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Original Article

Study on Anthropometric Parameters of Dry Tibia of Human Origin to aid Gender Identification in Forensic Investigation

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Abstract

The present study was undertaken to evaluate the significance of anthropometric parameters of dry human tibia in determining gender in a sample representing the Tamil Nadu region of India.

The present cross-sectional study was conducted on dry tibia of human origin at Karpaga Vinayaga Institute of Medical Sciences and Research Centre, in October 2015, in relation to three important manually measurable anthropometric parameters: the proximal epiphysial breadth (PEB), the distal epiphysial breadth (DEB), and the maximum length (L) of dry tibia. The observations were tabulated and statistically analyzed using unpaired *t*-test and Mann-Whitney U test. Significance level was assessed with p value < 0.05.

The present study found significant differences ($p < 0.0001$) in the 3 studied parameters. In male tibias, it was statistically inferred that PEB, DEB and L of tibia is more than 6.9 cm, 4.8 cm and 35.2 cm, respectively. On the other hand, in female tibias, it was inferred that the respective parameters are less than 6.6 cm, 4.5 cm and 35.1 cm.

On comparison with various other studies done in different parts of the world, it was inferred that the values of one race may not apply to another; and those of one zone may not apply to another. Therefore, it is suggested that one should consider separate values for different zones while attempting to establish parameters for gender identification of skeletal remains.

Keywords: Forensic Science, Forensic Medicine, Dry Tibia, Anthropometry, Gender Identification

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دراسة على مُعَلِّمات أنثروبومترية (القياسات البشرية) للعظم الجاف للساق بشرية المصدر للمساعدة في تحديد الجنس في التحري الجنائي.

المستخلص

أجريت هذه الدراسة لتقييم أهمية المُعلمات الأنثروبومترية (القياسات البشرية) من العظم الجاف للساق البشرية في تحديد نوع الجنس على عينة تمثل منطقة تاميل نادو Tamil Nadu في الهند.

أجريت الدراسة المقطعية الحالية على عينات متعددة من السيقان البشرية الجافة في معهد كارباغا فيناياغا للعلوم الطبية ومركز الأبحاث Karpaga Vinayaga Institute of Medical Sciences and Research Centre ، في أكتوبر 2015، لدراسة ما يتعلق بقياس ثلاثة معلمات مهمة من القياسات البشرية: الامتداد المشاشي السفلي، والامتداد المشاشي العلوي والطول الأقصى للساق الجاف. حيث تم عمل جداول للملاحظات وتحليلها إحصائيا باستخدام اختبار- ت للقيم غير المرتبطة واختبار مان- ويتني. وحُدد مستوى الدلالة الإحصائي عند قيمة دلالة إحصائية أقل من $p < 0.05$.

توصلت الدراسة إلى وجود فروق ذات دلالة إحصائية بقيمة تساوي ($p < 0.0001$) في مُعَلِمات الدراسة الثلاثة، في عظام الساق عند الذكور، تم الاستدلال إحصائيا أن الامتداد المشاشي السفلي هو أكبر من 6.9 cm، بينما الامتداد المشاشي العلوي يتجاوز 4.8 cm، والحد الأعلى لطول الساق ظهر أكبر من 35.2 cm. من ناحية أخرى، في عظام الإناث، ثبت أن المعايير آنفة الذكر كانت أقل من 6.6 cm للامتداد المشاشي السفلي وأقل من 4.5 cm للامتداد المشاشي العلوي وأقل من 35.1 cm للحد الأعلى لطول الساق.

استنتجت الدراسة من خلال المقارنة مع دراسات أخرى مختلفة أجريت في أجزاء مختلفة من العالم أن قيم عرق ما قد لا تنطبق على عرق آخر؛ وقد لا تنطبق استنتاجات منطقة جغرافية ما على منطقة أخرى. ولذلك، تقترح الدراسة أن يتم اعتماد قيم منفصلة للمناطق مختلفة أثناء محاولة اعتماد مُعَلمات لتحديد هوية بقايا الهيكل العظمي.

