cm and in females it is 20.937 cm. The maximum mean right foot lengths in present study among males and females are in youngest age groups (i.e. 18-29 years) while it is least in oldest age groups (i.e. more than 48 years) as already described in Table 6 and 8.

The mean right foot length showed significant bisexual difference. Males have greater foot length than females this is consistent with the below mentioned studies in table- 10. The mean foot length measured is similar with the study conducted by Rani et al, while there are slight variations in right foot length in both genders with the other study. This might be attributed to different geographical areas covered along with different nutritional patterns in the study group.

TABLE – 10: Foot Length Comparison

Authors	Population studied	Condition in which bone studied	Sex	Side	Min	Max	Mean
Zeybek et al[11]	Turkey (136M,113F)	Percutaneous	M	R	23.3	29.1	25.601
			F	R	20	25.6	23.046
Rani et al[12]	Delhi (150M,150F)	Percutaneous	M	R	19	26.5	23.384
			F	R	17.7	24.5	20.599
Krishan,Sharma A[13]	Himachal Pradesh (123M,123F)	Percutaneous	M	R	21.8	28	24.72
			F	R	20.4	25.4	22.65
Kanchan et al[14]	Punjab (100M.100F)	Percutaneous	M	R	21.5	30	26.3
			F	R	21.1	28.1	23.8
Sen J, Ghosh S[15]	North Bengal (225M,225F)	Percutaneous	M	R	21.1	27.3	23.96
			F	R	19.7	24.9	22.23
Bhavna, NathS[16]	Delhi (503M)	Percutaneous	M				24.88
Chikhalker et al[17]	Maharashtra (147M,153F)	Percutaneous	Both		20.85	28	24
Nachiket et al[18]	Karnataka (50M,50F)	Percutaneous	M		23.3	28.9	25.67
			F		20.8	26.4	23.27
Present Study	Delhi (100M,100F)	Percutaneous	M	R	21.0	27.1	23.231
			F	R	19.1	23.1	20.937

Prediction of stature with least standard error of estimate can be derived by regression equations given by Zeybek et al in Turkish population. But their equations can be used for that population only.

In the present study correlation coefficient in males is 0.177 for right foot length. In females it is more 0.456 being highest (0.570) in more than 48 year age group. Thus females give better results than males. However the value of 'r' significantly increased to 0.654 and 0.658 when both males and females were combined. So, if the age of a person is known, then better results can be obtained by using independent linear regression equations as shown in table 11.

TABLE 11: Comparison of Regression Equations Derived

Authors	Sex	Regression equation	SEE (+/-) cms	r value
Zeybek et al[11] (Turkey)	Both			0.875
				0.865
	M			0.678
				0.667
	F			0.741
				0.711
Rani et al[12] (Delhi)	M	98.320+3.050×RFtL	4.460	0.808
	F	90.207+3.374×RFtL	3.464	0.808
Krishan,Sharma A[13] (Himachal Pradesh)	M	69.028+4.01×RFtL	4.44	0.732
	F	73.88+3.61×RFtL	3.50	0.739
Kanchan et al[14] (Punjab)	Both	91.271+2.883×RFtL	4.157	0.791
	M	93.269+2.819×RFtL	3.878	0.759
	F	103.270+2.365×RFtL	4.398	0.512
Sen J, Ghosh S[15] (North Bengal)	Both	39.737+5.029×RFtL		0.810
	M	84.041+3.264×RFtL		0.624
	F	68.642+3.638×RFtL		0.682
Bhavna, Nath S[16] (Delhi)	M	119.74+1.92×FtL	4.77	0.546
Chikhalker et al [17](Maharashtra)	M+F	79.722379+3.650632×FtL		0.6102
Nachiket et al[18] (Karnataka)	Both	27.02+5.629×FtL		0.90
	M	80.208+3.608×FtL		0.68
	F	45.132+4.794×FtL		0.81
Present study (Delhi)	Both	70.974+4.022×RFtL	6.9789	0.654
	M	139.029+1.157×RFtL	6.8744	0.177
	F	76.026+3.709×RFtL	6.0907	0.456

Table 12 depicts the bisexual variations. By using unpaired t-test the Mean differences, t- value and p- value of various measurements in both males and females were derived. Sex differences are statistically significant (p<0.01) for all the measurements as shown below.

TABLE 12: Bisexual Variations in Various Measurements Among Males and Females.

Variable	*Mean difference*	*t* – value	*p* - value	Inference
Right foot length	2.2940	16.942	< 0.001	Highly significant

Table 13 and 14 shows the regression equations and multiplication factors respectively derived by this research work

TABLE 13: Regression Equations Derived

Sex	Side	Regression equation	SEE (+/-) cms	r value
Males	R	139.029+1.157×RFtL	6.8744	0.177
Females	R	76.026+3.709×RFtL	6.0907	0.456
Combined	R	70.974+4.022 × RFtL	6.9789	0.654

TABLE – 14: Multiplication Factors Derived

Parameter	Multiplication factor for males	Multiplication factor for females
Right foot length	7.141	7.339

CONCLUSIONS AND SUMMARY

1) The mean value of supine length /average height in male is about 12 cm more as compared to female.
2) Right foot length showed positive correlation with supine length.
3) Supine length averages about one centimeter more than the measurement of standing height.

4) Regression equations derived for combined cases too shows significantly positive correlation thus can be applied irrespective of sex and age.
5) Significant bisexual differences are seen in foot lengths. The length is observed to be less in females as compared to males.
6) Correlation of stature gives better estimate for stature in females with foot length.
7) Multiplication factors were derived in both genders in the present study but are less accurate than regression equations.
8) Regression equations derived in this study can be used for the population all over the country as present study done in cosmopolitan population.

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