DOI: 10.7860/IJARS/2019/37766:2448

Estimation of Length of Femur from its Proximal Segment in Maharashtrian Population

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ABSTRACT

Introduction: Stature is an important parameter in identification of an individual. It can be calculated from length of long bones especially femur and tibia. Bony markers such as head and neck of femur can used in determining the length of femur and thereby stature of an individual.

Aim: To find a relation, if any between dimensions of proximal segment of femur and its length and to derive regression equations for the same.

Materials and Methods: This study included 280 femora (136 right and 144 left), which were measured for Length of femur, circumference, vertical diameter and transverse diameter of head, vertical and transverse diameter of neck, anterior and posterior neck length with Osteometric board and Vernier callipers. Then, the data was analysed statistically using student t-test, Pearson‘s correlation coefficient and linear regression analysis. A p-value of < 0.05 was considered significant and <0.01 highly significant.

Results: The mean length of femur was 412.56+30.34 mm (Right 414.96±30.57 mm, Left 410.29±30.05 mm). The length of femur correlated significantly with dimensions of its proximal end (p<0.01). Linear regression equations for length of femur from proximal femoral end dimensions were derived.

Conclusion: Regression equations for length of femur from proximal femoral end dimensions derived in this study will be useful for anthropologists, archaeologists and forensic investigators for determining the length of femur and thereby stature and identity of an individual.

Keywords: Bony markers, Femoral length, Identity, Long Bones, Regression equation, Stature

INTRODUCTION

Estimation of stature plays a significant role in the field of forensic anthropology. It is an important element in the identification of an individual, living or dead [1]. Different body parts can be used for the estimation of stature [2]. It has been found that the weight bearing bones of lower limb have the highest degree of correlation with stature [3-5].

Femur is the longest and strongest bone in the human body. It has a shaft, proximal end and distal end [6]. An intact femur, bearing the highest degree of correlation with the stature, is widely used for deriving regression equation for estimating stature [3]. In cases where the intactness of the femur is lost, estimation of stature from femur becomes difficult [2]. In such cases, regression equation for length of femur from its fragments help in estimating its approximate length and thereby stature of a person [7]. Dimensions of femur varies in different regional and ethnic groups, so population specific formula for estimation of femoral length is required [2].

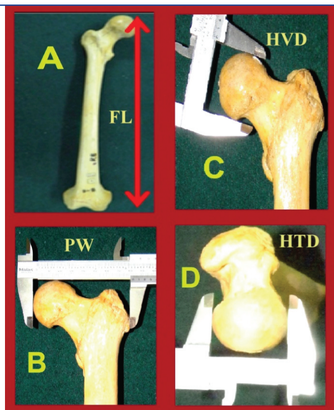
The present study was conducted to find out a correlation between length of femur and dimensions of its proximal segment in Maharashtrian population and to derive regression equations for the same. This study will be of immense value for forensic investigators and archaeologists, especially when they could find only fragmentary body parts.

MATERIALS AND METHODS

The present study was a cross sectional, observational study conducted at the department of Anatomy of Armed Forces Medical College Pune, BJ Medical College Pune and Government Medical College Aurangabad, India. It was carried out over a period of three years during May 2010-April 2013. Prior approval of institutional ethics committee was taken for doing measurements of femur. The present study included 280 adult human femora (136 right and 144 left).

All femora were intact and fully ossified indicating adult bones. Femora with pathological changes such as cortical bone deterioration, arthrosis, extreme osteophytic activity, diffuse osteoarthritis, fracture and visible abnormalities were excluded from the study. Osteometric board, flexible measuring tape and Vernier caliper were used for measurement of various parameters. All measurements were repeated thrice by same observer and the mean values were recorded to minimise error during measurement. Values were recorded in millimetres.

