

## Original Article

# Role of Estimation of Total Length of Femur from its Fragments on Medico-legal Cases

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## ABSTRACT

In most forensic anthropological investigations, stature is estimated using the combined dimensions of bones responsible for living stature or using regression equations based on complete long bone length measurements. However, in mass disasters, burns and in skeletal cases where many of these bones are carried off by the animals these methods cannot be applied because intact long bones are not available. As a result anthropologists have developed methods for reconstructing stature based on measurements of fragments of long bones. From these measurements bone length is estimated and then the estimated bone length is used to estimate stature. This study was done on 162 grossly normal and completely ossified femora (86 males and 76 females femora) taken from osteology sections of the departments of Anatomy and Forensic Medicine, SGRDIMSAR, Amritsar. With the help of improvised osteometric board the maximum total length of all the femora and linear, transverse, sagittal and circumferential measurements of the segments were taken simultaneously. The ranges, arithmetic means, standard deviations, correlation coefficient and regression equations were then calculated with the help of stature formulae, the length so calculated may be used in determining the probable stature of a person. In conclusion, our study demonstrated that length of femur can be estimated from measures of different segments of bone.

**Keywords:** Femur length, Fragmentary measurements, Stature, Regression equation

## INTRODUCTION

In Forensic practice fragments of long bones (because of injury, mutilation, destruction or post mortem gnawing by wild animals) are often presented as the only available source. To establish identity under such circumstances, it is necessary in the first instance to make an estimate as accurate as possible of the probable length of the bone from such a fragment and then employ it in statural formulae. Muller<sup>1</sup> studied the mean proportions of various parts of long bones to their total length. Chandra et. al<sup>2</sup> used four linear segment lengths and one transverse dimension (bicondylar breadth) of 200 femora to estimate femoral length. Steele and McKern<sup>3</sup> formulated regression equation for each segment.

Chandra and Nath<sup>4</sup> used a single transverse dimension of humerus and femur to compute a multiplication factor for reconstruction of bone length. Pelin<sup>5</sup> and Chibba<sup>6</sup> have indicated that population specific formulae are appropriate and produce more accurate results. Dan Utpal et al<sup>7</sup> established the relation between fragment of tibia and tibial length and subsequently stature in Indian Bengali population. In the present study an attempt has been made for estimation of femoral length using fragmentary measurements pertaining to linear transverse, sagittal and circumferential dimensions of the femur.

**MATERIAL AND METHODS**

86 male and 76 female femora well macerated with cartilage removed after sufficient time to assure complete drying of the bones were taken from Osteology sections of the department of Anatomy and Forensic Medicine, SGRDIMSAR, Amritsar. Bones with any injury deformity or artifact were discarded. All the measurements including maximum length were taken by one of the authors following standard measurement techniques (Table 1; Figure-1) with anthropometric set consisting of osteometer and calipers.

