



## Morphometry of the Talus on the Basis of Sexual Dimorphism

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### ABSTRACT

*Introduction: Talus is the second largest tarsal bone of the foot, having no muscular or tendinous attachments over it. Various studies have been done over the morphological features of the talus on the basis of sexual dimorphism. In this study, length, breadth, height and volume of talus are used for the same. Material and method: In the present study, 221 dry adult human talus of known sex were used, obtained from the Department of Anatomy, M P Shah Medical College, Jamnagar. Length, breadth, height and volume of both male and female talus were taken. Cut Point, Identification Point and Demarcating Points were calculated. Results: Mean length, breadth, height and volume of male talus are more as compared to female talus in the Gujarati population of present study. Conclusion: Length, breadth, height and volume of talus are useful metrical features of talus for the sex determination.*

**Keywords : Length of talus, Breadth of talus, Height of talus, Volume of talus, Cut point**

### INTRODUCTION

As evolution continues from lower animals to human, erect posture comes into play. Having erect posture, the human foot has to play its role in weight bearing and locomotion, that's why it is much more specialized.

In the human foot, seven tarsal bones occupy the proximal half of the foot. The tarsal bones of the foot and the carpal bones of the hand are homologous, but the tarsal elements are larger, reflecting their role in supporting and distributing body weight.<sup>1</sup> Talus is the key tarsal bone of the human foot. It is unique in the sense that it has no muscular or tendinous attachments.<sup>2</sup> Talus (the tarsal bone of the foot) is homologous with the scaphoid (the carpal bone of the hand).<sup>3</sup>

Most bones, those are conventionally used for sexual dimorphism are often recovered either in a fragmented or incomplete state, so it has become necessary to use denser or robust bones, those are often recovered intact e.g. patella, talus, calcaneus.<sup>4</sup> All human populations show at least some sexual dimorphic features regarding talus. These features are population specific and show racial variations also. In this regard, measurements of the talus can give much information to anatomists, physical anthropologists and also forensic experts. Various studies of the talus have been done on the basis of sexual dimorphism. In the present study, length, breadth, height and volume of talus of known sex have been measured and tried to analyze on the basis of sexual dimorphism.

### MATERIAL AND METHOD

Present study was conducted on 221 dry adult human talus of known sex. The bones were obtained from the dead bodies donated to the Department of Anatomy, M P Shah Medical College, Jamnagar. Out of total 221 talus, 127 were of male and 94 were of female. Out of 127 male talus, 57 were of right

side and 70 were of left side. Out of 94 female talus, 44 were of right side and 50 were of left side. Pathological, fractured or talus of unknown sex were excluded from the study. Only fully ossified, adult and talus of known sex were included in the study. By using Sliding caliper following measurements of the talus were taken:

#### 1. Length of the Talus (mm) (photograph 1):

Length of the talus was taken as the distance between foremost part of rounded articular surface of head and floor of the groove for flexor hallucis longus muscle (by taking the length measurement from the floor of this groove, instead of from the apex of the lateral tubercle, we can avoid the introduction of any variations due to the difference in the degree of the development of the lateral tubercle).<sup>5</sup>



**PHOTOGRAPH 1: Showing the method of the measurement of length of talus by using sliding caliper**

#### 2. Breadth of the Talus (mm) (photograph 2):

Breadth of the talus was measured as the distance between the tip of lateral process of talus and medial side of talus, at right angle to the transverse plane of trochlea.<sup>6</sup>



**PHOTOGRAPH 2: Showing the method of the measurement of breadth of talus by using sliding caliper**

**3. Height of the Talus (mm) (photograph 3):**

Height of the talus was measured as the distance between horizontal plane with the bone base and the highest point on the superior surface of trochlea (usually located on the medial rim of the trochlear articular surface).<sup>7</sup>

**4. Volume of the Talus (cm<sup>3</sup>):**

Volume of talus was calculated by multiplication of values of length of talus, breadth of talus and height of talus.<sup>8</sup>



**Photograph 3: Showing the method of measurement of height of talus by using Sliding caliper**

To avoid intra-observer error, each measurement was taken at three different times and their average was used as final