الكلمات المفتاحية: علوم الأدلة الجنائية، الطب الشرعي، عظم الساق الجاف، القياسات البشرية (الأنثروبومترية)، تحديد الجنس.

1. Introduction

Expert opinion on identification of an individual from skeletal remains is a routine forensic practice. Sex determination is a vital component of establishing the identity of skeletal remains. An expert forensic opinion is incomplete without it. Determination of sex from human skeletal remains has always been one of the most challenging experiences for a forensic expert, especially when bones like the tibia are the only available part of skeletal remains. The tibis, and certain other bones, are not usually used to determine the sex of skeletal remains. Hip bone, skull, mandible, sacrum, and femur are most widely used. The femur has been the only long bone known to have some reliable and useful sex differentiating features, while the others like the tibia, need further research. In some cases, the tibia is the only skeletal remains available; therefore, further research is needed to establish the importance or usefulness of anthropometric parameters in determining the sex of dry tibia.

The tibia, unlike any other long bone, has a weight bearing function. Therefore, its morphology does not seem to differ significantly between males and females. However, it is a tough bone, and therefore, remains unaffected for many years and decades following the burial of the body.

Iscan and Miller suggested that epiphysial measurements are more reliable indicators of sex because the functional demands of weight and musculature rely on these parts of the bone [1]. Studies by Ratna et al. and Gonzales et al. have also documented a similar point of view [2-3]. The author of the present study agrees with Krogman and Iscan, who recommended that parameters should be based on specific populations as skeletal morphology and morphometrics differ between population samples [4].

The present study was undertaken to evaluate statistical values for the proximal epiphysial breadth (PEB), the distal epiphysial breadth (DEB), and the maximum length (L) of dry tibias of human origin representing the Tamil Nadu region of India. It also aimed to establish whether statistically significant differences exist between parameters of male and female dry tibia. Observations of the present study were tabulated, statistically analyzed and discussed by comparing the results with that of various other studies [5-13].

2. Materials and Methods

This cross-sectional study was conducted in the Department of Anatomy at Karpaga Vinayaga Institute of Medical Sciences and Research Centre on 33 dry tibias (teaching collection of the Anatomy department) of human origin of known gender in October 2015. Care was taken by the author to segregate the sample into male and female gender based on the data reported by Dangar et al. [5, 6] on proximal and distal tibial epiphysis dimensions. Tibias with proximal tibial epiphysis dimensions between 7.1 to 7.8 cm were considered male, between 4.7 to 6 cm were considered female, and those between 6 to 7.1 cm were considered dimorphic. Tibias with distal tibial epiphysis dimensions between 4.3 to 4.9 cm were considered male, between 2.8 to 3.2 cm were considered female, and those between 3.2 to 4.3 cm were considered dimorphic. Morphology (size and muscular markings) of tibia was also taken into account for gender differentiation of those tibias which exhibited sexual dimorphism by application of data reported by Dangar et al. [5, 6]. Dry tibias of known gender, present in entirety with fused epiphysis, were included. Tibias with fused epiphysis were considered because sexual differentiation of human tibia gets completed after complete fusion of the epiphyses. Malformed tibias, and those with unfused epiphyses were excluded from the study. The total number of dry tibias was 34, one of which was excluded based on the exclusion criteria. Sample size was thus 33, of a total of 34 dry tibias, with 95% confidence level and confidence interval of 3. Sample size was calculated using the 'Survey system' software.

Tibias with male features (M) were 17, and those of female (F) were 16. Anthropometric parameters considered for the present study were, the PEB, the DEB, and the maximum L of tibia. All the three parameters were measured using Hepburn's osteometric board.