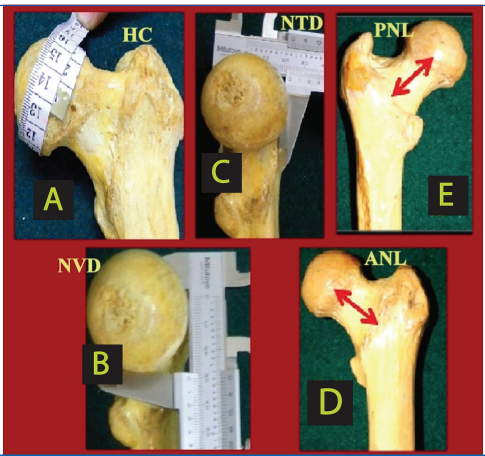
The Length of Femur (FL) was measured as the straight distance between the highest point of head and the lowest point on the medial condyle of femur with the help of osteometric board [Table/Fig-1A] [8]. Proximal Width (PW) was taken as the maximum width between the medial most point of head of femur and the lateral surface of greater trochanter [Table/Fig-1B]. The Vertical Diameter of Head of Femur (HVD) was measured as the distance between highest and lowest points of head of femur in the equatorial plane [Table/Fig-1C]. The Transverse Diameter of Head of Femur (HTD) was measured as a distance between the most lateral and most medial points of head of femur in the equatorial plane [Table/Fig-1D]. The Circumference of Head (HC) was measured at the same points as diameters with the help of flexible measuring tape [Table/Fig-2A] [8].



[Table/Fig-1 (A-D)]: Dimensions of proximal segment of femur.

Neck Vertical Diameter (NVD) was measured as the minimum diameter of the neck of the femur between its superior and inferior borders [Table/Fig-2B]. Neck Transverse Diameter (NTD) was measured in the narrowest part of the neck as the distance between anterior and posterior surfaces with the help of sliding calliper [Table/Fig-2C] [9].

Anterior Neck Length (ANL) was measured along the long axis of the neck anteriorly between the base of the head and the mid-point of the intertrochanteric line [Table/Fig-2D]. The Posterior Neck Length (PNL) was measured along the long axis of the neck posteriorly between the base of the head and midpoint of intertrochanteric crest with the help of sliding calliper [Table/Fig-2E] [10].



[Table/Fig-2 (A-E)]: Dimensions of proximal segment of femur.

STATISTICAL ANALYSIS

All the measurements were tabulated and analysed statistically. Minimum, maximum, mean, standard deviation and p-values were determined. Pearson's correlation coefficient was used to find a correlation between FL and dimensions of its proximal segment. The p-value of <0.05 was considered as significant and <0.01 highly significant. The values of femur length were compared with those reported in previous studies in different ethnic groups using the unpaired t-test to see if the difference between the two is statistically significant.

Regression equations were formulated for estimation of length of femur from dimensions of its proximal segment. Statistical Package for Social Sciences version 17.0 (SPSS version 17.0) was used for statistical analysis.

RESULTS

The length of femur ranged from 355 mm to 485 mm with mean 412.56 mm and standard deviation 30.34 mm among 280 femora [Table/Fig-3]. Measured variables of femur, PW, HVD, HTD, HC, NVD and NTD showed significant positive correlation (p<0.01) with length of femur. HVD displayed highest degree of correlation (Pearson's correlation coefficient- 0.758) with length of femur [Table/Fig-3].

Measure-ments	Minimum	Maximum	Mean	Std Devia-tion	Correlation with FL	p-value
FL	355.00	485.00	412.56	30.34	-	-
PW	65.30	98.22	82.63	6.19	0.580**	<0.01
HVD	33.90	49.00	40.53	3.51	0.758**	<0.01
HTD	34.00	49.00	40.44	3.47	0.747**	<0.01
HC	108.00	153.00	126.69	10.55	0.604**	<0.01
NVD	22.00	34.54	27.82	2.82	0.476**	<0.01
NTD	17.10	31.19	23.21	2.84	0.563**	<0.01
ANL	19.48	48.10	29.92	4.04521	0.019	0.747
PNL	22.30	50.00	35.23	4.22528	0.092	0.127

[Table/Fig-3]: Dimensions of proximal segment total femora and Pearson correlation coefficient between length of femur (FL) and dimensions of its proximal segment (n=280).
** Correlation is significant at the 0.01 level (2-tailed); FL: Length of Femur; PW: Proximal Width; HVD: Vertical Diameter of Head; HTD: Transverse Diameter of Head; HC: Circumference of Head; NVD: Neck Vertical Diameter; NTD: Neck Transverse Diameter; ANL: Anterior Neck Length; PNL: Posterior Neck Length

The dimensions of the proximal segments of right femora were measured. The length of right femur ranged from 355 mm to 485 mm with mean 414.96 mm and standard deviation 30.57 mm. The variables of upper end of femur proximal width, head vertical diameter, head transverse diameter, head circumference, neck vertical diameter and neck transverse diameter showed highly significant positive linear correlation with length of femur. Head vertical diameter showed highest degree of correlation with femur length (correlation coefficient 0.784) [Table/Fig-4].

