

## Original Research Article

# Sexual dimorphism: metric measurements based study in human talus bone

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## ABSTRACT

**Background:** Identification is the act of establishing the identity of an individual. This is a dynamic process and human remains in form of bones can serve as an excellent tool for establishing the sexual identity of the deceased, along with other methods such as DNA, fingerprints, blood group identification etc. Metric analysis of various bones can serve as a viable alternative in cases when morphological analysis is not possible due to damage to the skeletal remains or as an additive analytical tool to establish a positive identity.

**Methods:** Metric analysis of various parameters of randomly selected 100 pairs of human talus bones (50 male and 50 female) as a means of establishing sexual identity from skeletal remains obtained from unidentified and unclaimed dead bodies brought for autopsy.

**Results:** In the present study we found that the values of all the various dimensions measured were higher among the male subjects as compared to that in female samples as was expected. On further analysis, this difference was found to be statistically significant ( $p < 0.001$ ). For the right sided and left sided talus bone, the probable accuracy for various parameters ranged between 83.3% to 100% each, thus indicating strong correlation between sex of the subject and various measurements.

**Conclusions:** The tarsal and their dimensions are highly sexually dimorphic and are useful in determining sex in individuals of this region.

**Keywords:** Calcaneum, Identification, Metric analysis, Talus

## INTRODUCTION

Forensic osteology is a domain of forensic anthropology which is principally concerned with the analysis of the human skeleton for medico-legal purposes. Biological identity of humans is associated with four basic features: sex, age, stature, and ethnic origin. Since the methods for age and stature estimation are sex-dependent, the first crucial step for biological identification process is sex

determination.<sup>1</sup> Sexing based on skeletal studies can be done using morphological traits of pelvis, skull and mandible or by the metric method based on measurements of various bones.

These methods used are, however, population-specific because these traditional sex estimation methods are limited by various environmental or physical insults or observer bias in case of morphological method.

In such cases, the application of metric method can be used to sexually differentiate unclassified skeletal remains.<sup>2,3</sup> The sex determination of a skeleton is based on three steps:- DNA analysis, observation of morphological traits and the use of metrical data with discriminant functions. Each method has its own advantages and limitations, depending upon the condition of preservation of the sample.

Although the molecular methods are very helpful for the determination of sex, they are not very accurate when applied to old samples. Skeletal sex may be determined by studying morphological parameters or performing quantitative analysis of selected skeletal measurements. The morphological methods are simple and have good accuracy; however, they are prone to subjective bias of the observer. The use of metric analysis methods can reduce the subjectivity of sex determination and helps in increasing its accuracy, especially in cases where the samples have been poorly preserved.

Most research on the metric assessment of individuals using the tarsal bones has focused primarily on the calcaneum and talus and the usefulness of these bones for sex determination among different populations has been demonstrated. Different studies done on various tarsal bones have shown that talus is the most sexually dimorphic bone among the tarsals. Dimorphism in the human skeletal system and in dentition is well established.

This has been studied in detail focussing more on the determination of sex from different parts of the skeleton than on the degree of dimorphism.<sup>4</sup> Based on these facts and observations from similar studies, the research was undertaken using talus samples from modern adult population of Haryana region, to assess the metric measurements of talus bone of both feet and in both the sexes along with determining and comparing accuracy of these parameters for differentiation of sex of an individual.

## METHODS

The present study was undertaken in the Department of Forensic Medicine and Toxicology, Pt. B.D. Sharma PGIMS, Rohtak.

### Sample size

A total of 100 pairs of talus bones (50 male and 50 female), one from each foot were collected from unidentified dead bodies brought in the department for post-mortem examination.

### Inclusion criteria

- Only intact adult talus bone samples from known and recognizable sex were collected. The age of the

subjects was derived from established bone age based parameters.

### Exclusion criteria

- Individuals with any skeletal defects, congenital anomaly, fractured, fragmented and burnt bones were excluded from the study. Old age samples were not used because of appearance of age related changes which could have affected the results.

