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Determination of Correlation Between Supine Length And Percutaneous Measurements of Tibial Length in Cadavers

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Abstract : *Identification is an important aspect of Forensic Medicine which can be done by multiple means. Anthropometry is a simple and easy to use tool. As lower limb is major contributor in stature hence most predictive and gives closer estimate. This study was carried out with aim & objectives to find out correlation between supine length and tibial length, derivation of regression equations and multiplication factors and also to find out bilateral & bisexual variation if any. This was hospital based analytical cross sectional study involving 200(100 Males and 100 Females) cadavers. Tibial length showed significant positive correlation with supine length. Tibial length also showed significant bisexual variation ($p<0.001$), but no bilateral variation in either gender. The best prediction of supine length in both the sexes and for combined cases can be done by left tibial length. Multiplication factors derived were less accurate than regression equations hence for more accurate estimation individual regression equation derived from that particular part and sex should be used.*
Keywords: *Anthropometry, Identification, Supine length and Tibial length.*

I. Introduction

Article 6 of the universal declaration of human rights states that everyone has the right of recognition everywhere as a person before the law.[1]Identification, one of the major attributes of forensic medicine is the determination of the individuality of a living or dead. Identification of a living person is required in criminal and civil cases. The identity of a corpse is of paramount importance in the investigation of any death where the body is decomposed, skeletalized or mutilated as in case of Mass disasters such as earthquakes, flood, fire explosions and railway or aircraft accidents.[2]Identification is based on various criteria which include "the big four" of anthropometric measurements (i.e. age, sex, race & stature),religion, dactylography, podogram, superimposition, teeth, and DNA fingerprinting etc.[3] Though for the purpose of identification DNA is considered to be a far better tool, however DNA analysis is costly, time consuming, comparative and facilities are still limited. This becomes especially important in case of non urban settings, therefore the role of anthropometry to identify an individual becomes of paramount importance in such scenarios. The origin of forensic anthropology can be traced to the end of the nineteenth century when the French criminologist Alphonse Bertillon in 1882 devised the first classification and identification system to identify criminals based on anthropometry. Since then, anthropometry has continuously been used in forensic examinations of unknown commingled human remains.[4]Bones and teeth survive much longer than soft tissue hence used for identification in anthropometry.[5]Height is sexually dimorphic and statistically more or less normally distributed. Characteristic variations in proportions were shown to appear between major races and furthermore even among smaller ethnic groups.[6]Trunks and limbs exhibit consistent ratios among themselves.

This relationship is very useful anthropologically to find racial differences and medico legally, when only parts of the deceased body are available. Stature can be estimated through the anatomical method (Fully Method, George Fully-1956) and the mathematical method (for incomplete remains).[7]Mathematical methods related to derivation of formulae that can be applied directly to estimate stature from a given bone/part of body. It allows estimation of stature from the length of one or few skeletal elements like major long bones of limbs (e.g. Trotter, 1970) , crania (e.g. Rayan and Bidmos, 2007) , other whole bones, as well as fragmentary remains (e.g. Simmons, 1990).[8] One can utilize a regression equation (first evolved by Trotter & Gleser, Dupertuis and Hadden) that reflects the relationship between an individual's stature and the body part.[9] Further two more methods of stature estimation; FORDISC 3 and revised Fully method were developed.[10] Supine length averages about one centimetre more than the measurement of standing height.[11]Lower limb length is the greatest contributor to standing height, hence most predictive equations are based on the length of lower limb, which give a closer estimate than those of the upper limbs.[12,13]Present available formulae derived are from western population which cannot be used in our vast homeland of India with many different ethnic populations, having their own variations.[14] Till date many study have been done on living persons but there is lack of anthropometric data from cadavers. Hence the present study was aimed and concentrated on anthropometric measurement of

bilateral tibial length among cadavers and its correlation with supine length to find out multiplication factors and regression equations for the adult cosmopolitan population of Delhi- NCR.

II. Aims and objectives

1.1 Aim: Determination of correlation between supine length and percutaneous measurements of Tibial length in cadavers.

1.2 Objectives

1.2.1 Correlation between supine length and percutaneous measurements of Tibial length of both sides in male and female independently.

1.2.2 Derivation of **multiplication factor** and **regression equation** for each parameter to be subsequently used for determination of supine length and thus stature in dead bodies.

