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Original Article

Anatomy Section

Sex Determination from Talus among Gujarati Population of Anand Region by Discriminant Function Analysis

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ABSTRACT

Introduction: The three most vital determinations that must be made when dealing with skeletal remains are sex, age and race. Many skeletal features vary by gender, thus determination of sex is prerequisite for the identification of an individual. The success in sex determination from bones is limited by the availability of bones in fragments. The talus is apt for studying sexual dimorphism as it is often well preserved due to its durability.

Aim: To determine accuracy of talus in sex determination and to derive sex discriminant function equations specific for Gujarati population of Anand region.

Materials and Methods: Seven measurements of 58 adult human tali (36 male and 22 female) have been taken by digital sliding vernier caliper. The seven measurements taken in the present study are talar length, width of the talus, head-neck length, length and breadth of the trochlea, transverse and antero-posterior diameter of the posterior articular surface for the calcaneus. Data has been statistically analysed by discriminant function analysis.

Results: Univariate analysis showed that the mean (SD) values of all the parameters of talus are significantly greater in males as compared to females (p<0.001 indicating good discrimination). Discriminant function analysis with stepwise method revealed that length of the trochlea, head-neck length and transverse diameter of the posterior articular surface for the calcaneus emerged as the most significant discriminating parameters with correct classification rate of 96.6%.

Conclusion: The sex discriminant function equations derived in the present study can be used for sex determination studies on the tali obtained specifically from Gujarati population of Anand region.

Keywords: Foot bones, Osteometric study, Sex estimation, Tarsal bones

INTRODUCTION

The estimation of biological sex is one of the four pillars (e.g., sex, age at death, ancestry and stature) in the forensic analysis of human skeletal remains [1]. Success in sex determination is limited by the fragmented, scattered, incomplete or burned remains [2], but in the forensic identification often fragmentary remains are available [3]. Owing to the high incidence of recovery of intact foot bones, several studies [4-8] have focused on sex determination using the talus and calcaneus [9].

The compactness and the association of soft tissue (ligaments) make the talus more resistance to taphonomic factors (factors affecting decomposition and preservation), thus increasing its chance of preservation and eventual field recovery [10]. Thus, it is an ideal bone for sex determination studies.

The technique for sex determination fall into two broad categories: metric and observational [11]. The metric method is objective in that; it employs measurements and statistical results that can be repeated and validated [12]. Moreover, this method can detect dimorphism in skeletal remains that have ambiguous morphologic differences between either sex [13]. Discriminant function analysis is an entirely objective statistical technique for sex determination [14]. But, the results obtained from discriminant function analysis are population specific and thus cannot be applied to other geographical areas due to population differences [15].

The sexual dimorphism of the talus has been studied in some of the Indian populations like Gujarati, North Indian, Telangana [16-20] and in other population groups like North Italian, Egyptian, Korean, Japanese, South African Blacks and Whites [1,4,8-10,13,21-28]. These authors have derived discriminant function equations from talus measurements and its indices specific for their population groups.

India is a big country where nearly all types of geographical and climatic conditions exist and also wide variation exists in anthropometric dimensions among different types of population. This necessitates the study of sexual dimorphism in a more localised way to establish specific osteometric standards for different regions in India [29].

Extensive study has not been conducted earlier on Gujarati population on sex determination from talus. The present study was an attempt to derive discriminant function equations for sex determination from talus specifically for Gujarati population of Anand region. The sex discriminant function equations derived by previous researchers are specific for their particular population groups, as discriminant function equations are population specific.

MATERIALS AND METHODS

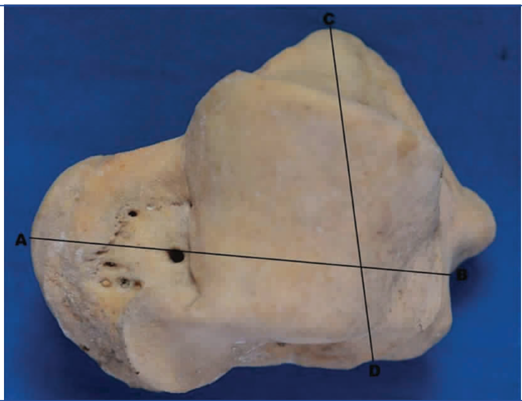
An osteometric cross-sectional study has been conducted on 58 adult human tali extracted from 11 female cadavers (22) and 18 male cadavers (36) of known age to know the accuracy of talus in sex determination. These cadavers were available in the Department of Anatomy, Pramukhswami Medical College, Karamsad that are used for dissection by MBBS and Physiotherapy students. The donated cadavers used for extracting bones in the present study were of the people of Gujarati ethnicity of Anand region as checked by the records maintained in the department. The study has been conducted for a period of three years from April, 2014 to April, 2017 and the permission for this study has been taken from the Institutional Ethics Committee (Reference number: HMPCMCE: HREC/FCT/49/Session 2/7 dt.25/3/14).

