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Morphometric measurement of Talus as a diagnostic tool for sexual dimorphism in South Indian population

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Abstract:
Talus is the second largest tarsal bone of the foot that forms the connecting link between the foot and the leg. Sex, age and race are the three most imperative conclusions that must be made when managing skeletal remains. Talus is one such denser bone that is often recovered intact for the identification of the individual in any traumatic injury. Talus can be used for sex determination studies. The present studies aims to determine the sexual dimorphism of talus and derive discriminant function equations that would be useful in determination of sex in south Indian population.
Materials and method: This study was conducted on dry human tali obtained from department of anatomy, K.S.Hegde medical academy, Deralakatte, Mangalore. A total of 102 (53 right male tali and 49 right female tali) dry human tali of undetermined age were selected for the study. 12 measurements were taken from each tali using digital vernier caliper. These measurements include talar length, talar width, neck length, neck width, talar height body, talar height neck, navicular articular surface height, navicular articular surface width, calcaneal articular surface length, calcaneal articular surface width, trochlear length, trochlear width.
Results: The mean values of all the variables differs significantly between males and females ($P<0.05$) except calcaneal articular width which does not differ significantly($P=0.273$). All the 12 measurements were subjected to stepwise discriminant analysis. The discriminant analysis selected 7 best variables. A mean discriminating score above 2.899 will indicate a male talus and below 2.899 will indicate female talus. These findings indicate that there exists definite sexual dimorphism in the morphometry of the talus in south Indian population.
Conclusion: The use of discriminant functional analysis in the present study will be useful for the investigators in the field of forensic science.

Key words: *Talus, sexual dimorphism, south Indian population, forensic*

Introduction :

Talus is a tarsal bone that receives the whole body weight and transmits it to the other tarsal bone. It forms the connecting link between foot and the leg. Talus is a short bone that is situated on the upper surface of the anterior two-thirds of the calcaneus. The superior surface and adjacent medial and lateral surface of the body of talus are received by tibio-fibular mortice and forms the ankle joint (1). Since the foot and ankle are weight bearing parts of the body, they exhibit size differences between males and females. In many traumatic injury, it becomes utmost important to identify the individual. Most of the bones that are conventionally (eg. Pelvis, skull, long bones) used for sex determination are often recovered either in a fragmented or incomplete state. This necessiates to use denser bone that is often recovered intact example patella, calcaneus, talus for sex determination studies (2). One of the demographic factors that necessitates for human identification is sex. This is done by two ways, one way is determining the sex by visual examination i.e non-metric features and the other way is by measurement of parameters that display sexual dimorphism i.e metric features. Interest in the degrees and patterns of variation of these skeletal traits between males and females is related to analysis of physical anthropology and to more practical purposes in forensic science (3).

The parts of the talus include head, neck and body. The head is directed anteriorly and articulates with the navicular bone. The body consists of trochlear surface which articulates with tibia. Lateral surface of the body carries a facet for the lateral malleolus of fibula. Inferiorly, the body of the talus presents articular facet for the calcaneum(4). In situations requiring postmortem identification where recovered skeletal material may be limited, this quality makes the talus an appropriate alternative for osteological analysis(5).

The sexual dimorphism of the talus has been studied by various authors. India is a country harboring nearly all types of geographical and climatic conditions and is characterized by wide variation in anthropometric dimensions among its population types. This necessitates the study of sexual dimorphism in a more localized way to establish specific osteometric standards for different regions in India (6). Thus the present study aims to access the sexual dimorphism of the talus and derive discriminant function equations that would be useful in determination of sex in south Indian population.

Materials and method:

This study was conducted on dry human tali obtained from department of anatomy, K.S.Hegde medical academy, Deralakatte, Mangalore. A total of 102 (53 right male tali and 49 right female tali) dry human tali of undetermined age were selected for the study. For the selection of talus specimens, simple random sampling techniques were used. Only the right talus was used for the study. The damaged and deformed tali were not included for the study.

Tweleve measurements were taken from each tali using digital vernier caliper. All the measurements taken followed Martin and Knussman's definition (7). These measurements include : talar length (TL), talar width (TW), neck length (NL), neck width (NW), talar height body (THB), talar neck height (TNH), navicular articular surface height (NASH), navicular articular surface width (NASW), calcaneal articular surface length (CASL), calcaneal articular surface width (CASW), trochlear length (TRL) and trochlear width (TRW). These measurements were carefully taken.

