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Reconstruction of Tibial Length and Stature from Fragmentary Dimensions

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INTRODUCTION

A forensic anthropologist is often called upon to examine the human remains that are recovered from a crime scene to reconstruct the biological nature of the individual at the time of death. Forensic anthropologist is trained to interpret postmortem changes in the human skeleton and differentiate prehistoric skeletons from unknown modern skeletons. Besides identification of war dead, forensic anthropologists are often called upon to assist in identification of mass disaster victims, where identification of individuals may not be as big a problem as the separation of commingled remains into individual skeletons. They also perform examination of the skeletal material to determine age, sex, race, stature etc., in such cases. But under such circumstances where no commingling exists, fragmented, burnt or partial skeletal remains pose much complications in examining them for identification.

Determination of age and sex of the skeletal material do not pose much complication when skull and pelvis are available. However, their absence may complicate the procedure of identification. With regard to the estimation of stature, a near accurate estimate can be obtained by certain methods which are based on the assumption that there exists a constant relationship between the long bone lengths and stature. Reconstruction of stature is an important aspect in the skeletal examination as after ascertaining the age and sex it is pertinent to know how tall the person was at the time of death. This task is accomplished by measuring the total length of the long bones of upper and lower limbs and applying the regression formulae or the multiplication factors that are based on the relatively constant relationship of each long bone to living stature. Though, stature of a recently dead, decomposed or mutilated but intact body may be obtained by simply measuring the body in supine position. However, the identification value of such measurements is dependent upon the availability of the antemortem height of the deceased. The accuracy of postmortem height is greater than the antemortem height because we are not certain as to when and how it was recorded. Age at which the antemortem height was recorded is important as with increase in age beyond 45 years the height is likely to decline due to atrophic changes that occur in the disc cartilage or bones. Thus the postmortem height is likely to fluctuate by 2-3cm either side of the antemortem height of an individual.

The systematic research on stature estimation started with the work of Beddoes (1887) who made an atempt to estimate stature from femoral length on the "Older Races of England" using separate formulae for males and females. Subsequently, Rollet (1888) published the earliest formal tables for estimation of statue using humerus, radius, ulna, femur, tibia and fibula of 50 male and 50 female French cadavera. Manouvrier (1892) reassessed Rollet's data and based his prediction tables on 26 males and 25 females.

Thomas Dwight (1894) described the following two methods for estimation of stature from the skeletonised remains, *i.e.*, Anatomical method, and Mathematical method. The anatomical method involves in simply putting the bones together, in reproducing the natural curves of the spine, in making due allownace for the soft parts and measuring the length. This method is workable when the complete skeleton is available. The mathematical method, on the other hand, is based on the proportion of the long bone lengths to the height of an individual. This method is workable even if a single bone is available. The mathematical method may be used in two ways, *i.e.*, by formulating prediction equations, or by computing multiplication factors, for reconstruction of stature. However, of these two methods, the anatomical method is more reliable and provides near accurate stature in comparison to the mathematical method. But due to a major limitation, *i.e.*, it requires whole skeleton, its use is highly restricted while mathematical method is much more frequently used.

Pearson (1899) following the mathematical method as suggested by Dwight, used Rollet's data and formulated sex specific regression equations for estimation of stature by not only using a single long bone but also from combination of more than one bones from upper and lower extremities as well.

Most researchers subsequent to Pearson followed his technique and formulated prediction equations for different population groups from different parts of the World (Macdonnel, 1901; Stevenson, 1929; Mendes-Correa, 1932; Breitinger, 1937; Telka, 1950; Dupertuis and Hadden, 1951; Trotter and Gleser, 1952, 1958; Fujii, 1958; Allbrook, 1961; Genoves, 1967; Oliver, 1969; Kate and Majumdar, 1976; Badkur, 1985; Lundy and Fieldsman, 1987). All these researchers used long bones of upper and lower extremities for formulating population and/or sex specific regression equations using single or multiple bones. The use of multiplication factor for estimation of stature was first advocated by Pan (1924). Multiplication factor was obtained as a proportion of a long bone to stature and then computing the average proportion. Pan's study was followed by a couple of researchers who formulated such multiplication factors for different Indian skeletal groups (Nat, 1931; Siddiqui and Shah, 1944; Singh and Sohal, 1952; Badkur, 1985).