Cut Point was taken as the middle value of the two mean. E.g. Cut Point for the length of talus was the middle value of the two means, first-mean length of all male talus and second-mean length of all female talus. All bones having length more than the Cut Point was identified as males and all bones having length less than the Cut Point was identified as females. By using same method, Cut Point for other parameters was calculated.<sup>8</sup> Identification Point was measured by using the minimum and maximum limits (range) for each measurement. Demarcating Point was measured by using mean  $\pm 3SD$  (calculated range  $\rightarrow$  which will cover 99.75% of the sample) for all the parameters.

Student "t" test was used and 'p value' was calculated by using statistical aids for comparison of various parameters of talus between male and female.

**OBSERVATION**

As shown in table 1, in the present study, mean length of male and mean length of female talus were 53.18 mm (range $\rightarrow$ 46-60 mm) and 48.49 mm (range $\rightarrow$ 43-55 mm) respectively. Mean breadth of male and mean breadth of female talus were 41.14 mm (range $\rightarrow$ 35-46 mm) and 37.52 mm (range $\rightarrow$ 32-42 mm) respectively. Mean height of male and mean height of female talus were 33.96 mm (range $\rightarrow$ 29-38 mm) and 30.68 mm (range $\rightarrow$ 26-35 mm) respectively.

As shown in table 2, in the present study, mean volume of the male talus was 74.70 cm<sup>3</sup> and mean volume of the female talus was 56.17 cm<sup>3</sup>.

Although the percentage of correctly identifying bone decreased from CP to IP to

DETAILS OF MEASUREMENT	LENGTH OF TALUS		BREADTH OF TALUS		HEIGHT OF TALUS	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
TOTAL NUMBER	127	94	127	94	127	94
MEAN(mm)	53.18	48.49	41.14	37.52	33.96	30.68
SD(mm)	2.55	2.74	2.52	2.31	1.69	1.80
CP	>50.83 mm	<50.83 mm	>39.33 mm	<39.33 mm	>32.32 mm	<32.32 mm
%CP(No.)	83.46%(106)	77.66%(73)	78.74%(100)	80.85%(76)	81.10%(103)	80.85%(76)
MIN-MAX(mm)	46-60	43-55	35-46	32-42	29-38	26-35
IP	>55 mm	<46 mm	>42 mm	<35 mm	>35 mm	<29 mm
%IP (No.)	18.11%(23)	15.96%(15)	29.92%(38)	13.83%(13)	14.17%(18)	8.51%(8)
MEAN $\pm$ 3SD(mm)	45.52-60.84	40.26-56.72	33.59-48.70	30.60-44.45	28.90-39.02	25.29-36.07
DP	>56.72 mm	<45.52 mm	>44.45 mm	<33.59 mm	>36.07 mm	<28.90 mm
%DP (No.)	5.51%(7)	14.89%(14)	9.45%(12)	6.38%(6)	6.30%(8)	8.51%(8)

**TABLE 1: showing the length, breadth and height of male and female talus (mm) and its statistical analysis.**

DP, but the accuracy of the method increased. Data for the length, breadth, height and volume of male and female talus were statistically highly significant, as p value for each of them <0.01.

**DISCUSSION**

1. Length of talus was also measured by Steele DG9, Barrett CH et al8, Murphy AMC7, Bidmos MA et al10, Ferrari J et al11, Gualdi-Russo E12, Torres TB13 and Lee UY et al14. Findings of present study are tabulated and compared with findings of these workers:

DETAILS	MALE	FEMALE
TOTAL NUMBER	127	94
MEAN(cm <sup>3</sup> )	74.70	56.17
SD(cm <sup>3</sup> )	10.24	8.32
CP	>65.43 cm <sup>3</sup>	<65.43 cm <sup>3</sup>
%CP(No)	82.68%(105)	87.23%(82)