Talar length (TL): Length of the talus was measured between anterior point on navicular facet to the most prominent posterior point on trigonal process. (Fig 1)

Talar width (TW): The maximum width of the talus was taken from the most medial point and the most lateral point of talus (Fig 1)

Neck length (NL): The maximum distance between the point on the anterior margin of navicular facet to the posterior point at the junction between neck and the body of the talus (Fig 1)

Neck width (NW): the maximum distance between the most medial and the most lateral part of the neck (Fig 1)

Talar height body (THB): it is the distance between the most prominent point on the superior surface to the inferior surface of the talus (Fig 4)

Talar neck height (TNH): it the maximum distance between the most prominent point on the superior surface to the inferior surface of the talus (Fig 5)

Navicular articular surface height (NASH): it is the distance between the most prominent point on the superior and the inferior margins on the navicular facet (Fig 3)

Navicular articular surface width (NASW): it is the maximum distance between the most medial and the most lateral point on the navicular facet (Fig 3)

Calcaneal articular surface length (CASL): it is the distance between the most medial and most lateral point on the calcaneal articular surface of the talus (Fig 2)

Calcaneal articular surface width (CASW): it is the maximum distance between the most medial and the most lateral point on the calcaneal articular surface (Fig 2)

Trochlear length (TRL): it is the distance between the anterior and the posterior margin of the trochlea (Fig 1)

Trochlear width (TRW): it is the distance between the medial and lateral point on trochlear surface of the talus (Fig 1)

The photographs of the tali were taken using a digital camera. The photographs were taken by keeping the talus on green background. The photographs were taken from superior, inferior, anterior and medial aspects of the bone.

Statistical analysis:

The data collected was analyzed using SPSS software version 16. For each measurement, mean and standard deviation was obtained (Table 1 and 2). The student t test was used to establish that a significance difference exists ($p \leq 0.05$) between the male and female measurement. The mean values of all the variables differs significantly between males and females ($P<0.05$) except calcaneal articular width which does not differ significantly($P=0.273$). The discriminant functional analysis used were the canonical correlation and Wilk's lambda (Table 3 and 4). All 12 measurements were entered into the stepwise discriminant function analysis. The stepwise discriminant analysis selected the best 7 variables from the 12 measurements (Table 5). A mean discriminating score above 2.899 will indicate a male talus and below 2.899 will indicate female talus.

Result:

By measuring the all the parameters of the tali in this study, the males presented a significantly greater ($p<0.05$) value than females for all the measurements except CASW. This indicated that there was a significant sexual dimorphism in the measurements of south Indian talus. The canonical correlation and Wilk's lambda function test is used to derive the discriminant function analysis. Both the tests showed the statistically significant discriminating power in the variables in both the sexes. Seven best variables were selected for deriving the discriminant analysis formula (Table 5).

Y=-42.225+0.237* neck width+0.185 *neck length+0.219* trochlear width+0.122* trochlear length+0.374*navicular+0.236*T height+0.239*talar length.

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By this we can suspect the sex of the talus as follows : a mean discriminating score for any measurement above 2.899 will indicate a male and below 2.899 will indicate female.

Discussion :

The sex determination of skeletal remains is one of the methods in forensic and anthropological basis is discriminant functional analysis. It is now a frequent practice, to use the discriminant function equation to sex unidentified skeletal remains (8). The talus has been described as being one of the durable bones of the foot (9). The study by Davies CM et al and Gualdi-Russo E suggested that the talus and calcaneum are considered to be good indicators for sexual dimorphism. This is possible because of the size of the bone and weight bearing nature of the foot (10,11). Accurate determination of sex is done by accurately estimating age at death, as rates of growth, development and degeneration vary by sex as well as population(12).

All the measurements taken were more than the measurements taken by Abdelaleem S (13) and Bidmos MA et al (2). But these findings are in agreement with the study by Agnihotri G et al., (14) and Koshy et al (15). The differences between these study findings can be attributed to the combination of environmental and genetic factors (16). When an independent t test was done for all the male and female tali except for CASW there was a significant difference in the measurements taken. This difference between male and female tali is due to the different body size. Difference in the muscular activity also contributes for the morphometric differences (13).

The bones that were used previously for the sexual dimorphism were thoracic vertebrae (17), clavicle, sternum, pelvic bone and mandible (18,19,20,21). But the complete recovery of these bones is difficult. The morphological characteristic of talus is better preserved during the recovery of human skeletons (22).

The present study is focused on the using the discriminant analysis of talus for the sexual dimorphism of human right talus. This discriminant functional tests for talus has been used by many authors (23). But the studies reported that the functions derived from the morphometric measurements for the sexual dimorphism varies in different population (14).