1.2.3 Comparison of each parameter statistically to extrapolate the **best parameter** in adult cosmopolitan population of Delhi-NCR.

1.2.4 To find out **bilateral** variation.

1.2.5 To find **bisexual** variation.

III. Material and methods

The necessary informed consent was obtained from next of kin/relative before taking the measurements. 200 (100 Males and 100 Females) dead bodies were selected for measurements in the mortuary of GTB hospital from November 2012 to February 2014. Only those individuals in whom there was no anatomical distortion of the portion of body in relation to stature were included in the study and cases with disease or defects in bones of lower limbs were excluded. 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. All the measurements were taken with dead body lying in supine position using scientifically standardized graduated instruments. Measurements were taken three times in centimeters and mean value was used for computation of data.

Instruments And Equipments Used

1- Standard Autopsy equipments.
2- Scientifically standardized graduated anthropometer for tibial length.

Figure-1-showing instruments used

1. Supine Length

Dead body was placed in supine position on flat hard surfaced autopsy table, with knee and hip joints extended, and neck and feet in a same plane. (Fig.2)

Thus supine length was measured from vertex of head to heel of foot using graduations on side of autopsy table.

Figure-2 Supine length measurement

2. Tibial Length

Tibial length was measured as the distance from medial condyle to the tip of medial malleolus. (Medial condyle is broad and smooth and can be felt just below the knee & as it becomes palpable, diverges anteriorly from the articulating femoral condyle).Figure-3

Figure-3 Tibial length measurements

IV. Observation And Results

Analytical cross sectional study which included all adult cases that were divided according to age in four groups of 10 year intervals with 25 individuals in each age group for uniform and fair comparison.

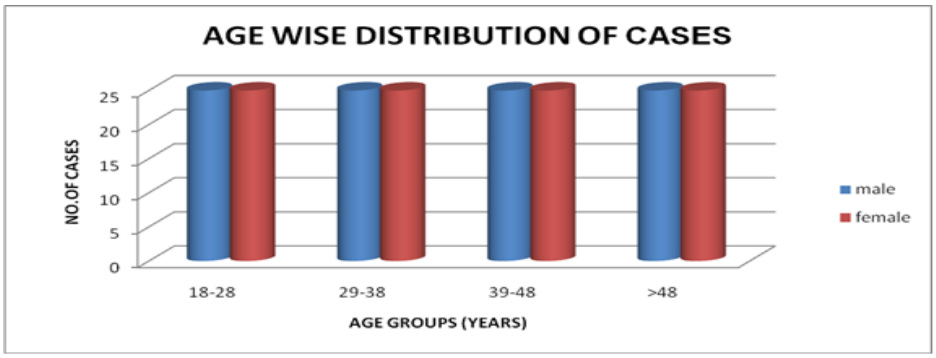


Figure-4 Describes graphical representation of cases

1. **Descriptive of supine length** 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 is more in males as compared to females as depicted below in Table – 1.

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

1.1 Descriptive of 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 – 2.

Age groups	No. of cases	Min	Max	Mean	SD
18 –28 years	25	157	180	167.22	6.4389
29– 38 years	25	**150**	**191**	165.88	8.7480
39 – 48 years	25	154	178	166.92	6.4091
>48 years	25	**150**	174	**163.58**	**5.6267**

1.2 Descriptive of 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 3.

Age groups	No. of cases	Min	Max	Mean	SD
18 –28 years	25	140	**175**	153.68	7.7229
29– 38 years	25	141	165	153.84	6.1079
39 – 48 years	25	**133**	164	153.84	7.6468
>48 years	25	141	165	**153.36**	**5.9626**

Tibial Length Comparison In males left sided dominance among maximum values was noted, however this was statistically insignificant. No bilateral variation observed in females. However significant bisexual differences were seen in tibial lengths. The length is observed to be less in females as compared to males as shown below in Table -4.

Sex	Side	Min	Max	Mean	SD
Male (n = 100)	**R**	**31.7**	**41.1**	**35.32**	**1.9677**
	L	**31.6**	**42.2**	**35.34**	**2.0209**
Female (n = 100)	**R**	**29.9**	**38.2**	**33.36**	**2.1919**
	L	**29.9**	**38.1**	**33.33**	**2.1764**

2. Descriptive Of Tibial Length In Males

2.1 Right Tibial Length The maximum values were seen in 29-38 yr age group. Minimum values were observed in age group of more than 48 yr with least mean right tibial length as depicted in Table – 5.

