

# A QUANTITATIVE PERSPECTIVE ON DIMORPHIC PROFILE OF TALUS IN NORTH INDIANS

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## ABSTRACT

**Introduction:** The Talus is the keystone of the human tarsus and is the weight bearing bone which is often recovered intact. It is vital for sex, race, age and sex determination.

**Aims:** The present study intends to assess the dimorphic status of Talus in North Indians on basis of size and weight. It addresses the possibility and reliability of sex/race identification using the metric attributes of talus in North Indians.

**Material and Methods:** 500 dry tali (250 males; 250 females) of known sex. Right left ratio 1:1 were taken. The study was conducted in the department of Anatomy in Government Medical Colleges of Punjab during the period 2011-2016.

**Results:** There exists a definite sexual dimorphism in the morphometry of talus for north indian population. The highly accurate scores obtained by the discriminant function analysis establish the dimorphic profile of the talus in north indian population. When the eight variables for both sides were taken into consideration the % accuracy of sex determination reached a maximum level of 100%. The predictive validity values indicate that the classification functions have proved to be a useful diagnostic tool to identify the sex of the northern indians.

**Conclusions:** It can be concluded that the talus of north indians is useful for the sex determination of skeletal remains in either a complete or fragmentary state.

**KEYWORDS:** Sexual dimorphism, Talus, North Indians.

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## INTRODUCTION

Sex, which is one of the demographic factors necessary for human identification, can be determined by visual observation of certain (non-metrical) features of bone and by measurements of other (metrical) parameters that display sexual dimorphism. The metrical method is, however, the preferred method because of its objectivity and repeatability. Metric sex

assessments are based on the levels of sexual dimorphism between males and females. Metric measurements on a number of bones have been used in the sex determination because of significant sexual dimorphism between males and females [1].

When a metric assessment of sex is complicated by the absence or destruction of the most useful bones of skeleton, measurements

obtained from the relatively robust tarsals may provide an accurate determination of sex. The talus and first cuneiform are considered to be the most dimorphic tarsals [2].

Talus is the second largest tarsal bone and is anatomically important. Talus is the link between the foot and the leg through ankle joint [3]. The talus is the keystone of the human tarsus and is a composite bone formed by the fusion of os tibiale and os intermedium [4]. It is the second largest of the tarsal bones and has a unique structure designed to channel and distribute body weight [5]. Talus is an intra articular bone, has no muscular or tendinous attachment and is held in place by various ligamentous and bony structures [6].

The talus is the most commonly fractured bone of the foot which takes part in formation of talocrural, subtalar and talocalcaneonavicular joints [7]. The adequate knowledge of anatomy of talus is significant not only to anatomists but also to the operating surgeons as fractures of the talus are quite common and lead to avascular necrosis, arthritis and when unrecognized to chronic pain and non union. Arthritis is the most common complication following talar fractures and may involve tibiotalar, subtalar and talonavicular joints[8]. As such the morphology of the talus needs to be studied in detail to establish parameters for north indian males and females.

The present study intends to address the problem of sex identification by using the metric attributes of the talus. Our rationale for choosing this bone is further strengthened by the fact that during locomotion the talus is a weight-bearing bone and all human populations show at least some sexual dimorphism in size and weight [9]. Also, the field of forensic anthropology involves the building of an ante-mortem profile of an individual from skeletal remains. This involves sex and race determination and age & status estimation. Since most bones that are conventionally used for sex determination are often recovered either in a fragmented or incomplete state, it has become necessary to use denser bones that are often recovered intact, like the patella, calcaneus & talus [10]. The present study also intends to assess the dimorphic reliability of different morphological parameters of talus and derive

scores for talus using discriminant functional analysis in north indian population. It is expected that the observations and inferences will be of significance for anatomists, anthropologists, forensic experts and professionals from other allied clinical sciences.

## MATERIALS AND METHODS

500 dry north indian tali (250 males; 250 females) of known sex with right left ratio 1:1 were taken. The Talar parameters were determined. The methodology for measuring different talar parameters was adopted from work done by Steele DG (1976) [11]. The study was conducted in the department of Anatomy in Government Medical Colleges of Punjab during the period 2011-2016.