The criteria of measurements for each talus bone were derived from earlier, similar research work done on prehistoric talus bone samples in South African population.<sup>5,6</sup> Digital weighing machine was used to measure the weight of each bone separately and metric measurements were taken from each talus bone using digital Vernier calipers. Following parameters were noted:

- Weight (W)
- Talar Width (TW)
- Talar Length (TL)
- Head Neck Length (HNL)
- Head Height (HH)
- Talar Height (TH)
- Trochlear Length (TrL)
- Trochlear Breadth (TrB)
- Length of Posterior Articular Surface (LPAS)
- Breadth of Posterior Articular Surface (BPAS)

### Data Analysis

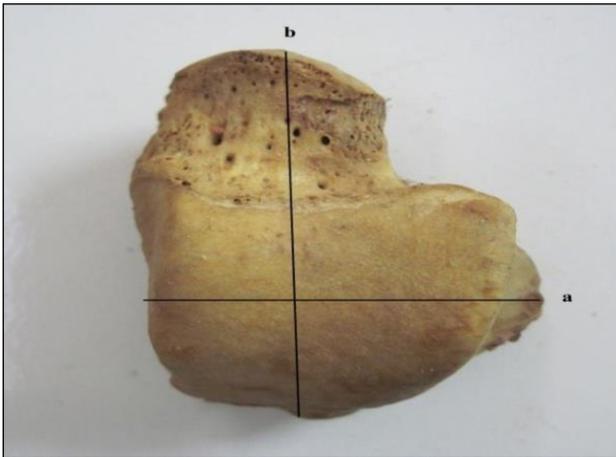
Repeat measurements were taken from each bone sample so as to minimize observer bias during the course of the study. As single bone measurements can be misleading, this study collected combinations of measurements from the two talus bones from each case to facilitate measuring the relative size of the bones to each other.

Data was entered in Microsoft excel master sheet and analysed using SPSS 15 (Statistical Product and Service Solutions) software. Descriptive statistics (mean, standard deviation, range, percentages etc) was applied wherever appropriate. Statistical analysis was performed using Pearson correlation test and separate cut off points for male and female specimen were also calculated by using ROC curve.

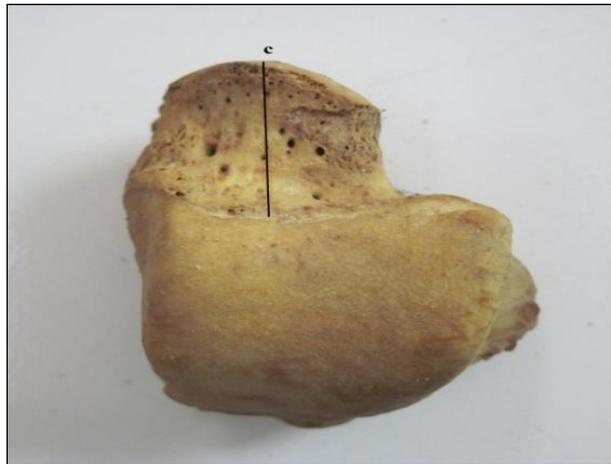
## RESULTS

The morpho-metric significance of ten variables were considered, which included Weight (W), Talar width (TW) (Figure 1), Talar length (TL) (Figure 1), Head-neck length (HNL) (Figure 2), Height of the head (HH) (Figure 3), Talar height (TH) (Figure 3), Length of the trochlea (TrL) (Figure 4), Breadth of the trochlea (TrB) (Figure 4), Length of posterior articular surface (LPAS) (Figure 5) and Breadth of the posterior articular surface (BPAS)

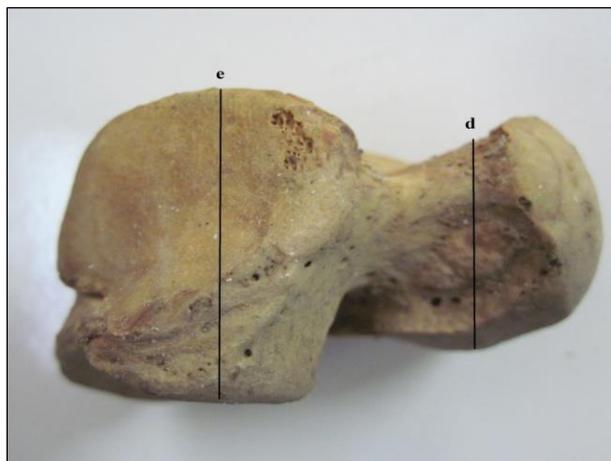
(Figure 5). The assessments were done for both the sides (right and left).



