Research Paper: Anthropometric Measurement of Maximum Tibia Length in South Indian Population

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ABSTRACT

Introduction: The human stature forms part of his or her biological profile. It becomes more important during personal identification in case of mass disasters and in search of missing persons. We measured various parameters of the dried tibia, then by applying linear regression we formulated maximum tibia length which can be conveniently used for arriving at human stature.

Methods: The obtained data were analyzed by descriptive statistics methods and expressed as mean (SD). The Pearson correlation coefficient (r) was used to express the relationship between the Maximum Tibia Length (MTL) and other parameters of tibia. The linear regression analysis was performed and the regression equation was arrived for the prediction of MTL.

Results: The mean (SD) score with respective Standard Errors of Estimate (SEE) for both right and left tibia were found, irrespective of the bone side. The mean maximum length of the right and left tibia were 37.50(3.03) cm and 37.05(3.12) cm, respectively. The mean maximum length of tibia, irrespective of side was calculated as 37.20(3.04) cm. The correlation coefficient between MTL and other tibial parameters were derived.

Conclusion: Estimation of maximum tibia length with regards to its measured anthropometric parameters in south Indian population can help in evaluating human stature even when a segment of tibia is available for measurement, which is population-specific.

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1. Introduction

The tibia is the large long bone located on the medial side of the leg with two ends and a shaft. Its proximal end articulates with the lower end of femur to form the knee joint along with patella. The distal narrow end of tibia and the lower end of fibula articulate with the talus to form the ankle joint. The Maximum Tibia Length (MTL) is used by many researchers in the estimation of human stature. Estimation of human stature with various measurements of an available long bone, is not an impossible task. The prediction of human stature with the help of MTL is of great use to forensic medicine and physical anthropology. The stature of an individual forms part of his or her biological profile. It is particularly useful in identification of missing persons and or dead bodies in mass disasters, cases of mass burial discoveries, as well as medico legal cases [1].

A number of authors have recognized that positive correlation between the stature and the length of long bones of the human body has made it feasible to employ the maximum length of these bones in reconstructing and estimating the stature of unknown individuals [2-4]. Previous research showed that morphometric measurements of long bone segments are also employed in determining the maximum length of long bones such as humerus, femur, tibia, and fibula [5-8]. The intact long bones are ideal in the estimation of the stature of unidentified individual. Anthropological reports reiterate that estimation of stature is more accurate if regression formulae are population specific [1]. The population-specific linear regression equations for stature estimation using various body parameters and morphometric study of various long bones have been documented for the south Indian population [7] and for the Indian population [9, 10].

The overall aim of the present study we to obtain and tabulate data on the morphometry of the tibia. Furthermore, the tibial segments were analyzed and a significant correlation with its maximum length was observed. Also, linear regression equation was formulated to estimate the Maximum Tibia Length (MTL).

2. Materials and Methods

In this study 36 intact adult human tibia (18 right sided and 18 left sided) were obtained from the bone bank of Anatomy Department of NRI Institute of Medical sciences, Visakhapatnam. The incomplete and deformed tibia were excluded from the setting of our research.

Measurement procedures

Measurements of the MTL were taken using the osteometric board. A measuring tape was applied to scale circumference of the mid shaft. The Vernier caliper accurate to 0.01 mm was used to measure distance between the two bony landmarks. A total of twelve morphometric tibial parameters were taken into consideration for the study. All measurements were made as per the standardized methods given [11, 12].