MIN-MAX(cm <sup>3</sup> )	51.15-96.14	38.52-72.34
IP	>72.34 cm <sup>3</sup>	<51.15 cm <sup>3</sup>
%IP(No.)	55.12%(70)	30.85%(29)
MEAN $\pm$ 3SD(cm <sup>3</sup> )	43.97-105.43	31.21-81.12
DP	>81.12 cm <sup>3</sup>	<43.97 cm <sup>3</sup>
%DP(No.)	28.35%(36)	10.64%(10)

**TABLE 2: showing the volume of male and female talus (cm3) (length x breadth x height) and its statistical analysis.**

Author	Population	Sex (side)	No	Mean (mm)	SD (mm)	CP (mm)	%CP	P value
Steele Dg.	White Americans	M	28	55.30	3.20	>52.50	81%	<0.05
		F	29	49.70	2.40	<52.50		
	Black Americans	M	33	55.20	3.60	>52.20	<0.05	
		F	30	49.20	2.70	<52.20		

Barrett Ch. et al (Ohio Valley Native Americans)	Late Archaic Era	M	15	56.90	3.60	>53.80	89%	---
		F	15	50.70	2.60	<53.80		
	Late Prehistoric Era	M	39	58.50	3.50	>55.65	90%	---
		F	35	52.80	2.10	<55.65		
	Proto-Historic Era	M	20	56.90	3.40	>54.10	89%	---
		F	18	51.30	2.60	<54.10		
Murphy Am.	Prehistoric Polynesians	M	23	53.23	2.57	>50.61	91.3%	<0.0001
		F	24	47.99	2.12	<50.61		
Bidmos Ma. et al	White South Africans	M	60	55.61	3.00	>53.36	87.5%	<0.05
		F	60	51.11	2.50	<53.36		
	Black South Africans	M	60	51.68	2.62	>49.37	80.8%	<0.05
		F	60	47.07	2.70	<49.37		
Ferrari J. et al	English	M	52	52.59	3.14	>49.72	86%	<0.001
		F	54	46.85	2.72	<49.72		
Gualdi-Russo E.	Northern Italians	M(Rt)	60	56.10	2.90	>52.65	91.5%	<0.001
		F(Rt)	50	49.20	2.30	<52.65		
		M(Lt)	56	56.10	2.90	>52.70		
		F(Lt)	51	49.30	2.10	<52.70		
Torres Tb.	White Americans	M	60	61.06	3.72	>57.25	92%	0.000
		F	59	53.43	3.32	>57.25		0.000
	Black Americans	M	54	60.84	3.52	>57.48		
		F	54	54.11	3.43	<57.48		
Lee Uy. et al	Korean	M	70	55.78	3.42	>53.93	75%	<0.01
		F	70	52.07	2.99	<53.93		
Present Study	Gujarati	M	127	53.18	2.55	>50.83	83.46%	<0.01
		F	94	48.49	2.74	<50.83	77.66%	

**TABLE 3: Showing the comparison of length of male and female talus (mm) of Gujarati population with the findings of other workers.**

By using CP of length of talus, Steele DG9 found average

Author	Population	Sex (Side)	No	Mean (mm)	SD (mm)	CP (mm)	%CP	P Value
Steele Dg.	White americans	M	28	43.00	2.90	>40.90	81%	<0.05
		F	29	38.80	1.80	<40.90		
	Black americans	M	33	43.00	2.70	>40.70		<0.05
		F	30	38.40	2.00	<40.70		
Barrett Ch. et al (Ohio Valley Native Americans)	Late archaic era	M	15	43.70	1.90	>41.02	88%	---
		F	15	38.34	2.10	<41.02		
	Late prehistoric era	M	39	46.00	2.40	>43.80	90%	---
		F	35	41.60	1.90	<43.80		
	Proto-historic era	M	20	43.50	2.40	>41.30	89%	---
		F	18	39.10	3.00	<41.30		
Murphy Am.	Prehistoric polynesians	M	24	44.23	3.02	>41.85	91.3%	<0.0001
		F	27	39.47	2.02	<41.85		
Bidmos Ma. et al	White south africans	M	60	42.25	2.10	>40.63	80.88%	<0.05
		F	60	39.02	2.70	<40.63		
	Black south africans	M	60	41.47	2.62	>39.55	80.89%	<0.05
		F	60	37.63	2.32	<39.55		
Ferrari J. et al	English	M	52	38.03	2.42	>36.20	86%	<0.001
		F	54	34.36	1.78	<36.20		
Gualdi-Russo E.	Northern italians	M(Rt)	60	43.30	2.20	>40.80	91.5%	<0.001
		F(Rt)	47	38.30	2.20	<40.80		
		M(Lt)	56	43.40	2.20	>40.95		
		F(Lt)	46	38.50	2.00	<40.95		
Torres Tb	White americans	M	60	44.65	2.63	>41.42	92%	0.000
		F	59	38.18	3.01	<41.42		
	Black americans	M	54	45.99	2.97	>43.26		0.000
		F	54	40.53	3.08	<43.26		
Lee Uy. et al	Korean	M	70	41.87	2.47	>40.48	75%	<0.01
		F	70	39.10	2.46	<40.48		
Present Study	Gujarati	M	127	41.14	2.52	>39.33	78.74%	<0.01
		F	94	37.52	2.31	<39.33	80.85%	

