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ORIGINAL ARTICLE

Significance of weight for sexual dimorphism of talus bone

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Abstract

The present study aims to determine the sexual dimorphism of talus bone by using weight as a parameter. 100 pair of talus bones of known sex obtained from unknown or unclaimed cadavers brought to the mortuary for autopsy were included in the study. Weight of right talus and left talus of 50 males and 50 females was measured using an electronic weighing scale in this cross-sectional study. All the measurements in male talus were greater than the measurements in female talus bones. Univariate discriminant and logistic regression analyses were conducted on the data to estimate sex from the weight of the talus bone. The overall accuracy came out to be 89% in both sexes (84%-90% in males and 88% - 94% in females). In contrast to Identification and Demarcating points, Limiting point showed maximum classification accuracy in sex determination. Weight of talus bone thus showed statistically significant sexual dimorphism results and can be used to estimate sex along with other parameters

Keywords

Talus bone; Sexual dimorphism; Discriminant analyses; Logistic regression analysis; Weight.

Introduction

The determination of sex from an adult human skeleton is a fundamental task for forensic and physical anthropologists. In these fields, it is important to determine the sex of a human skeleton regardless of its state of preservation. Sexing of the bone is not only dependant on the morphological traits but also the morphometrical analysis. Standards of skeletal identification vary among different population and the same cannot be used for another population.[1] Identification of sex by weight have been carried out for femur[2,3], clavicle[4,5], hyoid[6,7] and almost all other bones of the human skeleton which shows some degree of sexual dimorphism. Most of these bones as described in the above studies are often recovered either in fragmented or in incomplete state, so it has become necessary to use denser or robust bones which are often recovered intact e.g., patella, talus, calcaneus.[8]

Tarsals are fairly dense bones and can be more durable than other bones, such as the pelvis that are usually employed to determine biological sex.[8,9] Another advantage of taking tarsal bones is that feet are often protected by shoes which may retard the damage to the bones due to external agents.[10] Keeping in view these points, the aim of the present study was to assess the weight of talus bone of both feet and in both sexes and to determine and compare accuracy of this parameter for differentiation of sex of an individual by applying different statistical methods.

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Material and Methods

The present study was conducted in the Department of Forensic Medicine of Pt. B.D Sharma PGIMS, Rohtak, where 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 mortuary for medico-legal post-mortem examination. The study was a cross-sectional one, with purposive non-random sampling done on north Indian population. The study was started only after obtaining approval from the Institutional Ethical Committee. All the talus bones samples taken were from unidentified and unclaimed corpses aged more than 20 years from identifiable sex. Unknown and unclaimed dead bodies were chosen to avoid ethical dilemma due to undue disfiguration of known cadavers. The age of the subjects was derived from established bone age-based parameters. Dead bodies with any skeletal defects, congenital anomaly, bony fractures or 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 bones were removed by causing minimal disfigurement of the body from each ankle joint in a planter flexed position by making a horizontal incision over anterior aspect of ankle joint midway between the two malleoli and exposing the superior surface of talus. Then, soft tissues were dissected from medial and lateral side of talus freeing the bone of all its attachments. The separated bones from each foot were kept in two separate jars each containing plain tap water and the jars were labelled with the case id number, sex and the side of the foot. No chemicals were used to clean the bones to avoid any erosion of the bone. The bones were examined intermittently and once the soft tissue got separated, the bones were cleaned and dried at room temperature. All the bones were kept separately in duly numbered packets for further analysis. The dried bones were weighed using a digital weighing machine having an air tight chamber. Each bone was put over the weighing machine turn by turn and weighed to a precision of 0.01 gm. Three readings were taken with the electronic weighing machine at different times and the average was recorded. SPSS version 20 was used for analysis of results. Using the data obtained, a Kolmogórov–Smirnov test was performed to study the distribution of the sample and then a paired t test was performed to verify whether there were statistically significant differences between the right and left side. Descriptive statistics was used to calculate independent t test to verify whether statistically significant differences exist between two means and then further testing was done using discriminant analysis, logistic regression analysis and determination of identification, demarcating and limiting point. P-value of less than 0.05 was considered significant.

Identification Point for male talus was the maximum weight recorded for the female talus, while Identification Point for female talus was the minimum weight recorded for the male talus. All bones having weight more than the Identification Point for male were correctly identified as males and all bones having weight less than the Identification Point for female were correctly identified as females.[2-4] Demarcating Point was calculated by using mean ±3SD. Maximum weight recorded for the female talus by using calculated range was the Demarcating Point for male talus and the minimum weight recorded for the male talus by using the calculated range was the Demarcating Point for female talus. All bones having weight more than the Demarcating Point for male were correctly identified as males and all bones having weight less than the Demarcating Point for female were correctly identified as females.[2-7] Limiting point was chosen in the study, calculated from the average of male and female identification points.[6,7] Talus bone weighing greater than the limiting point was categorised as male and value less than that was grouped into female category.

Results

The purpose of the current study was to demonstrate that the talus bone showed significant sexual dimorphism and to explore and assess the degree of sexual dimorphism in weight of the bone to accurately estimate sex. The results of this study produced coefficients from a sample of talus bones recovered from North Indian males and females in medico-legal autopsy cases. Firstly, on applying normality test, the hypothesis that the sample did not follow a normal distribution was not rejected because of the results obtained on the Kolmogórov–Smirnov test ($p<0.05$). So, both the variables i.e., weight of talus on both sides were not normally distributed. On application of paired t-test on both the variables, no significant weight difference on both sides was found ($p>0.05$).