The following measurements were obtained: 1. MTL was measured as the maximum distance from the highest point of the upper part of the tibia to the lowest point of the tibia using osteometric board; 2. Bicondylar Tibial Width (BTW) was measured as the maximum transverse distance from the lateral side of the lateral condyle to the medial side of the medial condyle using the vernier caliper; 3. Anterior-Posterior Diameter of Medial Condyle (APDMC) was measured as the maximum anterior-posterior distance of the medial condyle of tibia; 4. Transverse Diameter of Medial Condyle (TDMC) was measured as the maximum distance from the medial side of the medial condyle to the medial intercondylar tubercle of intercondylar eminence of tibia; 5. Anterior-Posterior Distance of Lateral Condyle (APDLC) was measured as the maximum anterior-posterior distance of the lateral condyle of tibia;

6. Transverse Diameter of Lateral Condyle (TDLC) was measured as the maximum distance from the lateral side of the lateral condyle to the lateral intercondylar tubercle of the intercondylar eminence of tibia; 7. Mid Shaft Circumference (MSC) was measured as the maximum circumference at the mid length of the shaft of tibia; 8. Distal Articular Surface Length (DASL) was measured as the maximum transverse distance of the inferior surface of the tibia; 9. Transverse Diameter at the level of Nutrient Foramen (TDNF) was measured from medial tibial border to its interosseous border, at the level of nutrient foramen; 10. Maximum Diameter in the Middle of Tibia (MDMT) was measured from anterior crest of the tibia to its medial border, in the middle length of shaft of tibia; 11. Sagittal Diameter at the level of Nutrient Foramen (SDNF) was measured from anterior crest of tibia to its medial border, at the level of nutrient foramen; and 12. Distance of the Nutrient Foramen from the proximal end of the bone (DNF) was measured from the highest point of upper part of the tibia, to its nutrient foramen.

Statistical analysis

The obtained data in the current study were analyzed by descriptive statistics and expressed as mean (SD).

The comparison of differences between left and right tibia were performed using Student t test, which the results were not statistically significant.

The Pearson correlation coefficient (r) was used to express the relationship between the MTL and other parameters. The linear regression analysis was also performed and the regression equation was arrived, for the prediction of MTL. The statistical significances were noted at $P<0.05$. The GraphPad is the statistical online software we used for the analysis purpose, available at the following website (https://www.graphpad.com/quickcalcs/linear2/).

3. Results

Results are presented as descriptive statistics (mean±SD), with their respective Standard Errors of Estimate (SEE) for both right and left tibia (Table 1) using

Table 1. Morphometric values of the Right and Left tibia bone in South Indian population

Parameter	Side	Minimum	Maximum	Mean (cm)	SD (cm)	SEM
		Value (cm)				
MTL	Right	32	45	37.50	3.03	0.7165
	Left	32	42.4	37.05	3.12	0.7364
BTW	Right	5.6	7.4	6.71	5.60	1.3216
	Left	5.7	8.1	6.73	6.32	1.491
APDMC	Right	3.4	4.5	4.13	3.23	0.7632
	Left	3.8	5.3	4.41	4.56	1.0752
TDMC	Right	2.2	3.4	3.07	3.28	0.7754
	Left	2.4	3.4	3.09	2.46	0.58
APDLC	Right	3.1	4.6	3.79	4.42	1.043
	Left	3.1	4.3	3.70	3.55	0.8381
TDLC	Right	2.3	3.6	3.05	3.48	0.8214
	Left	2.2	3.5	3.07	3.90	0.921
MSC	Right	5.9	8.9	7.74	0.69	0.1569
	Left	6.5	8.8	7.71	0.82	0.1947
DASL	Right	3.2	4.4	3.92	3.76	0.8876
	Left	3.1	4.4	3.92	4.09	0.9652
TDNF	Right	1.7	2.5	2.18	2.14	0.4912
	Left	1.1	2.5	2.06	3.53	0.8328
MDMT	Right	1.9	2.6	2.42	2.32	0.5344
	Left	1.9	2.5	2.30	3.00	0.7093
SDNF	Right	1.1	3.3	2.30	4.55	1.0442
	Left	1.7	3.1	2.26	3.80	0.8971
DNF	Right	11	21	12.9	2.24	0.2585
	Left	9.5	17.5	12.8	2.02	0.4767

ANATOMICAL SCIENCES

Table 2. Morphometric values of tibia irrespective of the side of the bone of the South Indian population