All measurements were taken using vernier callipers with least count of 0.02. The following talar parameters were determined.

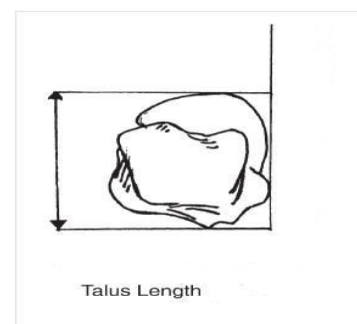
**Weight (gm):** The weight was measured by digital weighing machine for each bone and the reading was recorded in grams.

**Length of the talus (mm):** The maximum length of the talus was taken between the most posterior point of the trigonal process, to the most anterior point on the navicular facets shown in Figure 1.

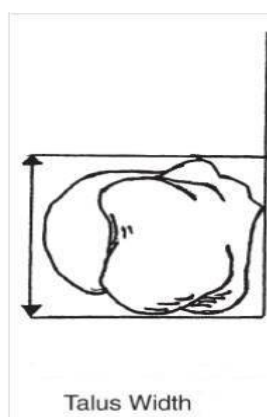
**Breadth of the talus (mm):** This reading was taken with the inferior face of the talus lying on the horizontal plane. The fixed end of the caliper was placed at the medial most point on the talus bone and the moving end was approximated to the most lateral point on the lateral surface. Thus the breadth was taken between the most medial point and the most lateral point (Figure 2).

**Height of the talus (mm):** The maximum height was measured and recorded as shown in Fig 3.

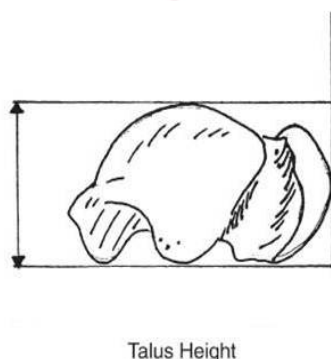
**Fig. 1:** Measuring the length of Talus.



**Fig. 2:** Measuring the breadth of Talus.



**Fig. 3:** Measuring the height of Talus.



The data obtained was further analyzed statistically. The various statistical methods used were: Mean, Standard Deviation, Coefficient of Correlation, Statistical Significance of Talar parameters in same sex (p-value), Statistical Significance of Talar parameters in sexes (p-value), and Stepwise discriminant Function Analyses. The discriminant function analysis is a widely used metrical statistical method that was developed in 1936 as reported by Thieme and Schull[12] and since then it has been widely used for the purpose of sex estimation. This method explores the differences between groups by determining which combination of variables can best predict group membership. The reliability of talus measurements in sex determination were determined and inferences was made. It is believed that the study will contribute to identification of sex which inspite of so many studies still poses a considerable challenge to forensic and physical anthropologists [13].

## RESULTS

The results are depicted in tables 1-5. Table 1 compares the talar parameters as measured for the right and left sides in the same sex. Table 2 compares these parameters as measured for a side amongst the sexes. Lack of statistical significance as demonstrated in table 1 ( $p > 0.05$ )

and confirmed statistical significance for comparison in table 2 ( $p < 0.05$ ) clearly indicates that there exists a definite sexual dimorphism in the morphometric profile of talus in north indian population.

Table 3 depicts the coefficient of correlation for talar parameters in males and females. The correlation coefficient values between different parameters as measured on right and left sides indicate that it is improbable to predict a parameter on one side when the same parameter on the other side is known. The correlation coefficients are partially positive for some pairs and partially negative for other pairs.

The results of the stepwise discriminant function analysis for talus are given in Table 4. For the talus, two variables were selected for each side and eight for both sides. When the eight variables for both sides were taken into consideration the percentage (%) accuracy of sex determination reached a maximum level of 100%.

The highly accurate scores obtained by the discriminant function analysis establish the dimorphic silhouette of the talus in north indian population. Also the accuracy of classification was found to be maximum (100%) when both left and right functions were taken into consideration. The predictive validity of the resulting classification functions was assessed. The predictive validity values indicate that the classification functions have proved to be a useful diagnostic tool to identify the sex of the northern indian individuals. This is in contrast to the predictive values obtained in southern Italians which were found to be less suitable or inadequate to sex the population. On average, the different classification functions failed to successfully predict the sex in 56.3% of the southern Italian males.