PEB was measured with the two wooden planks approximated at the outer most points on the lateral and medial surface of the proximal epiphysis of tibia [5]. DEB was measured with the two wooden planks approximated at the outermost prominence of the medial surface of medial malleolus on the medial side, and outermost edge of the fibular notch on the lateral side [6]. Some authors, like Seema and Mahajan [7], called PEB and DEB as 'upper end of tibia' and 'lower end of tibia', respectively (Whatever the nomenclature, measuring criteria remained the same). The third parameter, maximum L, was measured with the two wooden planks approximated at the superior surface of the proximal epiphysis of tibia on one side, and inferior most point of the medial malleolus on the other [7].

Measurements were observed to the nearest millimeter. The observations were tabulated and statistically analyzed with unpaired *t*-test and Mann-Whitney U test. Significance level was assessed with p value < 0.05. Statistical analysis was done using GraphPad software.

3. Results

Observed values for all the male [$n = 17$], female [$n = 16$] tibias were tabulated into a master-chart. Statistical values, namely mean, standard deviation (S.D.), standard error of mean (SEM), and 95% confidence interval (CI) of the difference in the mean of the male and female tibias parameters were estimated. Amongst the dry tibias ($n = 33$), there was a statistically significant difference between the parameters of male ($n = 17$) and female tibias ($n = 16$).

Mean value of PEB, DEB and L was higher in males as compared to females. Calculated *t*-value and *p*-value showed that the difference in the mean PEB, DEB and L in

Table 1- *Statistical findings with application of Unpaired t-test.*

Statistics	Male (n =17)			Female (n = 16)		
	PEB	DEB	L	PEB	DEB	L
Mean	7.212	4.818	38.018	6.244	4.106	33.675
S.D.	0.506	0.267	2.266	0.530	0.521	1.131
SEM	0.123	0.065	0.550	0.133	0.130	0.283
Unpaired t-test between male and female tibial length:						
***p*-value (PEB)**	$P < 0.0001$					
***p*-value (DEB)**	$P < 0.0001$					
***p*-value (L)**	$P < 0.0001$					

PEB, proximal epiphysial breadth; DEB, distal epiphysial breadth; L, length; S.D., standard deviation; SEM, standard error of the mean

male and females is statistically significant with $p < 0.0001$ (Table-1).

Table-2 indicates discriminant function analysis with application of Mann-Whitney U test, and Table-3 indicates the comparison between observed findings and statistically inferred results.

Comparison of PEB and DEB in males and females in the present study and other studies is shown in Table-4. The mean PEB value for males and females in the present study was 7.21 cm and 6.24 cm, respectively. In other studies, it varied from 7.10 cm to 7.91 cm in males and 6.39 cm to 6.98 cm in females. The mean DEB value for males and females in the present study was 4.82 cm and 4.11 cm, respectively. In other studies, it varied from 3.96 cm to 5.56 cm in males and 3.62 cm to 4.94 cm in females. It can be observed from the table that the reference values for the parameters varied from region to region.

Linear regression graphs were also plotted for PEB, DEB and L values. The horizontal axis indicates male tibia values, and the vertical axis indicates female tibia values (Figure-1-3).