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	33.3	38.9	35.72	1.8542
29 – 38 years	25	31.8	**41.1**	35.25	2.2522
39 – 48 years	25	33.0	38.9	35.54	2.1219
>48 years	25	**31.7**	38.6	**34.78**	**1.5632**

2.2 Left Tibial Length Minimum values were observed in age group of more than 48 yr with least mean left tibial length. The maximum values were seen in 29-38 yr age group as shown in Table – 6.

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	33.3	38.9	35.72	1.8435
29 – 38 years	25	31.7	**42.2**	35.28	2.4175
39 – 48 years	25	33.1	38.8	35.58	2.1515
>48 years	25	**31.6**	38.5	**34.78**	**1.5588**

3. Descriptive Of Tibial Length In Females

3.1 Right Tibial Length The values of minimum right tibial length in females seen in more than 48 yr age group and maximum value was seen in 18 -28 yr age group with highest mean right femoral length as described in Table – 7.

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	30.2	**38.2**	33.28	**2.1198**
29 – 38 years	25	30.0	36.9	**33.26**	2.1994
39 – 48 years	25	30.1	36.5	34.44	2.1444
>48 years	25	**29.9**	36.5	33.46	2.4197

3.2 Left Tibial Length The decreasing pattern in values were noted from 18-28 yr age group to more than 48 yr age groups having the minimum left tibial length in more than 48 yr age group but having maximum mean tibial length. Maximum value was seen in 18-28 yr age group as shown in Table – 8.

Age groups	No. of cases	Min	Max	Mean	SD
18 – 28 years	25	30.3	**38.1**	**33.22**	**2.0462**
29 – 38 years	25	30.1	36.9	33.24	2.1958
39 – 48 years	25	30.2	36.5	33.42	2.1328
>48 years	25	**29.9**	36.5	33.46	2.4360

Regression Equations Derived- On comparing age group wise right and left tibial length for prediction of supine length, best result was obtained for 29- 38 year age group in both the genders except for left tibial length in females. Among sexes males gave better estimate than females. Table -9 below shows various regression equations derived.

Sex	Side	Regression equation	SEE* (+/-) cms	r# value
Males	Right	SL=62.311+2.932×RTbL	3.8933	+0.830
	Left	SL=63.630+2.894×LTbL	3.7745	+0.841
Females	Right	SL=73.706+2.397×RTbL	4.3499	+0.772
	Left	SL=72.888+2.423×LTbL	4.3254	+0.775
Combined	Right	SL=46.673+3.294×RTbL	5.2367	+0.823
	Left	SL=46.900+3.287×LTbL	5.1378	+0.830

*SEE – standard error of estimates, # r value – correlation coefficient, p- value for all equations were=0.001

Males and females showed significantly positive correlation coefficient for right and left tibial length in all age groups. Among males best correlation shown by left tibial length(r=+0.937) in 29-38 year age group followed by right side(r=+0.929) in same age group. In females correlation coefficient was highest in 18-28 year age group being more for left tibial length(r=+0.857) followed by right(r=+0.840). Significantly positive correlation was noted when total cases were combined, so the regression equations can be applied irrespective of sex and age. Left tibial length in total cases gave better prediction of supine length with high correlation coefficient and lower standard error of estimate.