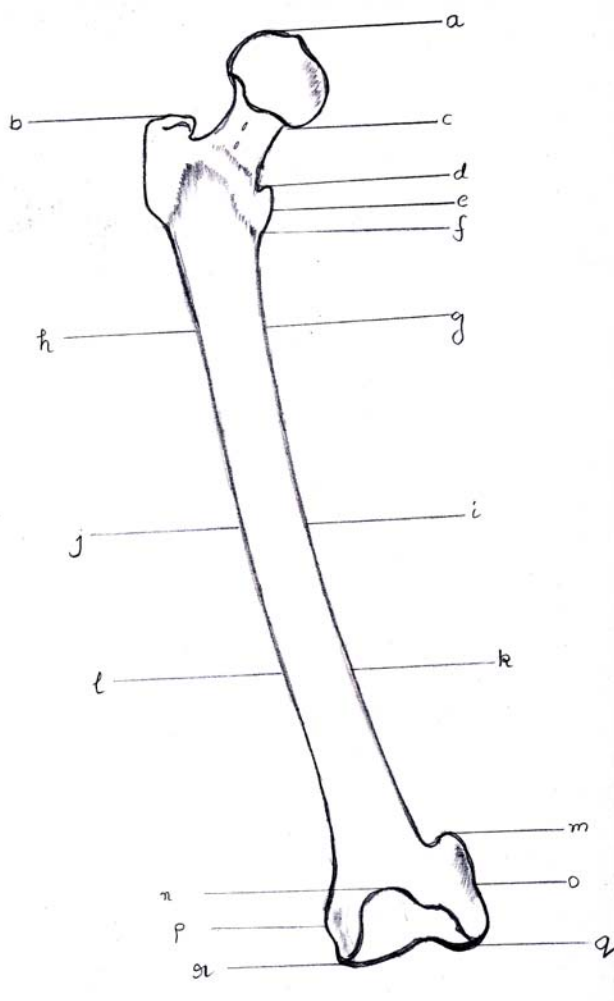


Figure 1: Details of Landmark on Femur

**Table 1: List of measurements used for estimation of body dimensions for femoras fragments**

Figure. 1	Measurements
a-c	Head height (HH)
c-d	Neck height (NH)
b-f	Trochanteric height (TH)
m-q	Height of medial condyle (HMC)
c-m	Shaft length
n-r	Height of patellar surface (HPC)
a-q	Maximum length (ML)
g-h	Upper shaft diameter (USD)
i-j	Mid shaft diameter (MSD)
k-l	Lower shaft diameter (LSD)
o-p	Bicondylar breadth (BB)
	Sagittal diameter at middle (SDM)
	Upper shaft circumference (USC)
	Mid shaft circumference (MSC)
	Lower shaft circumference (LSC)

**RESULTS**

**Table 2: Mean & Standard Deviation of Different Body Dimensions of Femoral Fragments in Males and Females**

S.I. No.	Body dimensions	Male (n=86)	Female (n=76)	t-value	P-value
		Mean ± SD (cm)	Mean ± SD (cm)		
1	Maximum length (ML)	43.36±2.54	41.62±1.76	7.49	<0.001
2	Head height (HH)	4.12±1.68	3.92±1.81	4.32	<0.001
3	Neck height (NH)	2.57±2.04	2.18±2.19	6.46	<0.001
4	Trochanteric height (TH)	5.84±1.64	5.49±1.91	6.52	<0.001
5	Height of medial condyle (HMC)	4.27±1.75	3.95±1.93	7.13	<0.001
6	Shaft length (SL)	32.87±0.86	31.45±0.89	6.12	<0.001
7	Upper epiphyseal breadth (UEB)	8.44±1.54	8.12±1.88	5.86	<0.001
8	Upper shaft diameter (USD)	2.78±1.84	2.67±2.21	7.58	<0.001
9	Mid shaft diameter (MSD)	2.45±1.76	2.41±2.15	2.18	<0.05
10	Lower shaft diameter (LSD)	2.87±1.89	2.68±2.22	4.14	<0.001
11	Bicondylar breadth (BB)	7.57±1.80	7.16±1.70	6.68	<0.001
12	Sagittal diameter at middle (SDM)	2.61±1.82	2.45±1.81	4.94	<0.001
13	Upper shaft circumference (USC)	8.31±1.60	7.98±1.80	5.42	<0.001
14	Mid shaft circumference (MSC)	8.24±1.53	7.82±1.77	5.64	<0.001
15	Lower shaft circumference (LSC)	9.18±1.58	8.57±1.92	6.18	<0.001

Table 2 displays the mean and standard deviation of different body dimensions of femoral fragments (cm) of males and females. Male femora exhibit larger dimensions for all the measurements and differential trends as assessed through the t-test, reveal highly significant sex difference for all the measurements at the p<0.001 level of significance except for midshaft diameter (MSD) where sex differences are significant at p<0.05 level.

**Table 3: Multiplication Factor of Different Body Dimensions for Estimation of Femoral Length among Males and Females**

S.I. No.	Body dimensions	Male (n=86)	Female (n=76)
1	Head height (HH)	10.52	10.61
2	Neck height (NH)	16.87	19.10
3	Trochanteric height (TH)	7.42	7.58
4	Height of medial condyle (HMC)	10.15	10.54
5	Shaft length (SL)	1.32	1.32
6	Upper epiphyseal breadth (UEB)	5.14	5.12
7	Upper shaft diameter (USD)	15.60	15.59
8	Mid shaft diameter (MSD)	17.70	17.27
9	Lower shaft diameter (LSD)	15.11	15.53
10	Bicondylar breadth (BB)	5.73	5.48
11	Sagittal diameter at middle (SDM)	16.61	16.69
12	Upper shaft circumference (USC)	5.22	5.21
13	Mid shaft circumference (MSC)	5.26	5.32
14	Lower shaft circumference (LSC)	4.42	4.86

Table 3 reveals that SL, BB, HH, TH, HMC, SDM and NH exhibit much higher correlation with femoral length among females while the remaining measurements exhibit a higher correlation with bone length among males.