Measure-ments	Minimum	Maximum	Mean	Std De-viation	Correlation with FL	p-value
FL	355.00	485.00	414.96	30.57	-	-
PW	65.30	98.22	82.23	6.20	0.616**	0.000
HVD	33.90	49.00	40.57	3.54	0.784**	0.000
HTD	34.00	49.00	40.59	3.47	0.772**	0.000
HC	108.00	153.00	126.50	10.44	0.682**	0.000
NVD	22.00	34.54	27.78	2.78	0.515**	0.000
NTD	17.10	31.19	23.28	2.85	0.548**	0.000
ANL	19.85	48.10	29.9633	4.23084	-0.028	0.743
PNL	24.30	50.00	35.4120	4.25122	-0.151	0.079

[Table/Fig-4]: Dimensions of proximal segment right femora and Pearson correlation coefficient between length of femur (FL) and dimensions of its proximal segment (n=136).
** Correlation is significant at the 0.01 level (2-tailed); FL: Length of Femur; PW: Proximal Width; HVD: Vertical Diameter of Head; HTD: Transverse Diameter of Head; HC: Circumference of Head; NVD: Neck Vertical Diameter; NTD: Neck Transverse Diameter; ANL: Anterior Neck Length; PNL: Posterior Neck Length

The length of left femora ranged from 355 mm to 485 mm. The mean length was found to be 410.29±30.05 mm. The variables of left femora like proximal width, head vertical diameter, head transverse diameter, head circumference, neck vertical diameter, neck transverse diameter, anterior and posterior neck length showed highly significant positive linear correlation with length of femur. Among the variables head vertical diameter showed highest degree of correlation with femur length (correlation coefficient 0.736) [Table/Fig-5].

Measure-ments	Minimum	Maximum	Mean	Std Devia-tion	Correlation with FL	p-value
FL	355.00	485.00	410.29	30.05	-	-
PW	65.30	98.22	82.60	6.20	0.549**	0.000
HVD	33.90	49.00	40.49	3.49	0.736**	000
HTD	34.00	49.00	40.30	3.48	0.722**	000
HC	100.00	153.00	126.80	10.83	0.712**	000
NVD	22.00	34.54	27.86	2.87	0.445**	000
NTD	18.20	31.19	23.13	2.83	0.577**	000
ANL	19.48	39.00	29.8763	3.87610	0.319**	0.000
PNL	22.30	44.60	35.0289	4.20696	0.411**	0.000

[Table/Fig-5]: Dimensions of proximal segment left femora and Pearson correlation coefficient between length of femur (FL) and dimensions of its proximal segment (n=144).
**Correlation is significant at the 0.01 level (2-tailed); FL: Length of Femur; PW: Proximal Width; HVD: Vertical Diameter of Head; HTD: Transverse Diameter of Head; HC: Circumference of Head; NVD: Neck Vertical Diameter; NTD: Neck Transverse Diameter; ANL: Anterior Neck Length; PNL: Posterior Neck Length

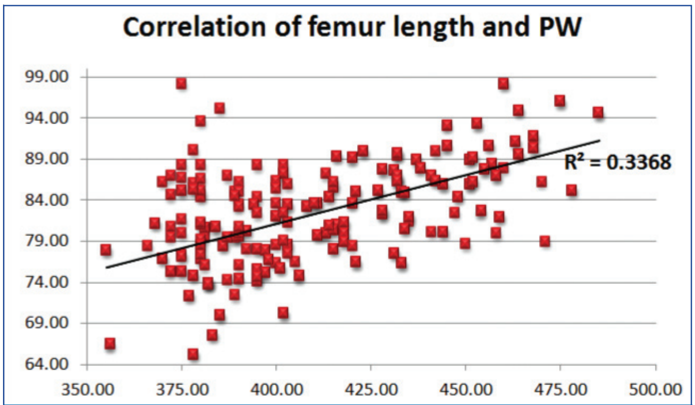
Linear regression equations for estimation of length of femur from its proximal segments for right and left femora were formulated. Anterior and posterior neck length of right femur did not show statistically significant linear correlation with femoral length, so regression equation for the same could not derived [Table/Fig-6].