Krogman and Iscan (1986) have listed various studies on stature estimation carried out in different parts of the World. Of numerous studies cited by them, almost all pertain to complete long bones. But what should be done with broken or burnt bones recovered in fragmentary state from a scene of crime. For such situations, they suggested that the bone length should be reconstructed from its fragments first before using them in statural formulae.

Over sixty year back, Muller (1935) used ceratin linear segment lengths of humerus, radius and tibia to formulate means of respective bone length recostruction from their fragmentary dimensions. This study opened a new vista of research in skeletal reconstruction. Thirty one years later Chandra et al. (1966) used four linear segment lengths of femur and formulated regression equations for estimation of femoral length. Steele and McKern (1969) modified Muller's method by replacing radius by femur and using the linear segment lengths of these bones, *i.e.*, humerus, femur and tibia, formulated regression formulae for estimation of bone lengths as well as stature from fragmentary dimensions. Steele (1970) further modified the earlier method for more accurate prediction of stature. This method was further reassessed by Simmons et al. (1990) who incorporated certain transverse measurements along with the linear segment lengths.

During the past eighteen years numerous studies have been conducted using fragmentary dimensions of almost all the long bones to formulate means of bone length and stature reconstruction (Mysorekar et al., 1980, 1982, 1984; Chandra and Nath, 1984, 1985; Shroff and Fakhruddin, 1986; Badkur and Nath, 1989, 1990a,b; Rao et al., 1989; Simmons et al., 1990; Nath and Badkur, 1990, 1993, 1995; Nath et al., 1995; Gupta and Nath, 1996, 1997a,b). Most of these studies incorported either linear segment lengths or a couple of transverse dimensions of the long bones of upper and/or lower extremity for estimation of respective bone length or stature. While certain studies (Badkur and Nath, 1989, 1990a,b; Nath and Badkur, 1990, 1993, 1995 and Nath et al., 1995) used multiple dimensions of the long bones, *i.e.*, linear, transverse, sagittal and circumferential, to reconstruct either bone length or stature from fragmentary dimensions of long bones.

Tibia is yet another important long bone of the lower extremity which directly contributes to the height of an individual like femur. Studies reported on tibia relating to reconstruction of tibial length or stature are scanty (Muller, 1935; Steele and McKern, 1969; Steele, 1970; Mysorekar et al., 1984; Badkur, 1985; and Gupta and Nath, 1996). Most of these studies have incorporated either linear segment lengths or a couple of transverse dimensions of tibia to reconstruct its length or stature except for the study of Badkur (1985) where multiple bone dimensions have been used.

The present study pertains to formulation of liner regression equations, based on fourteen (linear, transverse, sagittal and circumferential) dimensions of male and female tibiae, for reconstruction of tibial length and stature from fragmentary bone dimensions.

MATERIAL AND METHODS

Data for the present study comprises of 288 tibiae (164 male and 124 female) belonging to 144 documented skeletons from Medico-legal Institute, Bhopal, (Madhya Pradesh). All the skeletons belonged to Madhya Pradesh and were properly documented for sex, age and stature and ranged in age between 20 and 35 years of age. There was no information available regarding their ethnicity. A total of 14 measurements (5 linear, 5 transverse, 1 sagittal and 3 circumferential) were recorded on completely dry right and left tibiae, besides recording of documented height of all the 144 skeletons. All the measurements were taken in accordance with the techniques recommended by Martin and Saller (1959) and Bass (1971).

Description of various measurements on Tibia

1. *Height of Tibial Tuberosity (HTT):* It measures the straight distance betwen the highest and the lowest points (b&c) of the tibial tuberosity, using vernier calliper (Fig. 1).
2. *Height of Fibular Facet (HFF):* It measure the straight distance between the highest and the deepest points (d&e) on the fibular facet, using the vernier calliper (Fig. 1).
3. *Height of Medial Malleolus (HMM):* It measures the straight distance between the deepest point at the root of medial malleolus (f) and the distal most point at the tip of the medial malleolus (g), using vernier calliper (Fig. 1).
4. *Maximum Length of Tibia (ML):* It measures the straight distance from the most projecting point (a) of the intercondylar eminence to the distal most point (g) of the medial malleolus, using osteometric board (Fig. 1).
5. *Intercondylar Eminence Fibular Facet Length (IC-*

Fig. 1. Location of landmarks on tibia

EFFL): It measures the straight distance from the most projecting point (a) of the intercondylar eminence to the deepest point (e) on the fibular facet, using osteometric board (Fig. 1).