Figure – 5: Correlation between supine length and right tibia length in males

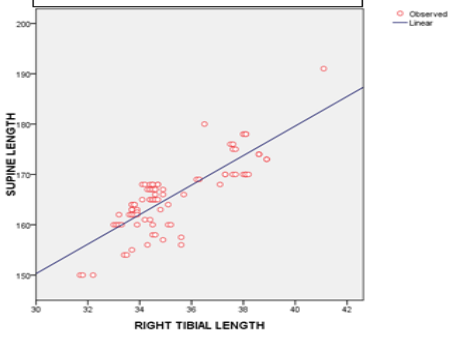


Figure – 6: Correlation between supine length and right tibia length in females

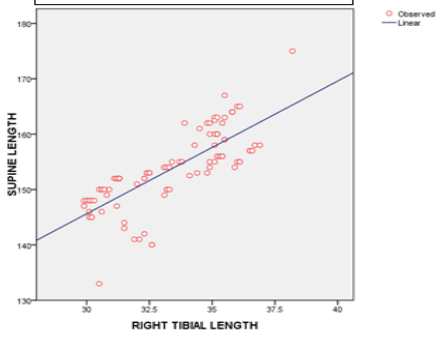


Figure – 7 Correlation between supine length and left tibial length in females

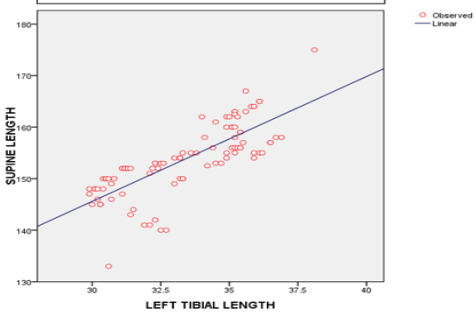


Figure – 8 Correlation between supine length and left tibial length in males

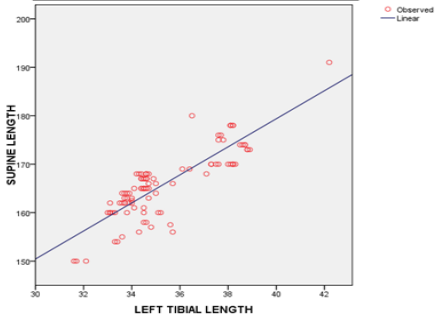


Figure – 9: Correlation between supine length and right tibial length in total cases

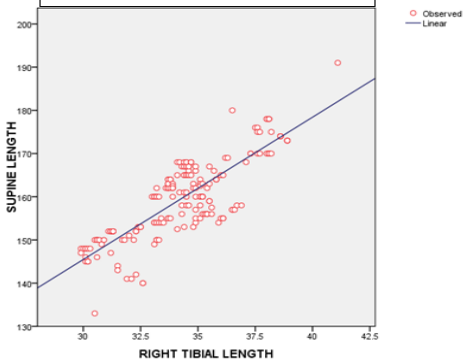
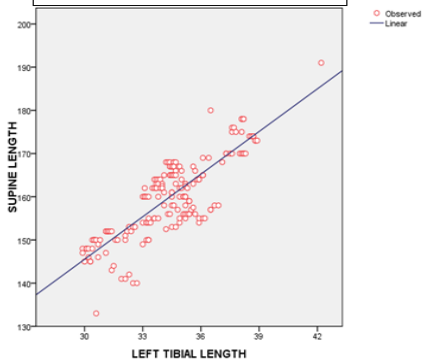


Figure 10– Correlation between supine length and left tibial length in total



Following Table-10 presents a comparison of actual supine length and supine length estimated from measurements of tibial length using linear regression equations. In both the sexes, the mean value estimates (mean estimated supine length) were close to actual supine length. This is due to the fact that regression equations were calculated from measures of central tendency.

	Males			**Females**		
Part studied	Min estimated supine length	Max estimated supine length	Mean estimated supine length	Min estimated supine length	Max estimated supine length	Mean estimated supine length
Right tibial length	155.25	182.81	165.90	145.37	165.27	153.67
Left tibial length	155	185.75	165.91	145.33	165.20	153.67
Actual supine length	**150 (min)**	**191 (max)**	**165.90 (mean)**	**133 (min)**	**175 (max)**	**153.68 (mean)**

Bilateral Variation In Tibial Length

In paired t- test it was observed that the tibial length did not exhibit any statistically significant bilateral variation in both the sexes ($p>0.05$) as shown in below in Table-11.

Variable	**Males**				**Females**			
	MD*	SD	*t*- value	p-value	MD	SD	*t*- value	*p-value*
Tibial length	-0.0180	0.1381	1.304	0.195	0.0250	0.1708	1.464	0.146

*MD=Mean Difference

Bisexual Differences In Tibial Length

By using unpaired t-test the Mean differences, t- value and p- value in both males and females were derived. There was statistically significant bisexual variation ($p<0.01$), as depicted in Table-12.