Multiple regression equations for estimation of length of femur from its proximal segments on right side formulated. FL= 128.347+ 4.104 (HVD) + 2.959 (HTD). Femoral length of left side FL=126.767+ 3.985 (HVD) +0.963 (HC).

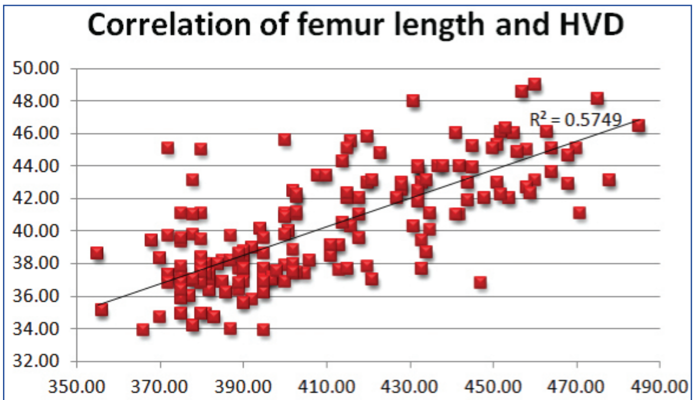
S No.	Regression Equations (Right)	Regression Equations (Left)
1.	FL = 163.757+3.040 (PW)±27.808	FL = 190.405+2.661 (PW)±28.146
2.	FL = 140.728+6.760 (HVD)±18.854	FL = 153.813+6.335 (HVD)±19.853
3.	FL = 139.272+6.793 (HTD)±19.692	FL = 158.923+6.238 (HTD)±20.265
4.	FL = 162.143+1.999 (HC)±23.473	FL = 159.944+1.974 (HC)±20.822
5.	FL = 257.427+5.671 (NVD)±22.773	FL = 280.256+4.668 (NVD)±22.059
6.	FL = 278.133+5.876 (NTD)±18.153	FL = 268.218+6.143 (NTD)±16.984
7.	---	FL = 336.346+2.475 (ANL)±18.574
8.	---	FL = 307.340+2.939 (PNL)±19.274

[Table/Fig-6]: Regression Equations for estimation of length of femur (FL) from its proximal segments.
FL: Length of Femur; PW: Proximal Width; HVD: Vertical Diameter of Head; HTD: Transverse Diameter of Head; HC: Circumference of Head; NVD: Neck Vertical Diameter; NTD: Neck Transverse Diameter; ANL: Anterior Neck Length; PNL: Posterior Neck Length

The scatter diagrams were drawn to show the relationship between length of femur with various parameters of upper end of femur like proximal width, vertical and transverse diameter of head of femur, circumference of head, vertical and transverse diameter of neck of femur [Table/Fig-7-12]. The R2 is the coefficient of determination, the value of coefficient of determination tells about strength of relationship between two variables. The coefficient of determination was maximum (0.5749) between femur length and head vertical diameter [Table/Fig-8].



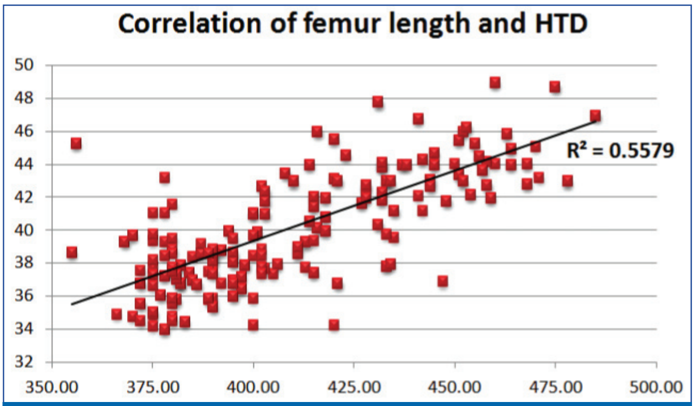
[Table/Fig-7]: Correlation between femur length and proximal width (n=280).
[PW- Proximal width, R^2 - Coefficient of determination]