6. *Upper End Breadth (UEB):* It measures the transverse distance between the most lateraly placed points on the medial and lateral condyles of tibia, using vernier calliper.
7. *Distal Epiphyseal Breadth (DEB):* It measures the distance between the most laterally placed points on the medial malleolus and the lower surface oe the distal epiphysis, using vernier calliper.
8. *Upper Shaft Circumference (USC):* It measure the circumference at the midpoint of the upper half of the tibial shaft, using thread and scale.
9. *Middle Shaft Circumference (MSC):* It measures the circumference at the middle of the tibial shaft, using thread and scale.
10. *Lower Shaft Circumference:* It measures the circumference at the midpoint of the lower half of the tibial shaft, using thread and scale.
11. *Upper Shaft Diameter (USD):* It measures the diameter of the tibial shaft where the upper shaft circumferencne is obtained, using vernier calliper.
12. *Middle Shaft Diameter (MSD):* It measures the diameter at the midpoint of the tibial shaft, using vernier calliper.
13. *Sagittal Diameter at the Middle (SDM):* It measures the antero posterior diameter at the mid point of the tibial shaft, using vernier calliper.
14. *Lower Shaft Diameter (LSD):* It measures the diameter of the tibial shaft where the lower shaft circumference is obtained, using vernier calliper.
15. *Stature (S):* It was obtained from the documented records for each skeleton.

After measuring the bones for the aforelisted fourteen measurements the data were subjected to statistical analysis for assessing the sex differences in various dimensions of tibia and computation of linear regression equations for reconstruction of tibial length and stature from these fourteen bone dimensions.

RESULTS AND DISCUSSION

Assessment of Bilateral Variations in the Fragmentary Measures of Male and Female Tibiae: In order to assess to bilateral variations in the different dimensions the data have been subjected to t-test. Tables 1 and 2 present the mean values of all the fourteen measurements obtained on the right and left male and female tibiae along with the values of t-test. It is apparent from table 1 that the male right tibiae have greater dimensions than the left ones for all the measurements except for HFF and UEB. These apparent variations reveal a non significant bilateral differences for all the measurements except for HFF and HMM, where the differences are significant ($p<0.05$).

A similar pattern is observed in case of female tibiae (Table 2) where only three out of fourteen bone dimensions exhibit greater mean values for the left tibiae (HTT, HFF and UEB). The differential trends reveal non-significant bilateral variations for all the bone dimensions except for HMM, where the differences are highly significant ($p<0.01$).

Assessment of Sex Differences in the Fragmentary Bone Dimensions as well as Documented Stature: Owing to the non significant bilateral variations observed in almost all the fragmentary bone dimensions (Tables 1 and 2) of male and female tibiae, the sides (right and left) have been pooled to assess the sex differences (Table 3). It is evident from the table that the male tibiae have greater dimensions for all the fourteen dimensions than the female ones. The average documented stature of males is also sufficiently greater than that of the females. The differential trends reveal highly significant sex differences ($p<0.001$) for all the bone dimensions as well as for stature except for HFF and HMM where the sex differences are non significant.

Based on the highly significant sex differences (Table 3) in twelve out of fourteen bone dimensions and stature the data have been treated separately for computation of correlation and regression analysis for formulation of regression equations for prediction of tibial length as well as stature from fragmentary bone dimensions.