**Table 4: Linear Regression Equation for Estimation of Femoral Length for Different Body Dimensions among Males and Females**

S.I. No.	Male		Female	
	Regression equation	Correlation coefficient (r)	Regression equation	Correlation coefficient (r)
1	FL=6.12+1.14 (SL)	0.879	FL=6.39+1.12 (SL)	0.923
2	FL=22.84+2.49 (MSC)	0.748	FL=19.21+3.13 (BB)	0.752
3	FL=24.87+2.19 (UEB)	0.734	FL=22.46+2.45 (MSC)	0.738
4	FL=27.02+1.78 (LSC)	0.712	FL=29.03+5.14 (SDM)	0.663
5	FL=21.59+2.62 (USC)	0.612	FL=21.31+5.18 (HH)	0.661
6	FL=29.51+2.37 (TH)	0.610	FL=21.83+2.48 (USC)	0.638
7	FL=29.55+3.54 (HH)	0.584	FL=22.62+2.34 (UEB)	0.610
8	FL=24.66+4.38 (HMC)	0.543	FL=26.35+2.78 (TH)	0.594
9	FL=29.22+5.77 (MSD)	0.521	FL=25.85+1.84 (LSC)	0.591
10	FL=24.59+2.48 (BB)	0.514	FL=23.57+4.57 (HMC)	0.478
11	FL=31.38+4.59 (SDM)	0.428	FL=29.83+4.89 (MSD)	0.418
12	FL=30.74+4.54 (USD)	0.412	FL=36.98+2.13 (NH)	0.410
13	FL=34.78+2.99 (LSD)	0.411	FL=32.02+3.44 (USD)	0.384
14	FL=40.04+1.29 (NH)	0.394	FL=33.21+3.14 (LSD)	0.367

Table 4 exhibits linear regression equations based on various measurements of fragments of femora. The

correlation coefficient (r) ranges between 0.879 and 0.394 for males and between 0.923 and 0.367 for females. The relationship of these fragmentary measurements with femoral length is variable in both the sexes e.g. BB exhibits a significantly high correlation among females (r=0.478) as against males (r=0.514). Similarly LSC among males exhibits a much higher correlation (r=0.712) with femoral length than among females (r=0.663).

## DISCUSSION

Measurements of long bones play an important role in the estimation of stature of an individual in paleoanthropology and forensic investigations.<sup>5, 8,9,10</sup> Height of individuals is also vital to medicolegal investigations. Thus, in forensic anthropology projection of stature from bones plays an important role in the identification of missing persons.<sup>11,12</sup> 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 bones fragments and their maximum length.<sup>13,14,15</sup>

This statistical method has been used in estimation of stature from intact long bones of upper and lower limbs in different population such as Americans<sup>16</sup>, Portuguese<sup>17</sup>, and Turkish.<sup>9</sup> Chandra and Nath<sup>4</sup> used a single transverse measurement to estimate bone length while Nath and Badkur<sup>18</sup> used multiple dimensions (linear, transverse, sagittal and circumferential) to estimate both bone length as well as stature. Owing to the significant sex differences (Table 2) in all the measurements, the sexes have been treated separately for computing regression formulae for estimation of bone length. Considering the linear regression equations the best estimates of femoral length are obtained using SL (r = 0.879), UEB (r = 0.734), MSC (r = 0.748) and SDM (r = 0.428) respectively with linear, transverse, circumferential and sagittal femur measurements.

This sequence among males remains unaltered for females except for the replacement of the transverse measurement UEB by BB. In view of relatively higher values of r for SL, BB and SDM with femoral length among females and that of UEB and MSC among males, the accuracy in predicted femoral length would be greater

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for females than males. Different linear regression equations formulated in this study would enable us to reconstruct femoral length in all these instances where skeletal remains of femur are identified from recovered skeletal material. It is essential for an expert to first identify the sex of the recovered skeletal material before entering the measured dimensions of the segments in respective linear regression formulae available for both the sexes to reconstruct bone length. The bone length thus estimated could be used subsequently for estimation of stature either by entering the estimated femoral length into statural formulae available for same population<sup>16</sup> or by using fresh regression formulae<sup>18</sup> from the fragmentary measurements of femur for reconstruction of stature.

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