**Figure 1: a- Talar width/TW. b- Talar length/TL.**



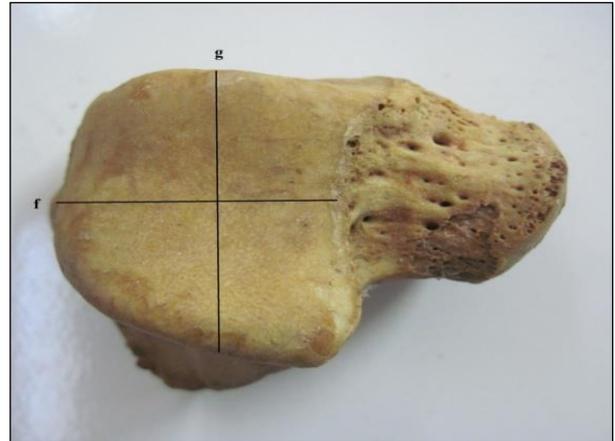
**Figure 2: c- Talar head neck length/HNL.**



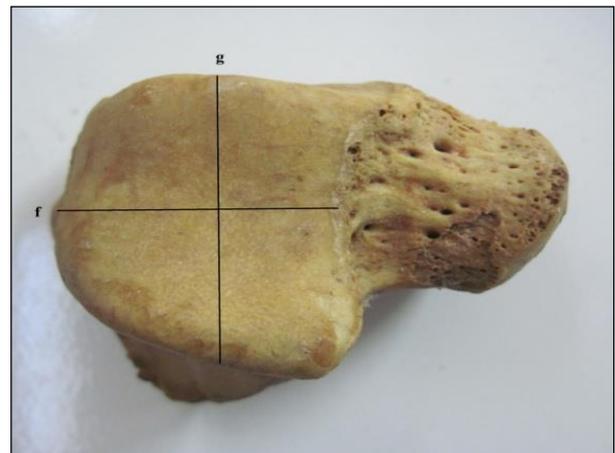
**Figure 3: d- Talar Height/TH. e-Talar head height/HH.**

In the present study we found that the values of all the various dimensions measured were higher among the

male subjects as compared to that in female samples as was expected.



**Figure 4: f-Trochlear length/TrL. g- Trochlear breadth/TrB.**



**Figure 5: h- LPAS. i-BPAS.**

On further analysis, this difference was found to be statistically significant ( $p < 0.001$ ) (Table 1). Authors also found out that the mean weight of male bones were greater than the female bones. Mean weight of right and left side of male bones were found to be 27.18 gms and 27.10 gms respectively and mean weight of right and left side of female bones were found to be 18.28 gms and 18.28 gms respectively.

For the right sided and left sided talus bone, the probable accuracy for various parameters ranged between 83.3% to 100% each, thus indicating strong correlation between sex of the subject and various measurements. Bilaterally, weight was found to be having strongest discriminating ability while talar height was least sensitive parameter although when compared to previous studies the discriminant ability was still comparable. Outcome of analysis for different parameters in prediction of male gender are given in Table 2.

**Table 1: Comparison of different parameters according to gender.**

Parameter	Male (n=50)		Female (n=50)		Significance	
	Mean	SD	Mean	SD	T	P
<b>Right side</b>						
Weight	27.18	4.53	18.28	2.90	11.69	<0.001
TW	40.36	2.46	35.34	2.03	11.12	<0.001
TL	56.98	3.28	49.38	2.38	13.25	<0.001
HNL	20.18	2.24	17.03	1.56	8.16	<0.001
TrL	30.48	2.44	27.26	1.67	7.72	<0.001
TrB	27.78	2.02	24.07	1.30	10.95	<0.001
HH	23.50	2.09	20.44	1.23	8.89	<0.001
TH	31.25	1.78	27.54	2.39	8.82	<0.001
LPAS	31.53	1.63	27.86	1.85	10.51	<0.001
BPAS	21.80	1.45	19.00	1.08	10.98	<0.001
<b>Left side</b>						
Weight	27.10	4.56	18.28	2.88	11.56	<0.001
TW	40.39	2.44	35.34	2.04	11.22	<0.001
TL	57.07	3.26	49.41	2.41	13.38	<0.001
HNL	20.15	2.26	17.02	1.60	8.00	<0.001
TrL	30.57	2.37	27.22	1.64	8.23	<0.001
TrB	27.74	2.08	24.05	1.25	10.74	<0.001
HH	23.67	2.02	20.47	1.23	9.57	<0.001
TH	31.31	1.85	27.56	2.41	8.72	<0.001
LPAS	31.57	1.61	27.71	2.27	9.82	<0.001
BPAS	21.81	1.40	18.97	1.07	11.39	<0.001