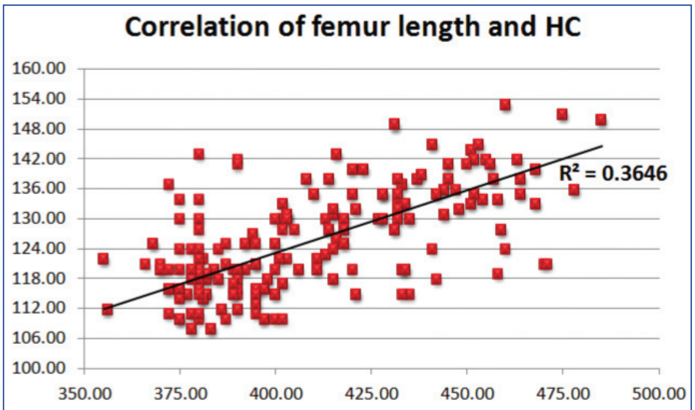
[Table/Fig-8]: Correlation between femur length and head vertical diameter (n=280).
[HVD vertical diameter of head of femur, R^2-Coefficient of determination]

DISCUSSION

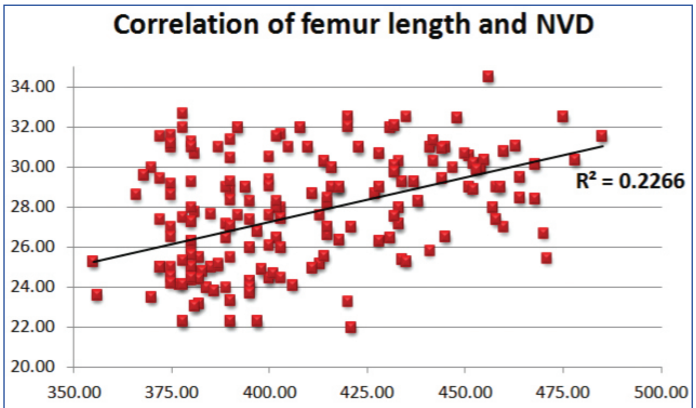
Stature is an important anthropometric parameter to establish an individual's identity in medico-legal issues relating to skeletal remains examination. Stature is estimated using combined dimensions of bones responsible for height or using regression equations based on intact long bone length measurements. In some instances like a mass disaster, these methods cannot be applied as intact long bones are not available [11]. The available regression equations for estimation of statute are not broadly applicable to the diversity of population as these equations are population specific [12]. The



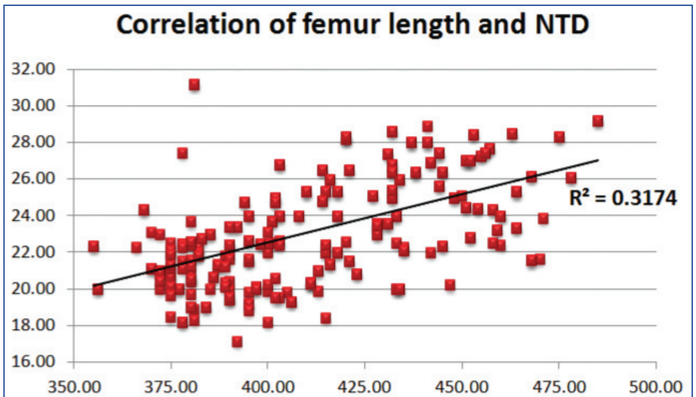
[Table/Fig-9]: Correlation between femur length and transverse diameter of head (n=280).
[HTD transverse diameter of head of femur, R2-Coefficient of determination]



[Table/Fig-10]: Correlation between femur length and circumference of head (n=280).
[HC circumference of head, R^2 - Coefficient of determination]



[Table/Fig-11]: Correlation between femur length and Neck Vertical Diameter (n=280).
[NVD vertical diameter of neck, R^2 - Coefficient of determination]



[Table/Fig-12]: Correlation between femur length and Neck transverse diameter (n=280).
[NTD transverse diameter of neck, R2 - Coefficient of determination]

anthropometric dimensions vary among different population groups, which could be due to the effect of genetic and environmental factors on growth and development of an individual [13].

The femur is one of the long bones frequently used for estimation of stature of the individual [14]. Bidmos MA et al., explained mathematical method for estimation of the stature from length of femur [15]. This method is used when intactness of femur is lost and only segments of femur are available [14]. In this method, a fragment of the femur is used to estimate the total length of the femur, and then the total length of the femur is used to estimate the stature of the individual [14]. This approach is also known as indirect method of stature estimation [16]. The regression formulae based on the length of the extremity long bones, particularly the femur, are considered the best estimators of stature [15,17]. Dimensions of femur vary in different regional and ethnic groups, so population specific formula for estimation of femoral length is required [4].