Variable	*Mean difference*	*t* – value	*p* - value	Inference
Right tibial length	1.9620	6.661	< 0.001	Highly significant
Left tibial length	2.0050	6.751	< 0.001	Highly significant

Multiplication Fators Derived

Parameter	**Males**	**Females**
Right tibial length	4.696	4.572
Left tibial length	4.693	4.609

V. Discussion

An individual stops growing in height on completion of union of epiphysis and diaphysis, which is usually by the age of 18- 20years.[15] The distinct advantage of mathematical method over anatomical is that a single body part can be used to estimate the living stature of an individual.[10] Although the loss of stature is seen with increasing age, a study by Friedlaennder et al,(1977) suggested that a decline in stature does not commence until the fifth decade of life.[16]The mean supine length for males in the present study was 165.90 cm and for females it was153.68 cm. Common finding to all the studies was that the mean height was more in males as

compared to females. This was even true when in this study, age group wise comparisons made among females and males. However the average height in both males and females among European populations was more as compared to present study as depicted below in Table-14.

Authors	**SUPINE LENGTH**						
	Population studied	**Min**		**Max**		**Mean**	
		M	**F**	**M**	**F**	**M**	**F**
Ozaslan et al[17]	Turkey (203M,108F)	154.6	146.2	197.5	184.8	171.9	161.7
Radoinova et al[18]	Bulgaria (286M,130F)	149	147	189	172	170.9	161.2
El-Meligy et al[19]	Egypt (500M,500F)	154.5	144.5	187	173	171.4	157.3
Rutishauseret al[20]	Uganda (334M,349F)	157.5	155.7	192.7	168	174.8	162.3
Choi et al[21]	Korea (57 M)	147		178		163.1	
Patel et al[22]	Gujarat (149M,136F)	155.7	143.2	183.5	169.6	171	156.1
Krishan et al[23]	Himachal Pradesh (123M,123F)	147.6	140.7	183.6	169.5	168.2	155.7
Kanchan et al[24]	Punjab (100M.100F)	151.4	143.1	180.6	171	167.4	159.5
Sen J, Ghosh S[25]	North Bengal (225M,225F)	145.5	133.5	178.5	169.6	162.2	149.5
Saini et al[26]	Rajasthan (50M,50F)	159	147.7	187.5	170	175	157.5
Chavan et al[27]	Maharashtra (100M, 100F)	152	140	186	164.5	167.8	151.4
Mohanty N[28]	Odisha (500M,500F)	145	135	178	169	162	152
Kaore et al[12]	Karnataka (200M,200F)	151.5	140.5	184.4	182	170.	156.2
Bhavna, Nath S29	Delhi (503 M)					167.6	
Rani et al30	Delhi (200M,100F)	150.1	148	184.5	173	169.5	159.5
Present study	Delhi (100M,100F)	150	133	191	175	165.9	153.6

Tibial Length: In present study there was no bilateral variation in tibial length, but significant bisexual variation seen which was consistent with the study conducted by Kaore et al in Karnataka population. Mean tibial length was more in males which was seen in all below mentioned studies and present study too. Mean tibial length in males was similar in study conducted by Kaore et al, Rani et al (in Delhi) and Choi et al (among Koreans) which was consistent with present study. Mean tibial length in females was similar in study of Mahakkanukrauh et al (in Thai) and in present study as shown in Table 15.

Authors	**Population studied**	**Condition in which bone studied**	**Sex**	**Side**	**Min**	**Max**	**Mean**
Radoinova et al[18]	Bulgaria(286M,130F)	Percutaneous	M		28.95	42.85	36.48
			F		28.40	39.55	34.45
El-Meligy et al[19]	Egypt(500M,500F)	Percutaneous	M		32.30	45.6	38.78
			F		29.50	40.9	34.95
Mahakkanukrauh et al[31]	Thailand(132M,68F	Dry Bones	M	R	31.80	42.10	36.10
				L	32.00	42.10	36.19
			F	R	28.20	38.10	33.75
				L	28.40	38.00	33.88
Choi et al[21]	Korea (57 M)	Dry Bones	M	R	31.5	39.5	35.2
				L	31.4	39.4	35.2
Chavan et al[27]	Maharashtra(100M,100F)	Percutaneous	M		31	42	37.32
			F		30	44	34.44
Kaore et al[12]	Karnataka (200M, 200F)	Percutaneous	M	R	26.10	43.50	35.77
				L	26.10	43.40	35.73
			F	R	21.50	39.50	32.19
				L	21.40	46.50	32.14
Bhavna, Nath S[29]	Delhi (503 M)	Percutaneous	M				36.48
Rani et al[30]	Delhi (200M,100F)	Percutaneous	M	R	25.82	46.20	34.90
				L	25.90	46.20	35.06
			F	R	21.20	37.20	30.77
				L	21.30	37.30	30.90
Present Study	**Delhi (100M,100F)**	**Percutaneous**	**M**	**R**	**31.70**	**41.10**	**35.34**
				L	**31.60**	**42.20**	**35.34**
			F	**R**	**29.90**	**38.20**	**33.36**
				L	**29.90**	**38.10**	**33.34**

