

## STUDY OF DISTAL DIMENSIONS OF TIBIA IN CORRELATION WITH THE LENGTH OF TIBIA

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### ABSTRACT

**Background:** In forensic analysis, the estimation of the stature is key in identification of an individual. The stature of an individual can be estimated from long bones especially the tibia and the femur as these have direct correlation to the height of an individual. The tibia is ideal in this application as it resists erosion and keeps its anatomical shape for long even after burial. Mechanical loading is especially high in the distal ends of long bones of the lower limb and as such they display significant inter-individual differences. The use of distal dimensions in estimation of the length of the tibia from skeletal remains has not been reported.

**Materials and methods:** 150 dry and processed tibias irrespective of side, grossly normal and complete were randomly collected from a medical college of south India. Unossified bones, bones with diseases and injuries have been excluded.

**Results:** In our study, the mean and standard deviation was calculated for each of the dimensions. The results were analysed with simple regression analysis. Pearson's coefficient determined for each parameter and tabulated. Simple linear regression equations were then deduced from the obtained data which would predict the expected maximum length of the bone from its various other parameters.

**Conclusion:** Simple regression equations are deduced from the obtained data, which would predict the expected maximum length of the tibia from its various parameters.

**KEY WORDS:** Distal dimensions of Tibia, Parameters of tibia, morphometric measurement of tibia, Tibia.

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### INTRODUCTION

Tibia is a long bone of the leg which lies medial to fibula and is exceeded in length only by femur. Distal end of tibia is slightly expanded,

distal surfaces. It projects inferomedially as the medial malleolus. The distal end when compared to proximal end is laterally rotated (tibial torsion). Tibial torsion is about 30 degree

in Caucasian and oriental populations, but is significantly greater in Africans. Smooth anterior surface bulges beyond the distal surface, separated from it by a narrow groove, continuing the shaft's lateral surface. Medial surface of shaft and malleolus is subcutaneous and visible. Posterior surface is crossed near its medial end by an oblique groove. Lateral surface is the triangular fibular notch, its anterior and posterior edges project and converge proximally to the interosseous border. The distal surface articulating the talus is wider in front, concave sagittally and transversely slightly convex. The medial malleolus, is short and thick and has a smooth lateral surface with a crescentic facet articulating with the medial talar surface [1].

In forensic analysis, the estimation of the stature is key in identification of an individual. The stature of an individual can be estimated from long bones especially the tibia and the femur as these have direct correlation to the height of an individual. The tibia is ideal for this as it resists erosion and keeps its anatomical shape for long even after burial [2]. Estimation of stature from the length of the tibia has so far employed techniques that require well preserved tibiae. Inter-individual differences in osteometric parameters, which include the length of these bones, is due to hormonal differences, differential loading at joints as well as differences in muscle bulk.

The long bones of the lower limb display these differences clearly and have thus been used in forensic analysis for stature estimation. Since the distal tibia bears body weight in a relatively small surface area during the stance phase of gait, it is subjected to high biomechanical strains that in turn affect bone modelling [3].

It is therefore possible to postulate significant differences in distal tibial dimensions. Such differences in the dimensions of the distal tibia have been reported for the fibular incisura, the medial malleolus and the tibial plafond [4]. Due to populational differences exhibited by osteometric dimensions, formula derived for a particular population is not applicable to other populations [5]. The use of distal dimensions in estimation of the length of the tibia from skeletal remains has not been reported.

## MATERIALS AND METHODS

Random collection of 150 dry and processed tibias irrespective of side which are grossly normal and complete were obtained from the Department of Anatomy, A.J Institute of Medical Sciences, Mangalore, and from skeleton sets used by medical students of A.J Institute of medical sciences, Mangalore for their academic study.

**Inclusion criteria:** 150 fully ossified and processed dry tibia bones irrespective of side, age, sex and race.

**Exclusion criteria:** Unossified bones, bones with diseases and injuries.

Data collected by measuring the following parameters of the distal end of the tibia by using Vernier calliper.

Length of the tibia, Width of the tibial plafond, Length of the tibial plafond, Height of the fibular incisura, Depth of the fibular incisura, Width of the fibular incisura, Breadth of the medial malleolus, Height of the medial malleolus

Length of tibia was defined as the vertical distance from the most superior point on the medial tibial condyle to the most inferior point on the medial malleolus [6].

On the fibular incisura, the following measurements were taken:

Width of the fibular incisura which is the distance between anterior and posterior tubercles 1 cm proximal to the tibial plafond;

Depth of the fibular incisura: the distance from the deepest point of the FI to a line between tips of the anterior and posterior tubercles

Height of the fibular incisura is the vertical distance between the tibial plafond and the point where the interosseous border of the tibia splits into anterior and posterior edges [7].

