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Reconstruction of Femoral Length from Its Proximal Fragments and Diaphyseal Segments in South Indian Population.

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ABSTRACT

Intact long bones of the upper and lower extremities have been used in the derivation of regression equations for the estimation of stature in different population groups. The objective of the present study is to assess the feasibility of estimation of the length of femur from the measurements of its proximal fragments and diaphyseal segments in South Indian population. The greatest accuracy in estimating living stature from long bones length will be obtained when sex and ethnic identity are available. For this purpose 280 (140 male – 70 right, 70 left and 140 female – 70 right, 70 left) adult dry femora from South Indian population, were taken to analyze the morphometric details of the proximal fragments and diaphyseal segments of femur. The femora were measured using the standard anthropometric techniques for total length and 7 fragments. Simple linear regressions ($p < 0.01$) were made to correlate each fragment with the total length of the femur. The derived formulae are population specific and are designed for use in forensic skeletal analyses of South Indian population.

Keywords: Femoral length, proximal fragments, diaphyseal segments, correlation, regression equation.

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INTRODUCTION

In archaeological approach, statures estimated from human skeletal remains is an essential step in assessing health, sexual dimorphism, and general body size trends among past populations [1]. The length of long bones is still employed to normalize data about robusticity of the upper and lower limbs, adjusting absolute values to size and shape of the body, because differences may be intra- and inter populational, as well as, between male and female individuals inside of a same group [2].

It has been demonstrated that the weight-bearing bones of the lower limbs have the highest correlation with stature and advised against the use of upper limb bones unless lower limb bones are not available [3].

It is well documented that the intact femur has the highest correlation with stature and as such has been widely used in the derivation of regression equations for stature estimation. As intact femur is not always present for analysis in Forensic cases, it has become necessary to derive regression equations for the estimation of stature from fragments of this bone [4].

Morphological difference in the selected bone, due to regional and racial factors, have made it necessary to work out separate regression equations for separate groups [5].

In most studies a small number of skeletons are available, thus it is necessary to accomplish new studies on larger sample for a better characterization of these relationships. Scholars had admitted that greatest accuracy in estimating living stature from long bones length will be obtained when sex and ethnic identity are available [6].

The sample size used in present study (280) was better for establishing a relationship between long bone length and stature. The present study is also a population specific study and the regression equation derived is specific for femora of South Indian population. We also segregated femora with respect to sex and side. However the statistical formula used in this method is appropriate when used only in specific population.

MATERIAL AND METHODS

Data for the present study comprises of 280 femora (140 male – 70 right, 70 left and 140 female – 70 right, 70 left) of South Indian origin from Anatomy department of Sri Siddhartha Medical College, Tumkur, Karnataka.

For the measurements of Maximum femoral length, an osteometric board was used. The measurements of fragments were made by means of anthropometric rod and sliding calipers. Each measurement was made thrice by the same examiner and the mean value was considered.

FML – Maximum Femoral Length – linear distance between the most superior part of head of femur and most inferior part of medial condyle. Instrument used – Osteometric board.

TCL – Distance from highest point on upper margin of greater trochanter to deepest point on medial condyle. Instrument used – Anthropometer rod.

DSL – Distance from lower margin of greater trochanter on lateral side of bone to the highest point of articular surface of condyle on anterior aspect. Instrument used – Anthropometer rod.

VHD – Vertical Head Diameter. The straight distance between the highest and deepest points of the head in the equatorial plane. Instrument used – sliding calipers

VND – Vertical Neck Diameter. The minimum linear distance between the superior and inferior points on the neck of femur. Instrument used – sliding calipers

VHA – Upper breadth of femur. The linear measurements between the most superior point on the fovea capitis of the femur to the inferior aspect of the greater trochanter. Instrument used – sliding calipers

THD – Transverse Head Diameter. Straight distance between most laterally placed points on equatorial plane. Instrument used – sliding calipers

SDN – Sagital Diameter of Neck. Distance between anterior and posterior surface of neck taken at right angles to vertical diameter. Instrument used – sliding calipers

Data was subjected to relevant statistical analysis to formulate regression equations to reconstruct femoral length from its fragments.

RESULTS

Table 1 and 2 shows mean values of maximum femoral length (FML) and its fragments (right and left sides) in males and females respectively. Statistical test for analysis of differences between right and left sides was accomplished.

It is apparent from table 1 that there is no bilateral difference in the right and left femora in males at $p<0.05$ level of significance.

Table 2 depicts that in females bilateral differences were significant only for 2 measurements namely FML and TCL at $p<0.05$ level of significance.

Table 3 presents Karl Pearson co-efficient of male femora which range between 0.756 and 0.239 for right side and 0.743 and 0.274 for left side.

Table 4 presents Karl Pearson co-efficient of female femora which range between 0.798 and 0.132 for right side and 0.005 and 0.850 for left side.

Tables 5 & 6 present's linear regression equations for reconstruction of femoral length from proximal fragments and diaphyseal segments in male and female femora.