**Table 1:** Showing statistical significance of talar parameters in males.

Parameters	Males			Females		
	Right Side	Left Side	'p' value	Right Side	Left Side	'p' value
Length	57.60 $\pm$ 1.98	57.1 $\pm$ 2.14	0.346	50.83 $\pm$ 3.63	50.28 $\pm$ 3.26	0.626
Breadth	40.60 $\pm$ 8.30	41.49 $\pm$ 2.99	0.639	37.38 $\pm$ 2.68	38.45 $\pm$ 3.50	0.219
Height	32.46 $\pm$ 1.60	32.35 $\pm$ 2.03	0.855	28.25 $\pm$ 3.03	29.16 $\pm$ 2.48	0.15
Weight	19.25 $\pm$ 4.89	17.60 $\pm$ 3.60	0.156	11.39 $\pm$ 4.23	11.76 $\pm$ 3.77	0.768

'p' > 0.05 Not Significant

**Table 2:** Showing statistical significance of talar parameters in sexes.

Parameters	Males	Females	P value and Significance
Right Length	57.60 ± 1.98	50.83 ± 3.63	<0.001
Left Length	57.1 ± 2.14	50.28 ± 3.26	<0.001
Right Breadth	40.60 ± 8.30	37.38 ± 2.68	0.042
Left Breadth	41.49 ± 2.99	38.45 ± 3.50	0.003
Right Height	32.46 ± 1.60	28.25 ± 3.03	<0.001
Left Height	32.35 ± 2.03	29.16 ± 2.48	<0.001
Right Weight	19.25 ± 4.89	11.39 ± 4.23	<0.001
Left Weight	17.60 ± 3.60	11.76 ± 3.77	<0.001

\*p'<0.05 Significant

**Table 3:** Showing Coefficient of correlation for Talar parameters males and females.

	Pairs	Correlation	Significance
Males	Pair 1	0.048	0.821
	Pair 2	-0.1	0.634
	Pair 3	-0.088	0.674
	Pair 4	0.145	0.49
Females	Pair 1	-0.284	0.169
	Pair 2	-0.091	0.666
	Pair 3	0.405	0.045
	Pair 4	-0.211	0.312

Pair 1: Right/Left Length, Pair 3: Right/Left Height  
Pair 2: Right/Left Breadth, Pair 4: Right/Left Weight

**Table 4:** Stepwise Discriminant Function Analysis For Talus in North Indians.

Functions	Eigen Value	Wilks Lambda	Cannonical Correlation	X2	df	p	Group centroid	Correct Males (%)	Correct Females (%)	Correct classification %
Left Lt L Lt H	1.57	0.39	0.78	44.83	1	<.0001	M=1.228 F=-1.228	100	96	98
Right RL RB	1.4	0.42	0.76	41.45	1	<.0001	M=1.158 F=-1.158	96	80	88
Left and Right RL Lt L RB Lt B RH Lt H RW LW	3.69	0.21	0.89	72.63	2	<.0001	M=1.882 F=-1.882	100	100	100

**Table 5:** Validity of Discriminant Functions on an independent sample of individuals.

	Original Accuracy (males) (%)	Original Accuracy (Females) (%)	Original Accuracy (Total)(%)	Cross-Validation on North Indian Males (%)	Cross-Validation on North Indian Females (%)	Cross-Validation on North Indian Sample (Total) (%)
Left Stepwise	100	96	98	100	96	98
Right Stepwise	96	80	88	96	76	86
Left and right Stepwise	100	100	100	100	100	100

## DISCUSSION

In the present study when the different parameters as measured for the talus on right and left sides were compared for the same sex they were found to be statistically insignificant. This is in consonance with the findings of Koshy et al[14] in south indian tali. When the 'unpaired t test' was utilized the parameters as measured for the same side in sexes were found to be statistically significant ( $p < 0.001$ ) in most cases. This indicates that there exists a definite statistically significant dimorphism for the morphology of the talus in North Indian population. These findings are in agreement with the findings in northern italians [15], koreans[16], prehistoric polynesian tali[17] of New Zealand and in other studies. It is postulated that this statistically significant dimorphism for talar parameters might be the result of a different pattern of walking or physical labor between sexes.