Parameter	Minimum	Maximum	Mean (cm)	SD (cm)	SEM
	Value (cm)				
MTL	32	45	37.20	3.04	0.5077
BTW	5.6	8.1	6.72	5.89	0.982
APDMC	3.1	4.6	4.27	4.13	0.6893
TDMC	2.2	3.4	3.08	2.86	0.4777
APDLC	3.1	4.6	3.75	3.98	0.6636
TDLC	2.2	3.6	3.06	3.65	0.6084
MSC	5.9	8.9	7.74	0.74	0.1226
DASL	3.1	4.4	3.92	3.87	0.6462
TDNF	1.1	2.5	2.12	2.92	0.4814
MDMT	1.9	2.6	2.37	2.95	0.4857
SDNF	1.1	3.3	2..83	4.15	0.6828
DNF	9.5	21	12.92	2.13	0.4712

ANATOMICAL SCIENCES

an online software (https://ncalculators.com/statistics/standard-error-calculator.htm). Table 2 shows the morphometric values of the tibial parameter irrespective of the side of bone. The mean (SD) maximum length of the right and left tibia were 37.50(3.03) cm and 37.05(3.12) cm, respectively. The mean maximum length of tibia irrespective of side was obtained 37.20(3.04) cm. The mean differences of all measured anthropometric parameters were not statistically significant. All SE of estimates were not of below 1.0 (Table 1).

Table 3. Correlation coefficient (r) between maximum tibia length and other tibia anthropometric parameters

Parameters	Right	Left	Total
MTL and BTW	0.255	0.864	0.500*
MTL and APDMC	-0.135	0.406*	0.139
MTL and TDMC	0.188	0.376*	0.332*
MTL and APDLC	-0.078	0.765	0.271
MTL and TDLC	-0.081	0.446*	0.237
MTL and MSC	0.622*	0.734	0.681*
MTL and DASL	0.421*	0.710	0.572*
MTL and TDNF	0.206	-0.099	0.023
MTL and MDMT	0.252	0.573*	0.443*
MTL and SDNF	0.060	0.500*	0.262
MTL and DNF	0.183	0.869	0.588*

ANATOMICAL SCIENCES

Table 4. Linear regression equation for estimation of maximum tibia length from measured anthropometric parameters of the South Indian population

Parameter	Left	Irrespective of the Side (Total)	Right	Verified With Observed Values
APDMC	2.787*X+24.76			2.787* APDMC+24.76 (Left)
TDMC	4.785*X+22.25		3.530*X+26.40	4.785*TDMC+22.25 (Left) and 3.530*TDMC+26.40 (Right)
TDLC	3.566*X+26.10			3.566*TDLC+26.10 (Left)
MDMT	5.955*X+23.36	4.822*X+25.76		5.955*MDMT+23.36 (Left) and 4.822*MDMT+25.76 (Total)
SDNF	4.105*X+27.77			4.105*SDNF+27.77 (Left)
BTW		2.009*X+23.73		2.009*BTW+23.73 (Total)
MSC		2.514*X+17.78	2.639*X+16.97	2.514*MSC+17.78 (Total) and 2.639*MSC+16.97 (Right)
DASL		4.390*X+20.00	3.201*X+24.89	4.390*DASL+20.00 (Total) and 4.390*DASL+20.00 (Right)
DNF		8.383*X+26.44		8.383*DNF+26.44 (Total)

ANATOMICAL SCIENCES

The correlation coefficient between MTL and other tibial parameters is shown in Table 3. Our data suggested that MTL was significantly ($P<0.05$) correlated with the parameters APDMC, TDMC, TDLC, MDMT, and SDNF, in relation to the left tibia. The obtained data also revealed a significant correlation at $P<0.05$ between the MSC and DASL parameters and with respect to the total result, regarding the right tibia i.e. significant correlations were found, irrespective of the side, BTW, TDMC, MSC, DASL, MDMT and DNF. The linear regression equation for the estimation of MTL is derived from its correlated parameters (Table 4).