**TABLE 4: showing the comparison of breadth of male and female talus (mm) of Gujarati population with the findings of other workers.**

81% of sexual dimorphism in the talus of White and Black Americans. Barrett CH et al8 found 89% 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. Murphy AMC7 found 91.3% of sexual dimorphism in the talus of Prehistoric Polynesians. Bidmos MA et al10 found 87.5% sexual dimorphism in the talus of White South Africans and 80.8% sexual dimorphism in the talus of Black South Africans. Ferrari J et al11 found 86% of sexual dimorphism in the talus of English population. Gualdi-Russo E12 found 91.5% of sexual dimorphism in the talus of Northern Italian population. Torres TB13 found average 92% of sexual dimorphism in the talus of White and Black Americans. Lee UY et al14 found average 91.5% of sexual dimorphism in the talus of Northern Italian population.

In present study, by using CP of length of talus, 83.46% of male talus were correctly identified as male talus and 77.66% of female talus were correctly identified as female talus. By using IP of length of talus, these values were 18.11% for the male talus and 15.96% for the female talus. By using DP of length of talus, these values were 5.51% for the male talus and 14.89% for the female talus. Number and percentage of correctly identified bones decrease from CP to IP to DP, but accuracy increases.

**2. Breadth of talus was also measured by Steele DG<sup>9</sup>, Barrett CH et al<sup>8</sup>, Murphy AMC<sup>7</sup>, Bidmos MA et al<sup>10</sup>, Ferrari J et al<sup>11</sup>, Gualdi-Russo E<sup>12</sup>, Torres TB<sup>13</sup> and Lee UY et al<sup>14</sup>.**

Findings of present study are tabulated and compared with findings of these workers:

By using CP of breadth of talus, Steele DG9 found average 81% of sexual dimorphism in the talus of White and Black Americans. Barrett CH et al8 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. Murphy AMC7 found 91.3% of sexual dimorphism in the talus of Prehistoric Polynesians. Bidmos MA et al10 found 80.88% sexual dimorphism in the talus of White South Africans and 80.89% sexual dimorphism in the talus of Black South Africans. Ferrari J et al11 found 86% of sexual dimorphism in the talus of English population. Gualdi-Russo E12 found 91.5% of sexual dimorphism in the talus of Northern Italian population. Torres TB13 found average 92% of sexual dimorphism in the talus of White and Black Americans. Lee UY et al14 found average 75% of sexual dimorphism in the talus of Northern Italian population.

In present study, by using CP of breadth of talus, 78.74% of male talus were correctly identified as male and 80.85% of female talus were correctly identified as female. By using IP of and 80.8% sexual dimorphism in the talus of Black Africans.

breadth of talus, these values were 29.92% for the male talus and 13.83% for the female talus. By using DP of breadth of talus, these values were 9.45% for the male talus and 6.38% for the female talus.