**Medial malleolus:** Height of medial malleolus (MM); the distance from its base at the tibial plafond to its tip. Breadth of medial malleolus: defined as its anteroposterior length [4].

**Tibial plafond:** Width of the tibial plafond (TP) which is the mediolateral dimension of the talar facet at the middle of the joint. Length of the tibial plafond; the anteroposterior dimension of the talar facet at the middle of the joint were

also measured [3].

**Fig. 1:** Method of measurement of Width of the tibial plafond.



**Fig. 2:** Method of measurement of length of the tibial plafond.



**Fig. 3:** Method of measurement of Height of the fibular incisura.



**Fig. 4:** Method of measurement of width of the fibular incisura.



**Fig. 5:** Method of measurement of breadth of the medial malleolus.



**Fig. 6:** Method of measurement of height of the medial malleolus.



**Fig. 7:** Measurement of length of tibia.



## RESULTS

In the present study, the mean and standard deviation was calculated for each of the dimensions. The results were then analysed under simple regression analysis which shows the relationship of the dimensions of the various parameters with the length of the tibia. Pearson's coefficient is determined for each of the parameter and tabulated. Simple linear regression equations are then deduced from the obtained data which would predict the expected maximum length of the bone from its various other parameters.

**Table 1:** Mean and standard deviation of parameters in centimetres.

Parameters	Mean	Standard deviation
Width of tibial plafond	2.703	0.1892
Length of tibial plafond	3.41	0.2044
Height of fibular incisura	4.27	0.509
Depth of fibular incisura	0.6946	0.2014
Width of fibular incisura	2.6	0.39
Breadth of medial malleolus	2.39	0.155
Height of medial malleolus	1.33	0.1767
Length of tibia	37.65	1.4866

**Table 2:** Standard error of estimate and coefficient of determination in centimetres.

Parameters	Standard error of estimate:	Coefficient of determination r <sup>2</sup>
Width of tibial plafond	1.4192	0.0942
Length of tibial plafond	1.4262	0.0857
Height of fibular incisura	1.4782	0.0178
Depth of fibular incisura	1.3097	0.2289
Width of fibular incisura	1.473	0.0246
Breadth of medial malleolus	1.2727	0.2719
Height of medial malleolus	1.3287	0.2063

The Simple linear regression analysis shows the coefficient of correlation (Pearson's correlation coefficient) between dependant variable and an independent variable.

In present study the dimensions of different parameters of distal ends of tibia are correlated with the length of the tibia. The Pearson's coefficient determines the strength of the relation between the variables.

**Table 3:** Pearson's coefficient.

Parameters	Pearson's coefficient
Width of tibial plafond	0.307
Length of tibial plafond	0.2928
Height of fibular incisura	0.1336
Depth of fibular incisura	0.4785
Width of fibular incisura	0.157
Breadth of medial malleolus	0.5215
Height of medial malleolus	0.4543

Simple regression formulae obtained which shows the formulae for the length of tibia from its distal parameters.

Simple regression formula relative to different dimensions:

$$\text{LENGTH OF TIBIA } Y = 31.122 + 2.4169 \times X \text{ (WIDTH OF TIBIAL PLAFOND)} \pm 1.4192$$

$$\text{LENGTH OF TIBIA } Y = 30.3852 + 2.12964 \times X \text{ (LENGTH OF TIBIAL PLAFOND)} \pm 1.4262$$

$$\text{LENGTH OF TIBIA } Y = 25.686 + 5.001 \times X \text{ (BREADTH OF MEDIAL MALEOLUS)} \pm 1.2727$$

$$\text{LENGTH OF TIBIA } Y = 32.541 + 3.8216 \times X \text{ (HEIGHT OF MEDIAL MALEOLUS)} \pm 1.3287$$

$$\text{LENGTH OF TIBIA } Y = 35.203 + 3.532 \times X \text{ (DEPTH OF FIBULAR INCISURA)} \pm 1.3097$$

$$\text{LENGTH OF TIBIA } Y = 36.0944 + 0.5995 \times X \text{ (WIDTH OF FIBULAR INCISURA)} \pm 1.4730$$

$$\text{LENGTH OF TIBIA } Y = 35.987 + 0.3903 \times X \text{ (HEIGHT OF FIBULAR INCISURA)} \pm 1.4782$$

## DISCUSSION

In forensic and archaeological analysis of skeletal remains, estimation of stature of an individual is important as such data can be used in medico-legal cases to identify an individual. In archaeological studies, analysis of the nutritional status and general body size of the population are considered [8]. The tibia can be used in the estimation of stature as it displays significant inter-individual and sexual differences.