Seven measurements of the talus of both sides have been taken using digital sliding vernier caliper to the nearest millimeter (mm). Only tali with intact required osteometric landmarks have been included in the study. All the measurements have been taken by single author and twice to avoid any interobserver and intraobserver error.

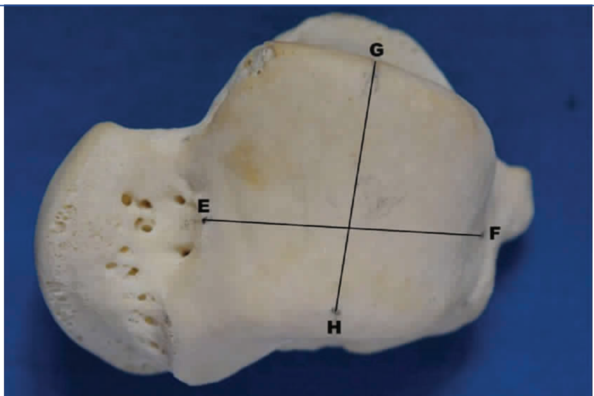
The methodology for measuring talar length and head-neck length has been adopted from Sakaue K but the measuring technique of the rest of the parameters has been modified so that the osteometric points for taking these measurements are more clear [27].

1. **Talar length (TL):** The projected distance from the most anterior point in the sulcus for the flexor hallucis longus muscle to the most anterior point on the head [Table/Fig-1] [27].
2. **Width of the talus (TW):** The maximum distance from the most lateral point on the lateral process to the point on the medial surface of the talus which lies in front of medial tubercle of talus [Table/Fig-1].
3. **Length of the trochlea (TRL):** The distance from the midpoint of the anterior margin of trochlear surface to the midpoint of the posterior margin of trochlear surface [Table/Fig-2].
4. **Breadth of the trochlea (TRB):** The distance from the midpoint of the lateral margin of trochlear surface to the midpoint of the medial margin of trochlear surface [Table/Fig-2].
5. **Head-Neck length (HNL):** The projected distance from the most anterior point of the head to the midpoint on the anterior margin of the trochlear surface [Table/Fig-3] [27].
6. **Transverse diameter of the Posterior Articular Surface for the Calcaneus (PCFTD):** The distance from most medial point of the posterior calcanean articular surface (at the level of groove for flexor hallucis longus) to the most lateral point of the posterior calcanean articular surface (at the level of the most lateral point on the lateral process) [Table/Fig-4].
7. **Antero-Posterior diameter of the Posterior Articular Surface for the Calcaneus (PCFAP):** The perpendicular distance at the level of the midpoint of the transverse diameter of the posterior calcanean articular surface [Table/Fig-4].

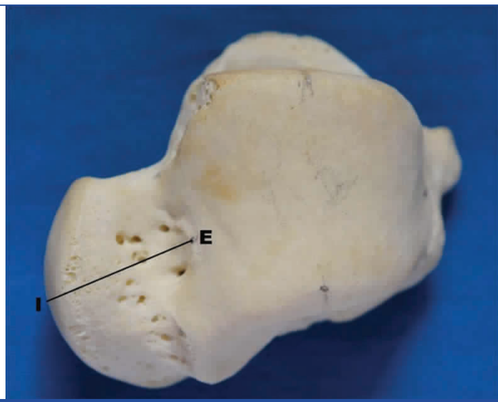
All the parameters of talus have been subjected to direct and stepwise discriminant function analysis using the Statistical Product and Service Solution (SPSS) software program.



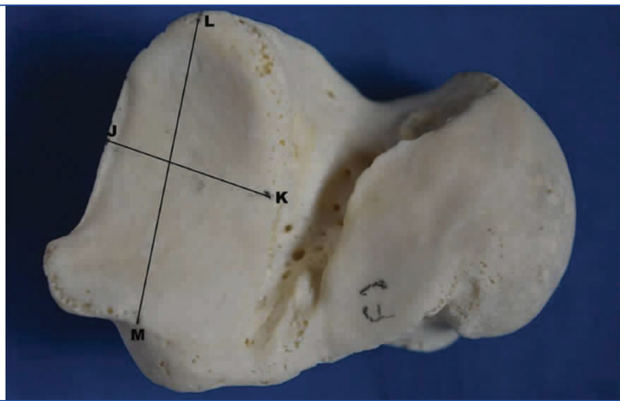
[Table/Fig-1]: Dorsal aspect of talus illustrating measurements: AB=Talar length (TL); CD=Talar width (TW).