Multiple regression formulae for calculation of FML from the measurements of fragments are as followed

Right male femur - FML = 4.999 + 0.368 DSL + 1.415 SDN + 0.254 TCL + 0.081 THD + 0.839 VHA + 0.651 VHD + 0.618 VND
Left male femur - FML = -0.701 + 0.517 DSL + 1.310 SDN + 0.219 TCL + 0.086 THD + 0.731 VHA + 1.533 VHD + 0.397 VND
Right female femur - FML = 1.055 + 0.522 DSL + 1.444 SDN + 0.282 TCL – 0.103 THD + 1.366 VHA + 0.290 VHD - 0.901 VND
Left female femur - FML = 1.356 + 0.639 DSL + 0.522 SDN + 0.314 TCL – 0.658 THD + 0.852 VHA – 0.087 VHD + 0.661 VND

Table 1: Comparision of bilateral measurements of male femora.

Male Femur		Right		Left		p value
		Mean	SD	Mean	SD	
1	FML	44.99	2.54	45.01	2.42	0.97
2	TCL	42.05	2.55	41.92	2.32	0.76
3	DSL	35.14	2.57	35.48	1.97	0.41
4	VHD	4.33	0.31	4.30	0.29	0.90
5	VND	3.22	0.25	3.24	0.30	0.66
6	VHA	8.99	0.73	8.95	0.94	0.67
7	THD	4.26	0.41	4.35	0.51	0.46
8	SDN	2.60	0.29	2.57	0.30	0.55

Table 2: Comparision of bilateral measurements of female femora.

Female Femur		Right		Left		p value
		Mean	SD	Mean	SD	
1	FML	40.97	2.26	41.67	2.17	0.01
2	TCL	37.72	2.50	38.60	2.16	0.03
3	DSL	32.34	2.34	32.86	2.18	0.17
4	VHD	3.83	0.29	4.29	3.04	0.08
5	VND	2.81	0.31	2.91	0.31	0.78
6	VHA	8.03	0.49	8.14	0.58	0.11
7	THD	3.79	0.32	3.85	0.35	0.45
8	SDN	2.25	0.30	2.33	0.28	0.15

Table 3: Karl Pearson co-efficient and p value in the correlation between maximum length and fragments of male femora.

Characteristics	Male femur	Karl Pearson's co-efficient	p value
FML-TCL	Right	0.756411	0.001
	Left	0.743633	0.001
FML-DSL	Right	0.72864	0.001
	Left	0.720328	0.001
FML-VHD	Right	0.627802	0.001
	Left	0.583086	0.001
FML-VND	Right	0.598563	0.001
	Left	0.595725	0.001
FML-VHA	Right	0.707994	0.001
	Left	0.525594	0.001
FML-THD	Right	0.602938	0.001
	Left	0.276464	0.020
FML-SDN	Right	0.239666	0.045
	Left	0.333452	0.004

Table 4: Karl Pearson co-efficient and p value in the correlation between maximum length and fragments of female femora.

Characteristics	Female femur	Karl Pearson's co-efficient	p value
FML-TCL	Right	0.798232	0.001
	Left	0.778496	0.001
FML-DSL	Right	0.783827	0.001
	Left	0.85066	0.001
FML-VHD	Right	0.343133	0.003
	Left	0.005499	0.964
FML-VND	Right	0.395173	0.001
	Left	0.386526	0.001
FML-VHA	Right	0.676125	0.001
	Left	0.548187	0.001
FML-THD	Right	0.47414	0.001
	Left	0.471749	0.001
FML-SDN	Right	0.132188	0.275
	Left	0.333452	0.004

Table 5: Regression Equations for reconstruction of femoral length (male).

Right Males	**Left Males**
FML= 13.28 + 0.75 TCL ± 3.33	FML= 12.56 + 0.77 TCL ± 3.56
FML= 19.68 + 0.72 DSL ± 2.89	FML= 13.61 + 0.88 DSL ± 3.69
FML= 22.43 + 5.20 VHD ± 3.39	FML= 23.80 + 4.93 VHD ± 3.61
FML= 25.49 + 6.05 VND ± 3.17	FML= 29.57 + 4.75 VND ± 2.55
FML= 22.88 + 2.45 VHA ± 2.68	FML= 32.80 + 1.36 VHA ± 2.44
FML= 29.02 + 3.74 THD ± 2.57	FML= 39.26 + 1.32 THD ± 2.47
FML= 39.57 + 2.08 SDN ± 2.67	FML= 39.28 + 2.22 SDN ± 2.46

Table 6: Regression Equations for reconstruction of femoral length (female).