**Table 2: Outcome of analysis for different parameters in prediction of male gender.**

SN	Parameter	AUC	Projected cut-off value	Projected Sensitivity (%)	Projected Specificity (%)
<b>Right Side</b>					
1	Weight	1.000	22.50	100	100
2	TW	0.944	37.48	90	100
3	TL	0.950	53.42	85.0	88.9
4	HNL	0.989	17.91	95.0	100
5	TrL	0.889	29.02	85.0	77.8
6	TrB	0.933	25.61	85.0	88.9
7	HH	0.983	21.80	95.0	88.9
8	TH	0.833	30.05	80.0	77.8
9	LPAS	0.989	29.68	95.0	100
10	BPAS	0.917	20.06	90.0	77.8
<b>Left Side</b>					
1	Weight	1.000	22.50	100	100
2	TW	0.95	38.17	90	100
3	TL	0.95	52.67	90.0	88.9
4	HNL	0.978	18.51	90.0	100.0
5	TrL	0.878	29.28	85.0	88.9
6	TrB	0.944	25.41	85.0	88.9
7	HH	0.969	22.35	85.0	88.9
8	TH	0.833	29.70	85.0	77.8
9	LPAS	0.992	29.99	90.0	100.0
10	BPAS	0.928	20.16	85.0	88.9

## DISCUSSION

Determination of sex is the first important step in the development of the biological profile in human osteology, whether analyzing a forensic case or an archaeological population.

Without an accurate determination of sex, we cannot accurately estimate age at death, as rates of growth, development, and degeneration vary by sex as well as population. There are many sex estimation methods that can be applied to human remains.

The present study was carried out with an aim to assess the metric measurements of talus bone of both feet in both sexes and to compare and determine accuracy of these parameters for differentiation of sex of an individual. The following table shows the various population groups studied by various authors.

Length of the Talus (left) was measured by Steele<sup>7</sup>, Wilbur et al<sup>8</sup>, Barret et al<sup>9</sup>, Murphy<sup>10</sup>, Bidmos et al<sup>5,6</sup>, Ferrari et al<sup>11</sup>, Russo<sup>12</sup>, Lee et al<sup>13</sup> and Mayank et al<sup>14</sup>. All these studies showed that mean talar length was higher in males as compared to females. So, our results are consistent with the results of previous studies (Table 3).

**Table 3: Comparison of length of male & female talus (mm) of Haryanvi population with the findings of other studies.**

Study	Average Talus length (males)	Average Talus length(females)	P value
Steele <sup>7</sup>	55.30 mm (Whites)	49.70 mm (Whites)	<0.05
	55.20 mm (Blacks)	49.20 mm (Blacks)	<0.05
Bidmos and Dayal <sup>5</sup>	55.61 mm (South African Whites)	51.11 mm (South African Whites)	<0.05
Barret et al <sup>9</sup>	56.90 mm (Late-Archaic Native American)	50.70 mm (Late-Archaic Native American)	<0.05
	58.50 mm (Late Prehistoric Native American)	52.80 mm (Late Prehistoric Native American)	<0.05
	56.90 mm (Proto-Historic Native American)	51.30 mm (Proto-Historic Native American)	<0.05
Bidmos and Dayal <sup>6</sup>	51.68 mm (South African Blacks)	47.07 mm (South African Blacks)	<0.05
Russo <sup>12</sup>	56.10 mm (North Italians)	49.20 mm (North Italians)	<0.001
Murphy <sup>10</sup>	53.23 mm (Prehistoric Polynesian)	47.99 mm (Prehistoric Polynesian)	<0.001
Wilber et al <sup>8</sup>	52.10 mm (Prehistoric Native Americans)	46.70 mm (Prehistoric Native Americans)	<0.05
Ferrari et al <sup>11</sup>	52.59 mm (English)	46.85 mm (English)	<0.001
Lee et al <sup>13</sup>	55.78 mm (Koreans)	52.07 mm (Koreans)	<0.010
Mayank et al <sup>14</sup>	53.18 mm (Gujarati)	48.49 mm (Gujarati)	<0.010
Present Study	57.07 mm (Haryana)	49.41 mm (Haryana)	<0.001