[Table/Fig-2]: Dorsal aspect of talus illustrating measurements: EF=Length of the trochlea (TRL); GH=Breadth of the trochlea (TRB).



[Table/Fig-3]: Dorsal aspect of talus illustrating measurement: EI=Head-Neck length.



[Table/Fig-4]: Plantar/Inferior aspect of talus illustrating measurements: LM=Transverse diameter of the posterior articular surface for the calcaneus (PCFTD); JK=Antero-posterior diameter of the posterior articular surface for the calcaneus (PCFAP).

RESULTS

[Table/Fig-5] shows that mean values of all the parameters of talus are greater in males than females and all the parameters of talus are statistically highly significant for sex determination (p-value < 0.001).

Parameter	Female (n=22) Mean (SD)	Male (n=36) Mean (SD)	Total (n=58) Mean (SD)	p-value*	95% CI of difference	
					Lower	Upper
TL	46.7 (1.9)	53.1 (2.4)	50.7 (3.8)	<0.001	5.2	7.6
TW	34.7 (1.5)	40.9 (2.5)	38.5 (3.7)	<0.001	5.0	7.4
TRL	28.1 (3.3)	33.8 (1.9)	31.6 (3.7)	<0.001	4.3	7.0
TRB	24.5 (1.3)	28.1 (1.8)	26.7 (2.4)	<0.001	2.7	4.4
HNL	21.6 (2.6)	25.3 (3.0)	23.9 (3.4)	<0.001	2.1	5.2
PCFTD	26.1 (1.5)	30.9 (1.7)	29.1 (2.9)	<0.001	4.0	5.7
PCFAP	17.9 (1.5)	21.3 (1.5)	20.0 (2.2)	<0.001	2.5	4.1

[Table/Fig-5]: Mean, standard deviation, p-value and Confidence Intervals (CI) of difference between the sexes.
*Independent sample t-test

All the parameters of talus have been entered into discriminant function analysis by direct method. [Table/Fig-6] shows unstandardised function coefficients of all the parameters of talus and also constant and sectioning point for deriving the discriminant function equation. The following discriminant function equation has been derived for sex determination from tali of Gujarati population specifically Anand region:

(D1) y=(0.119)×TL+(–0.026)×TW+(0.265)×TRL+(0.038)×TRB+(0.186)×HNL+(0.226)×PCFTD+(0.071)×PCFAP–26.880

y=discriminant function score. The Sectioning Point (SP) of this equation is –0.513

Stepwise analysis selected three best sex determinants among seven parameters of talus (TRL=length of the trochlea, HNL=head-neck length, PCFTD=transverse diameter of the posterior articular surface for the calcaneus). The correct sex classification rate subsequent to stepwise analysis is 96.6% which is equivalent to

Functions	Coefficient		Eigen value	Canonical correlation	Wilk's lambda	Sectioning point (SP)	Accuracy
	Standardised (SC)	Unstandardised					
D1: All parameters Direct			4.065	0.896	0.197	**−0.513**	**96.6%**
TL	0.265	0.119					
TW	−0.056	−0.026					
TRL	0.660	0.265					
TRB	0.062	0.038					
HNL	0.535	0.186					
PCFTD	0.367	0.226					
PCFAP	0.106	0.071					
(Constant)	**−26.880**						
D2: All parameters Stepwise			4.407	0.903	0.185	**−0.492**	**96.6%**
TRL	0.751	0.302					
HNL	0.696	0.243					
PCFTD	0.498	0.306					
(Constant)	**−24.240**						

[Table/Fig-6]: Discriminant function analysis of parameters of Gujarati tali (Anand region).

that obtained subsequent to direct discriminant function analysis of all the parameters of talus.

The following discriminant function equation has been derived using the three best sex determinants obtained subsequent to stepwise analysis:

(D2) y=(0.302)×TRL+(0.243)×HNL+(0.306)×PCFTD−24.240

The sectioning point (SP) of this equation is −0.492

The significance of the discriminant function equations listed above is as follows: 1) Enter measurements of the parameters of talus in the discriminant function equation; 2) A value of discriminant function score (y) is obtained; 3) Compare value of Discriminant function score (y) with value of Sectioning Point (SP) of that equation [Table/Fig-6]; 4) Value of y>SP indicates male talus and if y<SP then it's female talus.