The percentage of accuracy varies for different population. In the study done by Steele et al., in black and white Americans, there was 83% accuracy for predicting the sexual dimorphism of talus (24). In a study done by Bidmos and Dayal et al., in White south Africans there was an accuracy of 87.5% (2). In the study by Gualdi -Russo et al., in Northern Italians there was an accuracy of 91.5% (25). In the study by Agnihotri G et al., in north Indian population 100% accuracy was obtained in the morphometric measurement (14).

Conclusion:

The metric measurements obtained from the present study, proved that it is useful diagnostic tool for the determination of the sex of talus in south Indian individuals. The technological progress in foot and ankle surgery has been made possible by knowledge obtained from morphological research in technologies such as computed tomography, 3 D printing technology and computer aided design programs. Thus, the use of discriminant functional analysis in the present study will be useful for the investigators in the field of forensic science.

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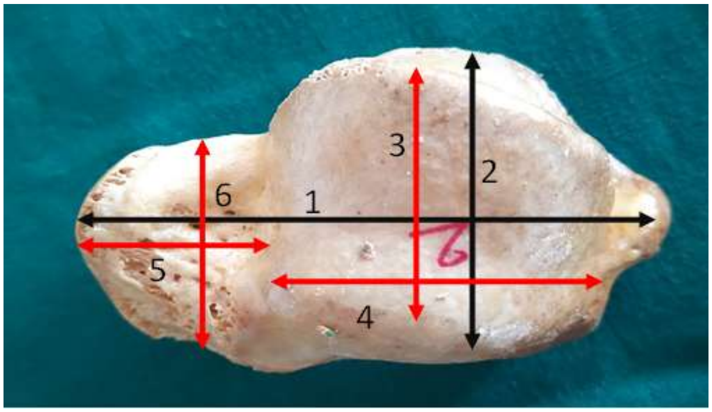

Fig 1: showing the superior view of right talus. Talar length (TL) (1), talar width (TW) (2), trochlear width (TRW) (3), trochlear length (TRL) (4), neck length (NL) (5), neck width (NW) (6).

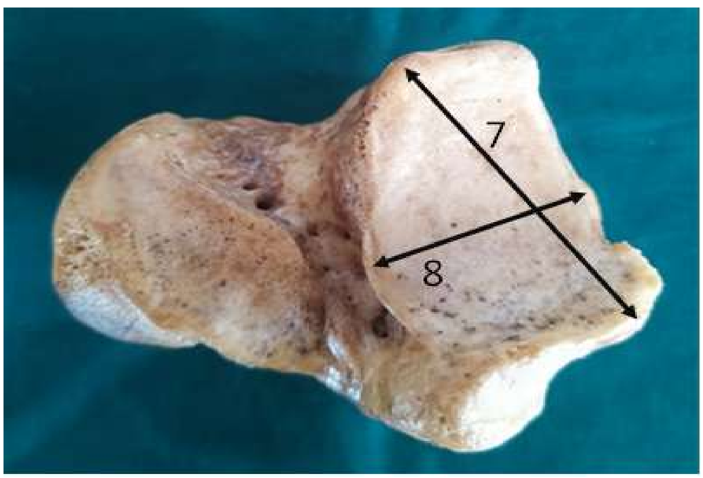

Fig 2: Inferior surface of the right talus showing calcaneal articular surface width (CASW) (7) and calcaneal articular surface length (CASL) (8).

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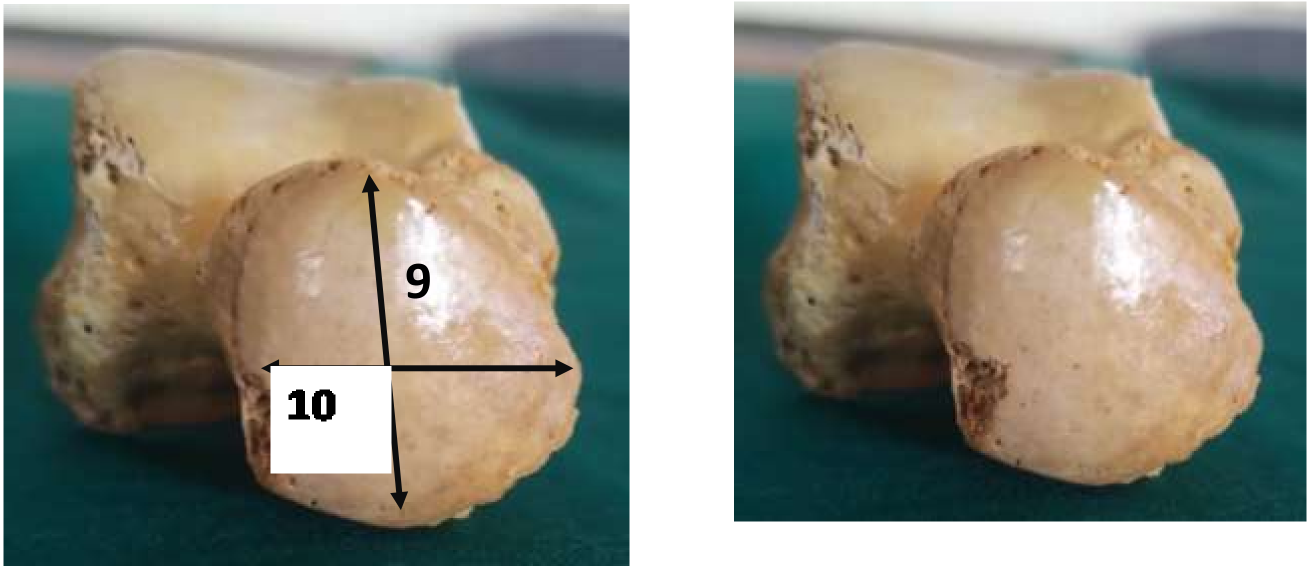