The determination of sex is an early important step in the analysis of skeletal remains because it makes the sequential analysis of the biological profile of human remains more sex specific. Size and architectural differences of bones between males and females can be used to differentiate the sexes. Previously, the atlas [18], 12th thoracic vertebra[19], hyoid bone[20], clavicle [21] sternum[22], pelvic bone [23], mandible[24], and teeth[25] have been analyzed in metric studies for the sex determination.

The talus, one of the tarsal bones, is a useful bone for human identification that is better preserved during the recovery of human skeletons compared with long bones, and is readily distinguished, even in a fragmentary state, because of its characteristic morphology [26]. The talus is a bone that is frequently excavated in archaeological or forensic fields because of its durability [11], and might be useful in the identification of unknown skeletal remains if the characteristics of the bone for biological profiling are known. The statistical analyses provide more replicable results and are more reliable and quantifiable estimations than visual estimates [27]. The present study focuses on the estimation of sex using discriminating statistics of the talus. The population specificity of



the discriminant function method has been noted by many authors [28].

Several statistical studies of the talus suggest that discriminant function scores using this bone's metric data are able to identify sex with high accuracy. However, the functions derived from metric studies are reported to be specific for the studied population and cannot be extrapolated to other population groups. Therefore, the aim of this study was to investigate the sex-discriminating potential of the metric data from the talus in North Indians (a South East Asian population) and to verify the specificity of the discriminant function scores by comparing the results with results of analyses in different populations.

The accuracy of the discriminant function equation derived from various studies in different populations ranges from 60.0% to 90.0%. Table 6 depicts the total percentage accuracy of sex determination in some populations using the discriminant analysis methodology.

**Table 6:** Showing percentage Total Original Accuracy for different populations.

Populations	Authors	Total Original Accuracy
Black and White Americans	Steele 1970 [11]	83
White South Africans	Bidmos and Dayal 2004 [10]	87.5
Black South Africans	Bidmos and Dayal [29]	86.7
Northern Italians	Gualdi-Russo 2007 [15]	91.5
Prehistoric Polynesians	Murphy 2002 [17]	91.3
North Indians	Present Study	100 (Right and Left Stepwise)

For the talus in north indians, two variables were selected for each side and eight for both sides. When the eight variables for both sides were taken into consideration the % accuracy of sex determination reached a maximum level of 100%. The highly accurate scores obtained by the discriminant function analysis indicate the dimorphic profile of the talus in north indian population. Also the accuracy of classification was found to be maximum (100%) when both left and right functions were taken into consideration. When only the left functions were taken into consideration the total original accuracy is 98% and when only the right functions are taken into consideration the total original accuracy is 88%.

The predictive validity of the resulting classification functions was assessed. The predictive validity values indicate that the classification functions have proved to be a useful diagnostic tool to identify the sex of the northern indian individuals. This is in contrast to the predictive values obtained in southern italians which were found to be less suitable or inadequate to sex the population. On average, the different classification functions failed to successfully predict the sex in 56.3% of the southern Italian males. On the other hand the discriminant functions derived from measurements of the talus in prehistoric New Zealand polynesians [18] indicated that when the dimensions of its trochlear articular surface were examined, the accuracy in sex determination was considerable. The talar measurements conducted by Wilbur [16] on native Americans were able to sex individuals with an accuracy of between 82% and 87%.

In the present study the highly accurate scores obtained by the discriminant function analysis and the absolute accuracy of classification when both left and right functions were taken into consideration indicate the dimorphic profile and high predictive value of north indian tali in sex determination. It can be concluded that the talus of north indians is useful for the sex determination of skeletal remains in either a complete or fragmentary state.

## CONCLUSION

The predictive validity values indicate that the classification functions have proved to be a useful diagnostic tool to identify the sex of the northern indian individuals. It can be concluded that the talus of north indians is useful for the sex determination of skeletal remains in either a complete or fragmentary state.

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## Conflicts of Interests: None

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