4. Discussion

From the results reported by various authors, it is ob-

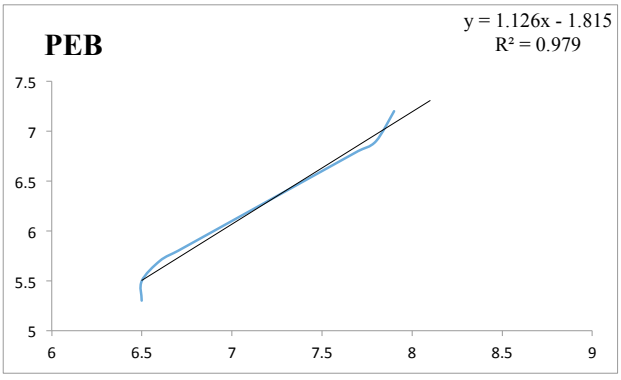

Figure 1- *Linear regression graph plotted for PEB values.*

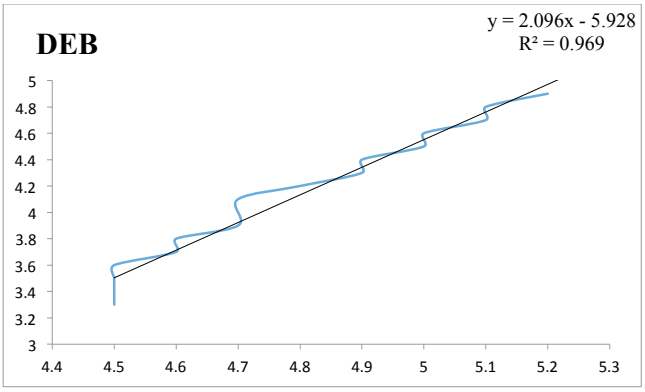

Figure 2- *Linear regression graph plotted for DEB values.*

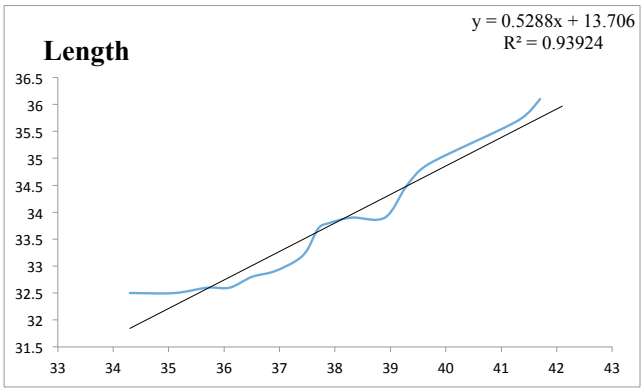

Figure 3- *Linear regression graph plotted for Length values.*

served that reference values for the parameters, PEB, DEB and Maximum L of Tibia varied from region to region. Race, along with genetic constitution, diet, nutrition status, and environment could possibly be the reasons. Dangar et al. reported low values for PEB (7.10 cm & 6.30 cm in male and female tibias, respectively) [5]; and they also reported low values for DEB (3.96 cm & 3.62 cm in male and female tibias, respectively) [6]. The lower value of DEB reported by Dangar et al. (2015) could possibly be due to the measuring method, which considered the distance between medial surface of medial malleolus and deepest center of the fibular notch [6]. With maximum length of tibia (L) as a parameter, a study by Seema and Mahajan in the Amritsar region of India was available for comparison [7]. Mean maximum length of tibia (L) reported by Seema and Mahajan in male and female tibias were 37.8 cm and 34.5 cm, respectively, which is comparatively similar to that of the present study. However, the mean maximum length (L) in female tibias in the present study was marginally lower (33.7 cm). The results of the present study, with reference to proximal epiphysial breadth of tibia (PEB), were more or less in line with that reported by the other studies. However, Iscan MY and Steyn reported a marginally higher value of PEB and DEB in their study on South African whites [11]. Overall, due to regional and racial variations, results reported by various authors have marginally differed from region to region, and therefore, the values of one race may not apply to another, and those of one zone may not apply to another. Therefore, it is required that we consider separate values for different zones when attempting to establish parameters for gender identification of skeletal remains.