DISCUSSION

Sex determination is considered as the first and most important step in the biological identification process of skeletal remains [30]. The main bones used in the sex identification are the pelvis and the skull [9]. The human pelvis provides the most reliable means for determining the sex of skeletal remains. The female pelvis is designed to offer optimal space for the birth canal, which is reflected in its morphology and the relationship of its parts to each other [31]. The bones of the postcranial skeleton that have been studied for sex determination with varying degree of accuracy are: femur (90.2%) [32]; tibia (68%-82%) [33]; patella (80.5%) [34]; clavicle (93.7%) [35]; humerus (87.5%) [36]; radius (71.7%-90.4%) [37]; sternum (100%) [38]. As often fragmentary remains are available, it is necessary that the sex determination studies should be focused on bones that are resistant to taphonomic factors.

Talus has been selected for sex determination in the present study as it is resistant to taphonomic factors and can be easily identified during excavations even in fragmentary state due to its unique morphology. The present study provides the baseline data for sex determination of the population of Anand region of Gujarat from the parameters of the talus. The sex can be determined from the talus (a robust bone) in Gujarati population of Anand region with an accuracy of 96.6%.

Discriminant function analysis is the most often used classification tool among authors for sex assessment. Thus, in the present study data has been statistically analysed by discriminant function analysis and sex discriminant function equations have been derived. But, discriminant function equations are population specific. Thus, the equations derived in the present study can be used for determination of sex from the talus available specifically from the Anand region of Gujarat.

[Table/Fig-7] shows that the mean values of all the parameters of talus are more in males than females of the same region in given racial groups. The same cannot be categorically stated in mixed groups or races as there is evident overlap (as seen in [Table/Fig-7] the mean value of talar length is more in females of Egyptians than males of Japanese) [1,8-10,13,21-24,26,27]. [Table/Fig-8] shows that within Indian population also, the mean value of talar length is more in males of North India and Telangana than males of Gujarati population [17-20]. These regional differences are due to variation in geographical and environmental conditions of different countries and even at different places within the same country.

The significant differences between males and females tali are due to differences in body size and in muscular activity of the individual, also cortical bone in males has higher growth than in females [39].

Steele DG and Hoover K reported that length measurements (particularly those of the talus) are the most useful for distinguishing between male and female in different human populations [4,40]. In South African Whites also, length measurements of the talus were found to be the best indicators of sex. In the present study also, two length measurements (length of the trochlea and head-neck length) have been found as the best sex predictors subsequent to stepwise analysis. But, in South African Blacks, height variables contributed greatly to separation of sexes. Thus, the best predictors of sex vary from population to population due to racial, geographical, environmental differences.

Dwight T has stated that the size of articular surfaces has long been established as a useful indicator of sex [41]. The present study also shows that the three measurements of the talus selected as the best sex determinants (TRL, HNL, PCFTD) involve measuring of articular surfaces.

In the present study, the correct sex classification rate of the best three sex determinants is equivalent to that obtained after direct discriminant function analysis of all seven parameters, that is, 96.6%. Thus, by using discriminant function equation with only three measurements, the sex from talus in Gujarati population of Anand region can be determined with an accuracy of 96.6%. This shows that the predictive value of sexual dimorphism does not depend upon the number of parameters but upon the sex discriminatory power of the parameters. Sakaue K has stated that in practice, functions with reduced set of measurements obtained by a stepwise procedure would be more applicable because of the probability of some breakages of bones [27].