Formulation of Sex Specific Regression Equations for Estimation of Tibial Length from Fragmentary Bone Dimensions: In order to formulate prediction equations, data on male and female tibiae have been subjected to correlation and regression analysis. Table 4 presents the values of correlation coefficient (r) between different dimensions of male tibiae with tibial length and the regression equations formulated for reconstruction of tibial length from all the bone dimensions. It is ob-

Table 1: Bilateral variations in different dimensions of male tibiae

S. No.	Bone dimensions	Observations (mm) Right (N=82) Mean	S.D.	Left (N=82) Mean	S.D.	Value of 't'
1	Height of Tibial Tuberosity (HTT)	45.98	6.35	45.93	7.06	0.43
2	Height of Fibular Facet (HFF)	17.72	2.49	18.61	2.61	2.22*
3	Height of Medial Malleolus (HMM)	15.76	2.00	15.01	1.97	2.42*
4	Maximum Length (ML)	377.58	17.27	377.40	17.11	0.11
5	Inter Condylar Eminence-Fibular Facet Length (ICEFFL)	369.17	16.97	368.44	17.18	0.27
6	Upper End Breadth (UEB)	71.15	4.23	71.49	4.37	0.51
7	Distal Epiphyseal Breadth (DEB)	49.53	3.57	48.71	3.28	1.51
8	Upper Shaft Circumference (USC)	92.82	7.33	92.04	6.37	0.73
9	Middle Shaft Circumference (MSC)	79.26	6.60	78.43	5.62	0.87
10	Lower Shaft Circumference (LSC)	71.62	5.30	71.45	5.11	0.20
11	Upper Shaft Diameter (USD)	23.57	2.52	23.22	2.42	0.91
12	Middle Shaft Diameter (MSD)	20.20	1.93	20.01	2.01	0.62
13	Sagittal Diameter at the Middle (SDM)	28.35	2.44	27.98	2.29	0.99
14	Lower Shaft Diameter (LSD)	20.37	1.98	20.31	2.01	0.18

* Significant at 5% level ($p<0.05$)

Table 2: Bilateral variations in different dimensions of female tibiae

S. No.	Bone dimensions	Observations (mm) Right (N=62) Mean	S.D.	Left (N=62) Mean	S.D.	Value of 't'
1	Height of Tibial Tuberosity (HTT)	42.09	6.11	42.65	6.80	0.49
2	Height of Fibular Facet (HFF)	17.52	2.27	17.97	2.32	1.09
3	Height of Medial Malleolus (HMM)	15.49	1.49	14.58	1.71	3.16*
4	Maximum Length (ML)	355.10	19.27	354.63	19.68	0.13
5	Inter Condylar Eminence-Fibular Facet Length (ICEFFL)	346.18	19.43	345.74	19.39	0.13
6	Upper End Breadth (UEB)	66.74	4.90	67.27	4.59	0.62
7	Distal Epiphyseal Breadth (DEB)	46.57	4.54	46.10	4.13	0.60
8	Upper Shaft Circumference (USC)	84.45	7.23	84.34	7.13	0.88
9	Middle Shaft Circumference (MSC)	73.45	6.57	72.65	6.19	0.70
10	Lower Shaft Circumference (LSC)	67.31	5.43	66.82	5.41	0.49
11	Upper Shaft Diameter (USD)	21.20	2.31	21.10	2.18	0.24
12	Middle Shaft Diameter (MSD)	18.80	1.84	18.71	1.76	0.27
13	Sagittal Diameter at the Middle (SDM)	25.93	3.21	25.93	2.77	0.00
14	Lower Shaft Diameter (LSD)	19.23	1.93	19.16	1.78	0.23

*Significant at 1% level ($p<0.01$)

served that ICEFFL, non fragmentary linear dimension, shows the highest correlation ($r = 0.992$) with bone length. USC shows the highest correlation among the circumferential dimensions while MSD exhibits the highest correlation among the transverse dimensions. The sagittal diameter at the middle (SDM) correlates moderately ($r = 0.523$) with tibial length while HTT shows the highest correlation among linear fragmentary dimensions ($r = 0.323$) with tibial length. The lowest correlation with tibial length is observed with HMM ($r = 0.239$).