The studies by danger et al. [5, 6], Seema and Mahajan [7], and Singh et al. [8] were done on right and left tibias separately. However, other studies [9-13], including the present study, have considered right and left sided tibias together for results. It is thus observed that the Indian authors have considered providing separate results for right and left tibia, unlike authors from abroad. Like the present study, most studies conducted abroad had average sample sizes, like that by Iscan and Steyn [11], which was done on south African whites and revealed a sample size of 50. The author of the present study declares average sample size as the only limitation of the study. However, Winter JCF showed that there is no fundamental objection to using a regular unpaired t test with small sample sizes [14]. In most of the simulated cases, the Type I error (incorrect rejection of a true null hypothesis) rate did not exceed the nominal value of 5%. The simulations further clarified that when the sample size is small, Type II errors (incorrectly retaining of a false null hypothesis) are negligible if the *p* value is greatly less [14]. In a simpler way, it can be assumed that statistical tests on large sample sizes can be considered reliable and valid with *p* value being anywhere less than 0.05; but to consider a statistical test reliable and valid with small sample sizes, a much lower *p* value is required.

5. Conclusion

The present study found significant findings for the

Table 2- *Discriminant function analysis with application of Mann-Whitney U Test.*

Parameters	*n* (M, F)	Z score	*p*-value	Statistical inferred results
PEB	33 (17, 16)	3.96241	0.00008	Significant at $p < 0.05$
DEB	33 (17, 16)	3.71026	0.0002	Significant at $p < 0.05$
L	33 (17, 16)	4.59279	< .00001	Significant at $p < 0.05$

Table 3- *Comparison between observed findings and statistically inferred results.*

Parameters	Observed Range (OR)	Statistically inferred results (R)
PEB	6.5 - 8.1 cm (M), 5.3 - 7.2 cm (F)	> 6.9 cm = M, < 6.6 cm = F, 6.6 to 6.9 cm = dimorphic
DEB	4.5 - 5.3 cm (M), 3.3 - 4.9 cm (F)	> 4.8 cm = M, < 4.5 cm = F, 4.5 to 4.8 cm = dimorphic
L	34.3 - 42.1 cm (M), 32.5-36.1cm (F)	> 35.2 cm = M, < 35.1 cm = F

Table 4- *Comparison of PEB and DEB values between male and female tibia reported by some other authors.*

Other studies	PEB				DEB			
	Male		Female		Male		Female	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kazuhiro et al. [10]	7.45	3.15	6.58	2.77	4.80	2.50	4.24	1.92
Iscan et al. [9]	7.35	2.78	6.58	4.68	4.53	2.18	4.05	2.55
Iscan M.Y. and Steyn M. [11]	7.91	4.88	6.98	3.65	5.02	2.89	4.44	2.35
Singh et al. [8]	7.29	0.31	6.39	0.43	4.79	0.53	4.27	0.27
Seema and Mahajan [7]	7.24	0.31	6.46	0.45	4.86	0.54	4.33	0.29
Dangar et al. [5]	7.10	0.30	6.30	0.37	-	-	-	-
Dangar et al. [6]	-	-	-	-	3.96	0.27	3.62	0.28
Kieser et al. (on Caucasoid) [13]	7.47	2.73	6.61	2.96	-	-	-	-
Kieser et al. (on Negroid) [13]	7.36	3.08	6.56	3.24	-	-	-	-
Mario et al. [12]	-	-	-	-	5.56	3.61	4.94	3.74
Present study	7.21	0.51	6.24	0.53	4.82	0.27	4.11	0.52

three studied parameters, namely, PEB, DEB, and maximum L of dry tibias of human origin. In male tibias, it was statistically inferred that PEB is more than 6.9 cm, DEB is more than 4.8 cm, and maximum L of tibia is more than 35.2 cm. In female tibias, the respective parameters are less than 6.6 cm, 4.5 cm and 35.1 cm.

From the present study, it was inferred that fragments of tibia, like PEB and DEB, could also prove useful for sex determination of an unidentified individual. These parameters have been studied by various authors before. However, as quoted earlier, standards should be used with reference to group from which they are drawn and upon which they are based. Therefore the results of the present study can prove more useful as reference for studies in India in the future, and for purpose of comparison with studies in other parts of the world.

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Declarations

This article does not contain any studies with human participants or animals.

Conflict of interest

None to declare

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None

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