In the present study, length of femur (FL) and various parameters of its proximal segment of 280 femora (136 right and 144 left) were measured and analysed statistically using independent samples t-test, Pearson's correlation coefficient and linear regression analysis. A p-value of <0.05 was considered significant and <0.01 highly significant. Mean length of femur in the study (412.56 mm) was significantly lower than femur belonging to other populations (p<0.01) [17-21]. This indicates that racial and ethnic variations are found in length of femur. This racial difference can be the result of genetic and environmental factors affecting growth and development of an individual [22]. [Table/Fig-12] compares the present study with studies done by other authors in different ethnic groups [1,17-21,23].

The mean length of femur is maximum among South Africans (454.56±24.67 mm) followed by French (443.6±21.8 mm), and Japanese (401.27±17.40 mm). Among Indian studies, Leelavathy N et al., Banglore (433.52±19.80 mm), Gargi Soni et al., Rohtak (425.09±26.18mm), C Magendran, Chennai (390.5±10.4mm). In the present study we reported length of femur 412.56±30.34. This shows regional and racial variations in length of femur [Table/Fig-13].

Sr No.	Name of worker	Sample Size	Mean	SD	p-value
1.	Rubin PJ et al., France [18].	32	443.6	21.8	<0.01
2.	Ozer I, Japanese [23].	45	401.27	17.40	<0.01
3.	Steyn M, South Africa [19].	106	454.56	24.67	<0.01
4.	Leelavathy N et al., Banglore [20].	40	433.52	19.80	<0.01
5.	Jubilant K A et al., Ghana [17].	50	449.70	23.40	<0.01
6.	Gargi Soni et al., 2010, Rohtak [21].	80	425.09	26.18	<0.01
7.	C Magendran, Chennai [1].	60	390.5	10.4	<0.01
8.	Present Study, Maharashtra	280	412.56	30.34	-

[Table/Fig-13]: Comparison of present study with studies done by other authors in different ethnic groups [1,17-21,23].

Statistically significant correlations were found between length of femur and dimensions of its proximal segment except anterior and posterior neck length in total and right femora whereas, in left femora, all dimensions showed statistically significant correlation with femoral length (FL). Vertical diameter of head (HVD) emerged as the best estimator of length of femur (correlation coefficient r = 0.784 on right side and r = 0.736 on left side). The Standard Error Estimates (SEE) of the regression formulae were relatively low (i.e., SEE, 18.15-28.14 mm), suggesting that the discrepancies between actual and estimated stature were relatively low. In the present study, we had used linear regression analysis to derive simple and multiple regression equations for formulating the length of femur.

Regression equations were also formulated for estimation of length of femur from dimensions of its proximal segment by Magendran C in Chennai, Singh S et al., in Bhopal, Asha KR et al., in Karnataka, Parmar AM et al., in Rajasthan, Khanal L et al., in Nepal, Jubilant KA et al., in Ghana, Umesh Babu R in Karnataka, Solan S et al., in South India, Ghosh T et al., in West Bengal and Desai SG in Gujrat [1-4,14,17,24-27].

Simmons T et al., studied on 200 males and females of black and white races (total sample = 800) to estimate stature from fragments of the femur [28]. They derived regression equations for estimation of length of the femur from each of the fragments. The height of individuals is an important parameter for medico-legal investigations. In forensic anthropology, the estimation of stature from the bones plays an important role in the identification of missing persons [29].

In the present study, we deployed multiple parameters because regression equations tend to be more accurate if multiple parameters are used for formulation.

LIMITATION

Sexual dimorphism in the morphometry of femur has not been taken into consideration while selecting femur for the study. Demographic characteristics such as age, occupation, sex and nutritional status etc were unknown. The precision of measurements could have been increased by use of digital calipers.

CONCLUSION

The present study showed statistically significant linear correlation between length of femur and dimensions of its proximal segment. Simple and multiple regression equations derived for estimation of femoral length from its proximal segment will be of immense value for forensic investigators and archaeologist for calculation of length of femur and thus in estimation of stature of an individual, especially when fragmentary body parts are found.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Jul 03, 2018**
Date of Peer Review: **Jul 24, 2018**
Date of Acceptance: **Dec 18, 2018**
Date of Publishing: **Jan 01, 2019**