The use of proximal and distal tibial dimensions, which are reported to display significant sexual differences to estimate the length of the tibia, is therefore useful in estimating the height of an individual. Pertinent to this is the fact that the systematic use of regression formulae derived in a specific population can under or over-estimate stature when applied in another population [9]. Thus, authors have recommended that regression equations which are obtained in a certain population should not be applied to other populations [10, 9]. In the current study, data was sex aggregated, though the greatest accuracy in estimating stature would be obtained when the sex was available [11]. However, it has been noted that differences of the tibia length were independent of sex. Therefore in our analysis both sexes were aggregated. Similar methods have been applied in the estimation of the length of the humerus [8].

In the estimation of the length of the long bone from its fragments, the use of accurately recognizable landmarks is mandatory [9]. Because of these reasons, the measures used to derive a

regression equation to estimate the length of the long bones become limited (8). Usually, the transverse dimensions along the diaphysis are not appropriate for estimating the length because of their inability in defining the precise landmarks. Therefore, the only leftover location opts for measurements on the fragments of the proximal or distal diaphysis. Hence, for our present study, the dimensions of the distal segments of the tibia alone were selected. This is so because these dimensions are affected greatly by the modelling that results from intensive biomechanical loading at the ankle joints.

Taer F, Toker S, Kilincoglu V. Conducted a study to determine the anatomical characteristics of the fibular incisura of the tibia and the distal end of the fibula that form together the tibiofibular syndesmosis joint and to obtain the morphometric data in both genders [7].

Study was performed on 35 dry adult tibia-fibula sets. 35% of cases presented a significantly concave shape ( $> \text{ or } = 4 \text{ mm}$ ) and 65% had shallow concave fibular incisura ( $< 4 \text{ mm}$ ) in both genders. In the present study 6 tibias showed fibular incisura depth being less than 4mm and the rest 144 tibias showed the depth of fibular incisura more than 4mm.

A study done by Rachana R Kulkarni found that the mean width of fibular incisura was 2.32 cm and the depth was 0.61 cm. 88.2% bones presented deeply concave fibular incisura and 11.8% presented shallow fibular incisura [12].

In a study conducted by Ebraheim et al., 60% cases presented a deeply concave and 40% shallow concave fibular incisura [13].

Several authors have derived linear regressions to estimate the maximum length of long bones from the measurement of its fragments in different populations (10,14,15,16,17).

In the present study we also derived regression equations to measure the length of the tibia from dimensions of its distal ends in south Indian population. The current study has demonstrated moderate correlations between the dimensions of the distal tibia and its length. The length of the tibia shows positive correlation with the width of the tibial plafond ( $r=0.307$ ), the breadth of the medial malleolus ( $r=0.5215$ ) and the depth

of the fibular incisura ( $r=0.478$ ). These findings concur with and extend the findings by Mandela Pamela et al., (2013) who demonstrated correlations between the length of the tibia and the distal dimensions of the tibia.

Determination of the length of the tibia is important in the estimation of stature [18]. Since these dimensions display positive correlation with the length of the tibia, they can be used in estimation of the length of the tibia. The equations derived for length estimation showed strong positive correlations and low coefficients of determination. This indicates that estimates obtained in their use, would have lower accuracy compared to incorporating the distance between the tibial plateau and plafond, and other landmarks along the length of the shaft of the tibia used by previous studies (11, 13, 10, 16). The equations derived in the current study may however be more useful in analysis of more fragmentary tibiae. Though useful in this regard, these equations should be applied cautiously due to the low accuracy yield.

## CONCLUSION

This cross sectional study was mainly aimed at finding the metric relation between the various dimensions of the tibia with the total length of the tibia, with an intention to derive formulae that would define the relationship. The findings in this study are useful in the following: 1. Contributes to the existing data regarding the tibial length and the length of its various parameters. 2. The derived formula may be used in forensic investigations where the stature of a person in question is to be determined and only incomplete bones are available. 3. Can be a help in archaeological and anthropological studies where excavations often yield incomplete bone remains. 4. The orthopaedicians can utilise the data in planning reconstructive surgeries involving the tibia bone.

## ABBREVIATIONS

**ML**- Mediolateral length,

**AP** – Anteroposterior,

**TP**- Tibial plafond,

**FI**- Fibular incisura

**MM** - Medial Malleolus

**Conflicts of Interests: None**

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