Right Females	**Left Females**
FML= 13.77 + 0.72 TCL ± 2.49	FML= 11.46 + 0.78 TCL ± 2.97
FML= 16.50 + 0.75 DSL ± 2.35	FML= 1.84 + 0.84 DSL ± 2.10
FML= 30.68 + 2.68 VHD ± 3.42	FML= 41.65 + 0.004 VHD ± 0.45
FML= 32.88 + 2.88 VND ± 2.29	FML= 33.77 + 2.71 VND ± 2.71
FML= 15.95 + 3.11 VHA ± 3.31	FML= 24.98 + 2.05 VHA ± 3.11
FML= 28.08 + 3.39 THD ± 2.91	FML= 30.23 + 2.96 THD ± 2.62
FML= 38.71 + 1.00 SDN ± 2.06	FML= 35.71 + 2.55 SDN ± 2.07

DISCUSSION

Physical anthropologists and forensic pathologists have given utmost importance to the methods of stature estimation from long bones. The bones of the lower extremity namely the femur and tibia have yielded consistent and good results. As compared to Fully's method regression analysis is a more appropriate method to define relationship between length of long bones and living height of individuals and between length of measurements of long bone fragments and their maximum length [4].

The linear regression equations to calculate stature from length of bones have been cited in 'Human Skeleton in Forensic Medicine' [7].

Muller [8] appears to be only worker who has studied the mean proportions of various parts of some long bones e.g. tibiae, humerii and radii to their total length.

A successful reconstruction of the total length of the humerus and femur from available fragments of the bones has been reported in a case by Gorden and Drennan [9].

However the statistical formula used in this method is appropriate when used only in specific population whence it was derived. Regression formula obtained in a specific population can underestimate or overestimate stature if applied in another population [10].

Population specific works have been done by various researchers. Studies were done in different races by Steele in American population, Bidmos in South African population [11, 12].

Even earlier works from India by Pan [13] on Hindus of Bengal, Bihar and Orrissa are noteworthy. Kate and Mazumdar also successfully estimated stature from length of femur and humerus by regression method in Indian sample [14].

Similar studies to estimate stature from femur were performed by Mysorekar [15], Rajendra Prasad [16] on Indian population. In another work Shrof et al [17] calculated the percentile length of each segment and compared to total length.

Further population specific studies were reported by Mukhopadhyay P on 65 dry adult male femora in Bengali population[5], Mahajan on 162 femora (86 males and 76 females) [18], Sarzoo on 200 femora on Gujarath population [19] and Sandeep to derive regression equation on 200 femora from inter trochanteric crest from Central Indian population [4].

South Indian studies by Chandran M on 60 adult South Indian female femurs [20] and Shwetha Solan on 150 femora [21] utilized fragments and segments of femora for estimation of femoral length.

In the present study, we used precise landmarks. Two diaphyseal measurements TCL and DSL) and 5measurements (VHD, VND, VHA, THD and SDN) of the proximal end were identified and selected in a sample of 280 adult femora.

While considering the descriptive statistics, mean value of FML in South Indian males varied from 44.99 (right) to 45.01(left). In females FML was 40.97(right) to 41.67(left).These values correlated with those of Sarzoo (43.71), Mukhopadhyay P (41.82), Sandeep (43.75),) Chandran M (39.5) and Shwetha Solan (Rt- 43.42 & Lt – 43.54). [19, 5, 4, 20, 21]

Correlation is a measure of association between two variables. In our study correlation of maximum length of femur with its proximal fragments with two diaphyseal segments was calculated in both the sexes bilaterally.

Mean values of FML, VHD, VND and VHA of South Indian female population were well correlated with that of study conducted on a similar population by Chandran M.

Among diaphyseal segments, TCL showed maximum correlation with FML in South Indian males bilaterally and South Indian females on the left side. In left femora of South Indian females, DSL had maximum correlation than TCL.

Among proximal fragments, VHA had superior correlation with bilateral femora of South Indian females and right femora of South Indian males. Left femora of South Indian males exhibited maximum correlation with VND. While comparing the correlations of comparable fragments of Chandran M study, the fragments VHA showed better correlations than other fragments.

Hence in medico legal situations where any of the proximal femoral fragments is recovered, regression formula using the Upper breadth of the femur (VHA) measurement will prove more useful. The correlation of the SDN on its own is very poor and should only be used in cases where the other fragments are not available.

The correlations tend to be greater where combinations of different femoral fragments rather than a single fragmentary length were used, indicating that it is preferable to estimate maximum femoral length using more than one fragment wherever possible, for higher predictive accuracy.

Since all the measurements in our study had positive correlation with the FML, it is prudent to derive simple linear regression analysis against the individual measurements to calculate FML from anyone of these markers (tables 5 &6).

CONCLUSION

The knowledge of the morphometric values of femoral fragments is important in forensic, anatomic and archaeological cases in order to identify unknown bodies and stature. In the present study, determination of the total length of femur has been done from 2 diaphyseal and 5 proximal femoral fragments. Extra fragments used in the study provide further scope to calculate regression formulae in future. In the present study, mean lengths of femoral fragments and mean total length of femur have been calculated bilaterally for males and females in 280 femora. This observation which is population specific and sex specific has not been done by previous authors in such large samples. As a result, these measurements may help to indicate the characteristic morphological features of femoral fragments in South Indian population.

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