**3. Height of talus was also measured by Steele DG<sup>9</sup>, Barrett CH et al<sup>8</sup>, Murphy AMC<sup>7</sup>, Bidmos MA et al<sup>10</sup>, Gualdi-Russo E<sup>12</sup>, Torres TB<sup>13</sup> and Lee UY et al<sup>14</sup>.**

Findings of present study are tabulated and compared with findings of these workers:

By using CP of height of talus, Steele DG9 found average 81% of sexual dimorphism in the talus of White and Black Americans. Barrett CH et al8 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. Murphy AMC7 found 91.3% of sexual dimorphism in the talus of Prehistoric Polynesians. Bidmos MA et al10 found 87.5% sexual dimorphism in the talus of White South Africans

Author	Population	Sex (Side)	No	Mean (mm)	SD (mm)	CP (mm)	%CP	P Value
Steele Dg.	White americans	M	28	32.70	2.70	>31.25	81%	<0.05
		F	29	29.80	1.70	<31.25		
	Black americans	M	33	32.30	1.90	>30.80		<0.05
		F	30	29.30	1.90	<30.80		
Barrett Ch. et al (Ohio Valley Native Americans)	Late archaic era	M	15	34.90	2.80	>32.40	86%	---
		F	15	29.90	2.30	<32.40		
	Late prehistoric era	M	39	36.00	3.60	>33.90	88%	---
		F	35	31.80	2.30	<33.90		
	Proto-historic era	M	20	33.60	2.20	>31.95	89%	---
		F	18	30.30	1.80	<31.95		
Murphy Am.	Prehistoric polynesians	M	23	29.09	1.28	>27.62	91.3%	<0.0001
		F	26	26.15	2.84	<27.62		
Bidmos Ma. et al	White south africans	M	60	33.44	2.10	>32.08	87.5%	<0.05
		F	60	30.73	2.10	<32.08		
	Black south africans	M	60	31.05	1.84	>29.52	80.8%	<0.05
		F	60	27.98	1.90	<29.52		
Gualdi-Russo E.	Northern italians	M(Rt)	60	32.30	1.80	>30.65	91.5%	<0.001
		F(Rt)	48	29.00	1.40	<30.65		
		M(Lt)	56	32.60	1.70	>30.90		<0.001
		F(Lt)	50	29.20	1.20	<30.90		
Torres Tb.	White americans	M	60	33.61	2.38	>31.27	92%	0.000
		F	59	28.93	2.68	<31.27		
	Black americans	M	54	32.44	1.57	>30.78		0.000
		F	54	29.11	1.93	<30.78		
Lee Uy. et al	Korean	M	70	32.69	1.78	>31.79	73.6%	<0.01
		F	70	30.89	2.26	<31.79		
Present Study	Gujarati	M	127	33.96	1.69	>32.32	81.10%	<0.01
		F	94	30.68	1.80	<32.32	80.85%	

**TABLE 5: Showing the comparison of height of male and female talus (mm) of Gujarati population with the findings of other workers.**

Gualdi-Russo E<sup>12</sup> found 91.5% of sexual dimorphism in the talus of Northern Italian population. Torres TB<sup>13</sup> found average 92% of sexual dimorphism in the talus of White and Black Americans. Lee UY et al<sup>14</sup> found average 73.6% of sexual dimorphism in the talus of Korean population.

In present study, by using CP of height of talus, 81.10% of male talus were correctly identified as male and 80.85% of female talus were correctly identified as female. By using IP of height of talus, these values were 14.17% for the male ta-

lus and 8.51% for the female talus. By using DP of height of talus, these values were 6.30% for the male talus and 8.51% for the female talus.

**4. Volume of talus (Length X Breadth X Height)(cm<sup>3</sup>) was also measured by Barrett CH et al<sup>8</sup> in three different era of Ohio valley Native American population namely Late Archaic, Late Prehistoric and Proto-historic.**

Findings of present study are tabulated and compared with

findings of Barrett CH et al<sup>8</sup>:

By using CP of the volume of talus, Barrett CH et al found that, in the Late Archaic era, 100% of male talus was correctly identified as male and 93.3% of female talus was correctly identified as female. In Late Prehistoric era, 94.9% of male talus was correctly identified as male and 68.6% of female talus was correctly identified as female. In Proto-historic era, 80% of male talus was correctly identified as male and 77.8%

of female talus was correctly identified as female.