Table 5 lists the values of correlation coefficient (r) between different bone dimensions of female tibiae with tibial length and the re-

Table 3: Sex differences in different measurements of tibia (R+L) and stature

S. No.	Bone dimensions	Observations (mm)				Value of 't'
		Male (N=164)		Female (N=124)		
		Mean	S.D.	Mean	S.D.	
1	Height of Tibial Tuberosity (HTT)	45.95	6.71	42.37	6.47	4.55*
2	Height of Fibular Facet (HFF)	18.17	2.59	17.75	2.30	1.43
3	Height of Medial Malleolus (HMM)	15.39	2.02	15.04	1.66	1.56
4	Maximum Length (ML)	377.54	17.16	354.86	19.48	10.48*
5	Inter Condylar Eminence-Fibular Facet Length (ICEFFL)	368.80	17.05	345.96	19.41	10.60*
6	Upper End Breadth (UEB)	71.32	4.31	67.00	4.76	8.04*
7	Distal Epiphyseal Breadth (DEB)	49.12	3.51	46.34	4.35	6.02*
8	Upper Shaft Circumference (USC)	92.43	6.88	84.40	7.18	9.63*
9	Middle Shaft Circumference (MSC)	78.84	6.14	73.05	6.40	7.79*
10	Lower Shaft Circumference (LSC)	71.54	5.20	67.07	5.43	7.09*
11	Upper Shaft Diameter (USD)	23.40	2.48	21.15	2.25	7.93*
12	Middle Shaft Diameter (MSD)	21.10	1.97	18.75	1.80	5.96*
13	Sagittal Diameter at the Middle (SDM)	28.16	2.37	25.93	3.00	7.06*
14	Lower Shaft Diameter (LSD)	20.34	2.00	19.19	1.86	4.97*
15	Stature (S)	1661.2	35.97	1542.90	40.20	18.58*

* Significant at 0.01% ($p<0.001$) level.

Table 4: Linear regression equations for reconstruction of tibial length from fragmentary dimensions of male tibia

S.No.	Regression equations	Value of 'r'
1	TL = 9.26 + 1.00(ICEFFL) ± 2.15	0.992
2	TL = 240.79 + 1.48(USC) ± 13.93	0.592
3	TL = 251.60 + 1.60(MSC) ± 14.20	0.571
4	TL = 246.31 + 1.83(LSC) ± 14.38	0.555
5	TL = 285.14 + 4.60(MSD) ± 14.69	0.527
6	TL = 271.00 + 3.78(SDM) ± 14.74	0.523
7	TL = 295.23 + 4.05(LSD) ± 15.27	0.470
8	TL = 266.65 + 2.26(DEB) ± 15.36	0.460
9	TL = 302.93 + 3.19(USD) ± 15.36	0.460
10	TL = 250.95 + 1.76(UEB) ± 15.49	0.445
11	TL = 339.49 + 0.83(HTT) ± 16.36	0.323
12	TL = 343.46 + 1.88(HFF) ± 16.58	0.282
13	TL = 346.23 + 2.04(HMM) ± 16.70	0.239

TL: Tibial Length

gression equations formulated for prediction of tibial length from fragmentary dimensions. ICEFFL, a non fragmentary dimension, as in case of males, exhibits the highest correlation ($r = 0.993$) with tibial length. UEB shows the highest correlation ($r = 0.561$) among the transverse dimensions followed by sagittal diameter at the middle (SDM) while among the circumferential dimensions, MSC exhibits the highest correlation ($r = 0.497$) with tib-

Table 5: Linear regression equations for reconstruction of tibial length from fragmentary dimensions of female tibia

S.No.	Regression equations	Value of 'r'
1	TL = 10.06 + 1.00(ICEFFL) ± 2.29	0.993
2	TL = 200.86 + 2.30(UEB) ± 16.25	0.561
3	TL = 267.68 + 3.39(SDM) ± 16.76	0.521
4	TL = 244.31 + 1.51(MSC) ± 17.04	0.497
5	TL = 247.71 + 1.29(USC) ± 17.26	0.477
6	TL = 254.31 + 1.50(LSC) ± 17.84	0.418
7	TL = 274.32 + 1.74(DEB) ± 18.10	0.388
8	TL = 293.50 + 3.29(MSD) ± 18.71	0.303
9	TL = 308.76 + 2.18(USD) ± 19.00	0.251
10	TL = 319.91 + 1.97(HFF) ± 19.10	0.233
11	TL = 310.67 + 2.30(LSD) ± 19.16	0.220
12	TL = 329.10 + 0.61(HTT) ± 19.23	0.202
13	TL = 321.38 + 2.23(HMM) ± 19.28	0.190