Summary statistics calculated for the left side talar width of the male and female samples separately demonstrate that average male dimensions for each tarsal are larger than those of females and is consistent with results from previous studies and also the results are population specific (Table 4). Steele found average 81% of sexual dimorphism in the talus of White and Black Americans.<sup>10</sup> Barrett et al found 88% sexual dimorphism in the talus of Late Archaic era, 90% sexual dimorphism in the talus of Late Prehistoric era and 89% sexual dimorphism in the talus of Proto-historic era of Ohio valley Native Americans.<sup>9</sup> Murphy found 91.3% of sexual dimorphism in the talus of Prehistoric Polynesians.<sup>10</sup> Bidmos et al found 80.88% sexual dimorphism in the talus of White South Africans and 80.89% sexual dimorphism in the

talus of Black South Africans.<sup>5,6</sup> Ferrari et al found 86% of sexual dimorphism in the talus of English population.<sup>11</sup> Russo found 91.5% of sexual dimorphism in the talus of Northern Italian population.<sup>12</sup> Lee et al found average 75% of sexual dimorphism in the talus of Northern Italian population.<sup>13</sup> In present study we found 95% sexual dimorphism by using CP of width of talus. Height of the Talus was also measured by Steele, Barret et al, Murphy, Bidmos et al, Russo, Lee et al and Mayank et al. All these studies showed that mean talar height value was higher in males as compared to females. So our results are consistent with the results of previous studies.<sup>7,9,10,5,6,12-14</sup> (Table 5). By using CP of height of talus, Steele found average 81% of sexual dimorphism in the talus of White and Black Americans.<sup>7</sup> Barrett et al found 86% sexual

dimorphism in the talus of Late Archaic era, 88% sexual dimorphism in the talus of Late Prehistoric era and 89% sexual dimorphism in the talus of Proto-historic era of Ohio valley Native Americans.<sup>9</sup> Murphy found 91.3% of sexual dimorphism in the talus of Prehistoric Polynesians.<sup>10</sup> Bidmos et al found 87.5% sexual

dimorphism in the talus of White South Africans.<sup>5</sup> Russo found 91.5% of sexual dimorphism in the talus of Northern Italian population.<sup>12</sup> Lee et al found average 73.6% of sexual dimorphism in the talus of Korean population.<sup>13</sup> In present study we found 83.3% sexual dimorphism by using CP of width of talus.

**Table 4: Comparison of width of male & female talus (mm) of haryanvi population with the findings of other studies.**

Study	Population	Talus Width (Males) (mm)	Talus Width (Females) (mm)
Steele <sup>7</sup>	White Americans	43.00	38.80
	Black Americans	43.00	38.40
Bidmos and Dayal <sup>5</sup>	White South Africans	42.25	39.02
Barret et al <sup>9</sup>	Late Archaic Era	43.70	38.34
	Late Prehistoric Era	46.00	41.60
	Proto Historic Era	43.50	39.10
Bidmos and Dayal <sup>6</sup>	Black South Africans	41.47	37.63
Russo <sup>12</sup>	North Italians	43.40	38.50
Murphy <sup>10</sup>	Prehistoric Polynesian	44.23	39.47
Ferrari et al <sup>11</sup>	English	38.03	34.36
Lee et al <sup>13</sup>	Koreans	41.87	39.10
Mayank et al <sup>14</sup>	Gujarati	41.14	37.52
Present Study	Haryana	40.39	35.34

**Table 5: Comparison of height of male & female talus (mm) of haryanvi population with the findings of other workers.**

Study	Population	Talus Height (Males) (mm)	Talus Height (Females) (mm)	P value
Steele <sup>7</sup>	White Americans	32.70	29.80	<0.05
	Black Americans	32.30	29.30	<0.05
Bidmos and Dayal <sup>5</sup>	White South Africans	33.44	30.73	<0.05
Barret et al <sup>9</sup>	Late Archaic Era	34.90	29.90	-
	Late Prehistoric Era	36.00	31.80	-
	Proto Historic Era	33.60	30.30	-
Bidmos and Dayal <sup>6</sup>	Black South Africans	31.05	27.98	<0.05
Russo <sup>12</sup>	North Italians	32.60	29.20	<0.001
Murphy <sup>10</sup>	Prehistoric Polynesian	29.09	26.15	<0.001
Lee et al <sup>13</sup>	Koreans	32.69	30.89	<0.01
Mayank et al <sup>14</sup>	Gujarati	33.96	30.68	<0.01
Present Study	Haryana	31.31	27.56	<0.001

## CONCLUSION

Talar dimensions are significantly sexually dimorphic, and therefore, useful in determining sex in individuals of this region and can be used to metrically estimate sex when other methods of sex determination are difficult or impossible due to poor preservation of more commonly used elements. The comparative approach of this study has yielded strong evidence of the need for population

specific standard. Keeping in mind the findings of this study, we suggest that such morphometric studies should be done on various smaller bones such as foot and hand bones which are relatively less studied.

Another point to be stressed is that since these parameters are population specific, so there is a need to study and generate population database for each group which could be used for the purpose of identification.

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