Fig 3: Anterior surface of the talus showing navicular articular surface height (NASH) (9) and navicular articular surface width (NASW) (10).

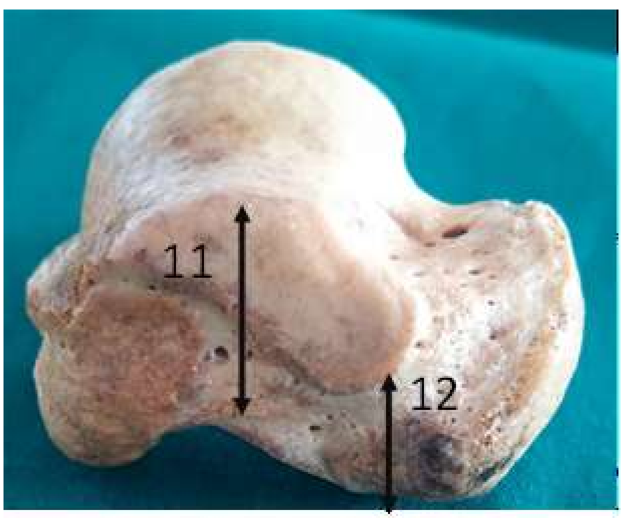

Fig 4: Medial aspect of the talus showing talar height body (THB) (11) and talar neck height (TNH) (12).

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Male tali					
Number		Min.	Max.	Mean	S.D
TL	53	50.1	60.72	56.02	2.7
TW	53	24.36	32.75	27.52	2.36
NL	53	8.06	13.88	11.20	1.84
NW	53	18.33	24.47	21.63	1.41
TRL	53	26.01	36.62	32.56	2.41
TRW	53	25.58	31.84	28.06	1.82
CASL	53	19.24	28.58	22.03	2.31
CASW	53	28.47	34.48	31.66	1.76
NASH	53	19.16	27.63	24.49	2.25
NASW	53	22.++36	28.98	25.44	1.81
TH	53	19	24.97	22.67	1.56
NH	53	18.24	22.80	20.81	1.36

Table 1: showing the mean and standard deviation of male tali

Female tali					
Number		Min.	Max.	Mean	S.D
TL	49	46.13	52.74	42.08	1.85
TW	49	22.42	27.65	25.16	1.54
NL	49	6.33	11.42	8.45	1.35
NW	49	16.46	22.90	19.26	1.53
TRL	49	27.21	32.88	29.62	1.41
TRW	49	21.46	27.84	25.39	1.55
CASL	49	18.31	24.89	20.94	1.63
CASW	49	26.61	36.30	31.18	2.41
NASH	49	18.24	29.10	21.24	2.08
NASW	49	18.19	23.67	20.89	1.54
TH	49	18.34	23.58	21.01	1.57
NH	49	17.21	21.69	19.01	1.34

Table 2: showing the mean and standard deviation of female tali

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	8.578[a]	100.0	100.0	0.946

First 1 canonical discriminant functions were used in the analysis.

Table 3: showing Canonical co-relation

Since the canonical correlation is high the better the function that discriminates the values

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.104	209.001	7	0.001

Table 4: Wilks lambda is significant. So there is statistically significant discriminating power in the variables included in the model.

	Function
	1
Talar length	0.239
T height neck	0.236
Navicular articular surface width	0.374
Trochlear length	0.122
Trochlear width	0.219
Neck length	0.185
Neck width	0.237
(Constant)	-42.225

Table 5: showing the unstandardized coefficients, constants that are used to formulate the discriminant function equation

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