TL: Tibial Length

Table 6: Linear regression equations for estimation of stature from fragmentary dimensions of male tibia

S.No.	*Regression equations*	*Value of 'r'*
1	S = 994.47 + 1.81(ICEFFL) ± 18.65	0.857
2	S = 987.62 + 1.78(ML) ± 19.00	0.851
3	S = 1369.01 + 3.16(USC) ± 28.88	0.604
4	S = 1392.37 + 3.76(LSC) ± 30.42	0.543
5	S = 1412.78 + 3.15(MSC) ± 30.56	0.537
6	S = 1449.56 + 7.52(SDM) ± 31.47	0.495
7	S = 1480.25 + 9.00(MSD) ± 31.52	0.492
8	S = 1494.65 + 7.12(USD) ± 31.58	0.490
9	S = 1420.98 + 4.89(DEB) ± 31.88	0.475
10	S = 1493.53 + 8.24(LSD) ± 32.23	0.457
11	S = 1389.91 + 3.80(UEB) ± 32.27	0.455
12	S = 1561.20 + 5.51(HFF) ± 33.28	0.395
13	S = 1580.57 + 1.75(HTT) ± 34.24	0.327
14	S = 1624.44 + 2.39(HMM) ± 35.91	0.134

S: Stature

ial length. Among the linear fragmentary dimensions, the HFF reveals the highest correlation with bone length while the least correlation is observed with HMM ($r = 0.196$).

The pattern of correlation between different fragmentary dimensions with bone length among male and female tibiae reveal sufficient variation. Among different type of fragmentary dimensions, *i.e.*, linear, transverse, sagittal and circumferential, the best prediction of bone length may be obtained using USC, MSD, SDM and HTT, pertaining to circumferential, transvere, sagittal and linear dimensions respectively among males. While among females, the best estimate of bone length is obtained using UEB, SDM MSC and HFF pertaining to transvere, sagittal, circumferential and linear dimensions respectively. The variation observed in the two sexes regarding the type of fragmentary dimensions providing the best estimate of bone length further suggests that these equations are sex specific.

Formulation of Sex Specific Regression Equations for Reconstruction of Stature From Fragmentary Bone Dimensions: After formulating regression equations for prediction of tibial length form its fragmentary dimensions an attempt has been made in the present study to formulate prediction equations for reconstruction of stature from fragmentary dimensions of tibia. Earlier Steele and Mckern (1969) used only linear segment lengths of tibia to formulate regression equations for estimation of stature. The present study incorporates transvere, sagittal and circumferential dimensions besides the linear ones to reconstruct stature from fragmentary dimensions of tibia. Table 6, depicts the relationship of various fragmentary dimensions besides maximum length (ML) of tibia with stature and the linear regression equations formulated for estimation of stature using all the fourteen dimensions of tibia. It is observed that among the non fragmentary linear dimensions ICEFFL shows greater correlation ($r = 0.857$) than the ML ($r = 0.851$) with stature among males. Of the three circumferential dimensions USC exhibits the hightest correlation ($r = 0.604$) with stature while SDM, a sagittal dimension, correlates moderately ($r = 0.495$) with stature. Among the transverse dimensions, MSD exhibits the highest correlation with stature ($r = 0.395$) while among the linear fragmentary dimensions, the HFF exhibits the highest correlation ($r = 0.395$). Thus, it is apparent that excepting the two linear non fragmentary dimensions *i.e.*, ICEFFL and ML, the best statural estimate for males is obtained through USC, SDM, MSD and HFF respectively pertaining to circumferential, sagittal, transverse and linear fragmentary dimensions of tibia.