Population	TL	TW	HNL	TRL	TRB	PCFTD	PCFAP
Late Archaic [21]	56.9 (M) 50.7 (F)	43.7 (M) 38.34 (F)	- -	- -	- -	- -	- -
Late Prehistoric [21]	58.5 (M) 52.8 (F)	46.0 (M) 41.6 (F)	- -	- -	- -	- -	- -
Proto-historic [21]	56.9 (M) 51.3 (F)	43.5 (M) 39.1 (F)	- -	- -	- -	- -	- -
New Zealand [22]	53.23 (M) 47.99 (F)	44.23 (M) 39.47 (F)	- -	- -	- -	- -	- -
South African Whites [23]	55.61 (M) 51.11 (F)	42.25 (M) 39.02 (F)	- -	- -	- -	- -	- -
South African Blacks [8]	51.68 (M) 47.07 (F)	41.47 (M) 37.63 (F)	20.85 (M) 19.56 (F)	32.54 (M) 28.80 (F)	30.59 (M) 27.91 (F)	34.07 (M) 30.63 (F)	22.06 (M) 19.85 (F)
British [24]	52.59 (M) 46.85 (F)	38.03 (M) 34.36 (F)	- -	- -	- -	- -	- -
North Italian [9]	56.1 (R)(M) 56.1 (L)(M) 49.2 (R)(F) 49.3 (L)(F)	43.3 (R)(M) 43.4 (L)(M) 38.3 (R)(F) 38.5 (L)(F)	- - - -	- - - -	- - - -	- - - -	- - - -
White Americans [26]	61.06 (M) 53.43 (F)	44.65 (M) 38.18 (F)	- -	- -	- -	- -	- -
Black Americans [26]	60.84 (M) 54.11 (F)	45.99 (M) 40.53 (F)	- -	- -	- -	- -	- -
Japanese [27]	50.8 (R)(M) 50.6 (L)(M) 46.0 (R)(F) 45.6 (L)(F)	40.6 (R)(M) 40.8 (L)(M) 36.8 (R)(F) 36.7 (L)(F)	21.8 (R)(M) 22.2 (L)(M) 19.6 (R)(F) 19.9 (L)(F)	32.5 (R)(M) 32.2 (L)(M) 29.2 (R)(F) 28.7 (L)(F)	28.8 (R)(M) 28.7 (L)(M) 25.7 (R)(F) 25.6 (L)(F)	31.4 (R)(M) 31.7 (L)(M) 28.1 (R)(F) 28.2 (L)(F)	21.5 (R)(M) 21.3 (L)(M) 19.3 (R)(F) 19.2 (L)(F)
Egyptian [10]	61.25 (M) 53.27 (F)	41.97 (M) 37.86 (F)	- -	42.53 (M) 32.69 (F)	36.00 (M) 30.3 (F)	25.82 (M) 23.9 (F)	38.2 (M) 37.67 (F)
Korean [13]	55.78 (M) 52.07 (F)	41.87 (M) 39.10 (F)	20.99 (M) 19.28 (F)	33.30 (M) 30.79 (F)	28.31 (M) 26.45 (F)	32.21 (M) 28.70 (F)	21.42 (M) 19.72 (F)
Portuguese [1]	58.54 (M) 51.32 (F)	42.35 (M) 37.59 (F)	- -	- -	- -	- -	- -
Present study (Indian Gujarati, Anand region)	53.1 (M) 46.7 (F)	40.9 (M) 34.7 (F)	25.3 (M) 21.6 (F)	33.8 (M) 28.1 (F)	28.1 (M) 24.5 (F)	30.9 (M) 26.1 (F)	21.3 (M) 17.9 (F)

[Table/Fig-7]: Comparison of mean values of parameters of talus of present study with population groups of other countries (unit: mm) [1,8-10,13,21-24,26,27].

Population	TL	TW	HNL	TRL	TRB	PCFTD	PCFAP
Indian Gujarati [17,18]	53.18 (M) 48.49 (F)	41.14 (M) 37.52 (F)	- -	- -	- -	31.01 (M) 28.04 (F)	22.92 (M) 21.21 (F)
North Indian [19]	57.6 (R)(M) 57.1 (L)(M) 50.83 (R)(F) 50.28 (L)(F)	40.60 (R)(M) 41.49 (L)(M) 37.38 (R)(F) 38.45 (L)(F)	- - - -	- - - -	- - - -	- - - -	- - - -
Indian Telangana [20]	58.2 (R)(M) 56.1 (L)(M) 50.5 (R)(F) 48.5 (L)(F)	41.2 (R)(M) 42.51 (L)(M) 35.5 (R)(F) 35.3 (L)(F)	- - - -	- - - -	- - - -	- - - -	- - - -
Present study (Indian Gujarati, Anand region)	53.1 (M) 46.7 (F)	40.9 (M) 34.7 (F)	25.3 (M) 21.6 (F)	33.8 (M) 28.1 (F)	28.1 (M) 24.5 (F)	30.9 (M) 26.1 (F)	21.3 (M) 17.9 (F)

[Table/Fig-8]: Comparison of mean values of parameters of talus of present study with other Indian population groups (unit: mm) [17-20].

CONCLUSION

The best three sex determinants of talus in the present study are TRL, HNL, PCFTD a correct classification rate of 96.6%. The sex discriminant function equations derived in the present study can be used for sex determination studies on the tali obtained specifically from Gujarati population of Anand region.

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