The prediction with least standard error was found in regression equations derived by Radoinova et al in Bulgarian population, but the equations can be used for that population only. As present study provided better correlation coefficient, regression equations derived can be used effectively as described below in Table 16.

Authors	Sex	Regression equation	SEE (+/-) cms	r value
Radoinova et al[18] (Bulgaria)	M	86.42+2.330×TbL	1.64	0.045
	F	92.73+2.002×TbL	2.28	0.066
El-Meligy et al[19] (Egypt)	Both	90.75+1.99×TbL	8.10	0.74
	M	91.74+2.05×TbL	8.24	0.75
	F	129.57+0.80×TbL	6.51	0.48
Mahakkanukrauh et al[31] (Thailand)	Both	43.130+3.281×TbL	5.54	0.803
	M	57.899+2.917×TbL	5.22	0.751
	F	63.968+2.629×TbL	5.79	0.678
Choi et al[21](Korea)	M	73.38+2.54×TbL	4.23	0.61
Chavan et al[27] (Maharashtra)	M	81.30+2.32×TbL	3.56	0.82
	F	95.28+1.63×TbL	3.69	0.68
Kaore et al[12] (Karnataka)	M	104.42+1.836×RTbL		0.789
		104.08+1.847×LTbL		0.796
	F	102.16+1.678×RTbL		0.737
		111.86+1.379×LTbL		0.650
Bhavna,NathS[29] (Delhi)	M	84.74+2.27×TbL	3.67	0.765
Rani et al[30] (Delhi)	M	104.971+1.850×RTbL	3.414	0.855
		105.324+1.831×LTbL	3.436	0.862
	F	107.100+1.705×RTbL	2.996	0.897
		107.199+1.694×LTbL	2.962	0.864
Present study (Delhi)	**Both**	**46.673+3.294×RTbL**	**5.2367**	**0.823**
		46.900+3,287×LTbL	**5.1378**	**0.830**
	M	**62.311+2.932×RTbL**	**3.8933**	**0.830**
		63.630+2.894×LTbL	**3.7745**	**0.841**
	F	**73.706+2.397×RTbL**	**4.3499**	**0.772**
		72.888+2.423×LTbL	**4.3254**	**0.775**

Multiplication factors as given by Pan (1924) for different bones among East Indians (Hindus) by measuring 142 males and females cadevera were as follows:

UPPER LIMB BONES	LOWER LIMB BONES
Humerus = 5.30	Femur = 3.70
Radius = 6.90	Tibia = 4.48
Ulna =6.30	Fibula = 4.48

Multiplication Factors Derived By Present Study

Parameter	Multiplication factor for males	Multiplication factor for females
Right tibial length	4.696	4.572
Left tibial length	4.693	

VI. Conclusions and summary

The bilateral mean tibial length in both the sexes was least in more than 48 year age group, which may be explained by age related changes in bones. Some studies show variations in measurements, attributed to different geographical areas covered, nutritional patterns along with different points of measurements. The mean value of supine length /average height in male was about 12 cm more as compared to female. Tibial length showed significant positive correlation with supine length. Tibial length also showed significant bisexual variation ($p<0.001$), and measurements of both sides were more for males as compared to females. No bilateral variation was noted in either gender. The correlation of supine length with right and left **tibial length** was best in 29-38 yr age group in both males and females. Regression equations derived from tibial length for combined cases also showed significantly positive correlation thus can be applied irrespective of sex and age. The best prediction of stature in both the genders and for combined cases can be done by **left tibial length**. Multiplication factors were derived for both the genders in the present study but are less accurate than regression equations.

Regression equations derived in this study can be used for the population all over the country as present study was done in cosmopolitan population.

VII. Future recommendations

For more accurate estimation individual regression equations derived from that particular part and gender should be used.

References

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