4. Discussion

The tibia plays an important role in anthropological research due to its resistance to disintegration and the ability to retain its anatomical form long after death [13]. Prior research suggests that tibial bone is considered in many forensic cases where stature is needed, to confirm the identity of unknown and unclaimed human remains; it is also carried out by establishing linear regression equations in relation to the maximum length of the tibia. [14-16].

In the present study, the morphometric tibial parameters were found to be correlated with the MTL with a view to establishing a linear regression equation which can be employed in forensic cases even when the retrieved tibial bone is fragmentary. Some authors have driven the further development that the regression analysis is an ideal method for establishing the relationship between length of the long bones and the stature of individuals, as well as the measured anthropometric parameters of the long bone fragments and their maximum length of bone [17].

The linear regression formulae were designed by Trotter and Gleser for the estimation of an individual stature [18]. It was also reported by researchers that all regression formulae employed in stature estimation should be population-specific [19, 20]. The regression formulae generated in the present study were respecting the south Indian population. Estimation of living stature using linear regression equation was successfully done with the tibial bone length [14]. The estimated stature of an unknown individual from the bones can help in identification of missing persons from recovered bony remains [21].

In our study, the data obtained from the morphology of the tibia were of unknown sex. Anthropologists advocate that individual's gender must always be considered to obtain higher accuracy in stature estimation [22, 23]. On the contrary, Petersen's study revealed that differences of the femur lengths did not depend on the sex [24]. Several authors have derived linear regressions to estimate the maximum length of long bones from the measurement of its fragments in different populations [25-27]. In the present study, regression equations were derived to estimate the MTL with regard to the correlating parameters. Significant correlations were observed on the left tibia, followed by irrespective of side of bone and lastly, the right tibia.

Mandela et al. derived regression equations to measure the length of the tibia from dimensions of tibia DSL. Their study demonstrated moderate correlations between the dimensions of the distal tibia and its length [28]. This agrees well with our results regarding the DSL of tibia. The MTL was estimated from the linear regression equations then compared with the observed mean MTL in the present study (Table 4) and as a result, the difference between the estimated MTL from the observed MTL was not statistically significant ($P<0.05$).

The present study provided regression formulae for estimation of the MTL from its measured parameters. This suggests that when either of the APDMC, TDMC, TDLC, MDMT and SDNF of the left side and MSC and DASL of the right side and BTW, TDMC, MSC, DASL, MDMT and DNF of the irrespective side are available in any fragmentary tibia in south Indian population, the formulae can be used to establish the MTL.

The mean (SD) length of the right side tibia was 37.50(3.03) cm and of the same for the left side tibia was calculated 37.05(3.12) cm (Table 1). When both were considered irrespective of sides, the mean score was found to be 37.20(3.04) cm (Table 2). Another study conducted on the central Indian population found 371.30(23.20) mm for the right tibia and 379.41(18.90) mm for the left tibia [16]. The MTL derived from our study was very close to the results of the study on the central India population.

Overall, our method was the one that obtained the most robust results. A reliable estimation of stature from skeletal remains will continue to play an important role in assessing a variety of forensic, anthropological, and archaeological issues. Investigators rely on regression techniques to estimate stature from long bones because of their simplicity; however, if skeletal remains are in fragments, stature estimation can still be obtained by first deriving the length of the bones from the available fragments [1].

The results of our study conclude that it is possible to estimate MTL from of its BTW, APDMC, TDMC, TDLC, MSC, DASL, MDMT, SDNF and DNF with relative accuracy. Our study may have direct applications in forensic, anthropometric, and also archaeological investigations for the identification of the remains of unknown bodies using linear regression equations in the south Indian population. Further explorations are required as these are just preliminary data formulae available for the south Indian population.

Ethical Considerations

Compliance with ethical guidelines

The research is on dry tibia and did not involve any animal and patients. The ethical approval is obtained from the our institutional ethical committee.

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Conflict of interest

The authors declared no conflict of interest.

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