Table 7 exhibits the relationship of all the fourteen bone dimensions of female tibia with stature along with the linear regression equations formulated for estimation of stature from fragmentary dimensions of tibia. It is observd that the two non fragmentary linear dimensioned, *i.e.*, ICEFFL ($r = 0.852$) and ML ($r = 0.846$) exhibit the highest correlation with stature as also observed among males (Tables 6). Among the fragmentary dimensions, UEB a transverse dimension exhibits the highest correlation ($r = 0.611$) with stature, while among the circumferential dimensions, USC exhibits the highest correlation ($r = 0.477$) followed by SDM ($r = 0.414$) while among the linear fragmentary dimensions, the HMM exhibits the highest correlation ($r = 0.196$). This indicates that excepting the two linear

Table 7: Linear regression equations for estimation of stature from fragmentary dimensions of female tibia

S.No.	Regression equations	Value of 'r'
1	S = 931.74 + 1.77(ICEFFL) ± 21.21	0.852
2	S = 923.06 + 1.75(ML) ± 21.64	0.846
3	S = 1196.68 + 5.17(UEB) ± 32.11	0.611
4	S = 1331.42 + 2.51(USC) ± 36.27	0.447
5	S = 1398.87 + 5.55(SDM) ± 36.92	0.414
6	S = 1354.68 + 2.58(MSC) ± 36.99	0.410
7	S = 1375.93 + 3.60(DEB) ± 37.35	0.389
8	S = 1366.98 + 2.62(LSC) ± 37.93	0.354
9	S = 1409.66 + 6.30(USD) ± 37.96	0.352
10	S = 1430.26 + 6.00(MSD) ± 39.06	0.269
11	S = 1445.03 + 5.10(LSD) ± 39.41	0.235
12	S = 1471.45 + 4.75(HMM) ± 39.76	0.196
13	S = 1486.43 + 3.18(HFF) ± 39.88	0.182
14	S = 1498.25 + 1.05(HTT) ± 39.97	0.169

S: Stature

non - fragmentary dimensions, *i.e.*, ICEFFL and ML, the best statural estimate for females is obtained through UEB, USC, SDM and HMM respectively pertaining to transverse, circumferential sagittal and linear fragmentary dimensions of tibia.

It may be concluded from the analysis that for estimation of tibial length USC, MSD, SDM and HTT would provide the best estimate of bone length among males while UEB, SDM, MSD and HMM would provide the best estimate among the females besides ICEFFL, a non fragmentary linear dimension which shows an overall highest correlation with bone length for both the sexes (Tables 4 and 5). While for the prediction of stature from fragmentary dimensions of tibia, USC, SDM, MSD and HFF respectively pertaining circumferential, sagittal, transvere and linear fragmentary dimensions provides the best statural estimate among males while UEB, USC, SDM and HMM pertaining to transvere, circumferential, sagittal and linear fragmentary dimensions would provide best statural estimate among females. However the best overall statural estimate is obtained through IEFFL and ML, linear non-fragmentary dimensions of tibia for either sex (Tables 6 and 7).

Thus depending upon the availability of bone fragments belonging to tibia, tibial length as well as stature could be reconstructed with reasonable accuracy using circumferential, sagittal and transvere dimensions as the measurements of these categories are significantly related to bone length and stature for either sex. However, the linear fragmentary dimensions should be used with certain reservation due to their relatively low correlation with tibial length and stature for either sex.

KEY WORDS Tibia. Fragmentary Dimensions. Bone Length. Stature Estimation. Regression Equations.

ABSTRACT An attempt has been made in the present study to reconstruct tibial length and stature from fragmentary dimensions of tibia. Data comprises of 288 tibiae (164 male and 124 females) belonging to 144 documented skeletons, ranging in age from 20 to 35 years. All the bones were measured for 14 measurements pertaining to linear, transverse, sagittal and circumferential dimensions besides recording of the documented stature of each skeleton. Analysis of data reveals non significant bilateral varaitions in all the bone dimensions for either sex, while the sex differences are highly significant for all dimensions ($p<0.001$). The prediction equations have been formulated separately for males and females for estimation of tibial length as well as stature. Among the fragmentary measures, the upper shaft circumference (USC) provides the best estimate for tibial length and stature for males while upper end breadth (UEB) provides the best estimate for tibial length and stature among females. Thus using these regression equations both tibial length and stature could be estimated for males and females with reasonable accuracy.

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