In the present study, by using CP of volume of talus, 82.68% of male talus was correctly identified as male and 87.23% of female talus was correctly identified as female. By using IP of the volume of talus, these values were 55.12% for the male talus and 30.85% for the female talus. By using DP of the volume of talus, these values were 28.35% for the male talus and 10.64% for the female talus.

Author	Population	Sex (Side)	No	Mean (mm)	SD (mm)	CP (mm)	%CP	DP (mm)	P Value
Barrett Ch. et al (Ohio Valley Native Americans)	Late archaic era	M	15	86.70	9.30	>72.60	100%	>84.90	0.16
		F	15	58.50	8.80	<72.60	93.3%	<58.80	
	Late prehistoric era	M	39	97.80	17.80	>83.95	94.9%	>96.80	0.10
		F	35	70.10	8.90	<83.95	68.6%	<44.40	
	Proto-historic era	M	20	83.80	13.90	>72.55	80%	>94.00	0.19
		F	18	61.30	10.90	<72.55	77.8%	<42.10	
Present Study	Gujarati	M	127	74.70	10.24	>65.43	82.68%	>81.12	<0.01
		F	94	56.17	8.32	<65.43	87.23%	<43.97	

TABLE 6: showing the comparison of volume of male and female talus (Length X Breadth X Height) (cm<sup>3</sup>) of Gujarati population with the findings of Barrett CH et al<sup>8</sup>.

### SUMMARY AND CONCLUSION

The present study was undertaken on 221 dry adult human talus of known sex. Out of 221 talus, 127 were male talus (57 right + 70 left) and 94 were female talus (44 right + 50 left). Four parameters of each talus were taken in this study: length of talus, breadth of talus, height of talus and volume of talus (length x breadth x height).

Mean length of male talus (53.18 mm) is more as compared to mean length of female talus (48.49 mm) in the Gujarati population of the present study. Further, the mean length of talus of Gujarati population is less than the mean length of talus of Black and White American; Late Archaic, Late Prehistoric and Proto-historic era population of Ohio valley Native American; White South African; Northern Italian and Korean population, while more than the mean length of talus of Black South African and English population.

Mean breadth of male talus (41.14 mm) is more as compared to mean breadth of female talus (37.52 mm) in the Gujarati population of the present study. Further, the mean breadth of talus of Gujarati population was less than the breadth of talus of Black and White American; Late Archaic, Late Prehistoric and Proto-historic era population of Ohio valley Native American; Prehistoric Polynesian; White South African; Northern Italian and Korean population, while more than the mean breadth of talus of English population.

Mean height of male talus (33.96 mm) is more as compared to mean height of female talus (30.68 mm) in the Gujarati population of the present study. Further, the mean height of

talus of Gujarati population was more than the mean height of talus of Black and White American; Prehistoric Polynesian; Black South African; Northern Italian population. The mean height of talus of Gujarati population was less than the mean height of talus of Late Prehistoric era Ohio valley Native American population.

Mean volume of male talus (74.70 cm<sup>3</sup>) is more as compared to mean volume of female talus (56.17 cm<sup>3</sup>) in the Gujarati population of present study. Further, the mean volume of talus of Gujarati population was less than the mean volume of talus of Late Archaic, Late Prehistoric and Proto-historic era population of Ohio valley Native American.

Thus, the length, breadth, height and volume of the talus are very important parameter for making models of bones of foot (particularly talus); and both male and female tali can be artificially made by considering the data of the present study for the routine study purpose in the department of anatomy and orthopedics.

In cases of forensic science, when whole skeleton is not available and sex has to be determined by using only a part of skeleton, especially talus, data of this study can be utilized. The study can also be useful to anatomists and physical anthropologists. In orthopedic surgical procedures (like arthrodesis, arthroplasty), population specific data of talus of the Gujarati population should be kept in mind.

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