Table 1: Descriptive statistics for weight of talus

Talus weight	Sex	Mean	SD	Range	Mean ± 3SD
Right	Male	27.18	4.534	18 – 35	13.58 – 40.78
	Female	18.28	2.899	11 – 25	9.58 – 26.98
Left	Male	27.1	4.564	18 – 35	13.41 – 40.79
	Female	18.28	2.878	11 – 25	9.65 – 26.91

SD = standard deviation

Table 2: Linear discriminant analyses for weight of talus

Statistical tests		Right talus	Left talus
Canonical Discriminant Function Coefficients Unstandardised	Coefficients	0.263	0.262
	Constant	-5.972	-5.947
Univariate Discriminant Analysis classification result summary	Male (%)	84	84
	Female (%)	94	94
	Overall accuracy (%)	89	89

Wilk's lambda for WRT (0.418 and WLT (0.423); Canonical correlation for both sides = 0.76, and Sectioning Point being – 0.585

Table 3: Logistic Regression classification result summary

	Right talus	Left talus
Male (%)	84	90
Female (%)	94	88
Overall accuracy (%)	89	89

Table 4: Regression models derived in the present study

Variables	R	R^2	SEE	P-value
WRT	0.763	0.582	0.326	<0.001
Regression Equation	Y= 2.988-0.065(x)			
WLT	0.760	0.577	0.329	<0.001
Regression Equation	Y= 2.984-0.065(x)			

WRT = weight of right talus; WLT = weight of left talus; SEE = Standard Error of Estimate

Table 5: Correct classification percentage of talus weight using Identification Points, Demarcating Points and Limiting Points

Sex	WRT	WLT	WRT	WLT	WRT	WLT
	IP (Correct classification %)	IP (Correct classification %)	DP (Correct classification %)	DP (Correct classification %)	LP (Correct classification %)	LP (Correct classification %)
Male	25(66)	25(66)	26.98 (48)	26.91 (46)	21.5 (92)	21.5 (90)
Female	18(56)	18(54)	13.58 (2)	13.41 (2)	21.5 (88)	21.5 (88)

WRT = weight of right talus; WLT = weight of left talus; IP = identification point; DP = demarcating point; LP = limiting point

Table 6: Comparison of data of present study with previous studies

Population		n	Mean	SD	Range	Mean± SD	IP %	DP %
Singh et al.[14] in Varanasi Population	WRTM	60	24.06	4.90	15.10-36.80	9.36-38.76	77	28
	WRTF	24	15.66	3.70	6.00-20.50	4.56-26.76	46	4
	WLTM	56	23.09	4.94	15.20-34.60	8.27-37.91	71	32
	WLTF	24	15.03	3.49	6.00-20.00	4.56-25.50	42	8
Ahmad et al.[15] in Pakistani Population	WRTM	52	29.23	3.68	22.40-34.20	18.18-40.28	85.7	85.7
	WRTF	24	22.25	0.68	20.99-23.50	20.49-24.61	61	0
	WLTM	54	28.76	4.45	22.20-36.98	15.41-22.11	85.7	71.4
	WLTF	30	22.15	0.71	20.49-23.11	20.02-24.28	50	0
Patel et al.[16] in Gujrati Population	WRTM	57	20.53	4.00	10.74-28.26	8.53-32.53	3.51	0
	WRTF	44	15.53	4.42	7.26-27.51	2.26-28.79	15.91	2.27
	WLTM	70	20.42	3.98	10.91-31.60	8.49-32.35	8.57	2.86
	WLTF	50	14.76	4.23	6.46-26.33	2.05-27.43	18	6
Present population	WRTM	25	27.18	4.53	18-35	13.58-40.78	66	48
	WRTF	25	18.28	2.89	11-25	9.58-26.98	56	2
	WLTM	25	27.10	4.56	18.35	13.41-40.79	66	46
	WLTF	25	18.28	2.78	11.25	9.65-26.91	54	2

WRTM = weight of right talus in males; WLTM = weight of left talus in females; IP = identification point; DP = demarcating point

The result of the descriptive test, univariate discriminant analysis and logistic regression analysis is shown in Table 1, Table 2 and Table 3 respectively. The mean value of male talus bones on both sides was statistically more than females and there was an overlapping zone in which both values from males and females found (Table 1). In univariate analysis, each of the significant measurements was individually subjected to discriminant analysis to test its efficiency in sex estimation (Table 2).[10] The results from the univariate analysis that were greater than the sectioning point were considered male individuals, and results that were less than the sectioning point were considered female individuals, while the results that were equal to the sectioning point were classified as indeterminate.[6] The logistic regression analysis also showed almost similar classification result as that of univariate discriminant analysis i.e. overall classification accuracy of 89% in both the variables (Table 3).

In Table 4, a correlation analysis was performed to verify how the variables relate to sex; if they were significantly related or are more highly related, since it was indicative of its predictive value, providing information on which variables will offer better results in the discriminant analysis. Both the variables showed almost similar coefficient correlations of 0.76 i.e., high positive significant correlations with sex of individual (p-value<0.001).

Table 5 shows the accuracy percentages of sex estimation from the identification, demarcating and limiting points of talus weight of both sides. Almost similar results were achieved by both the variables. Limiting point showed maximum sex classification accuracy whereas the Demarcating point the least. Table 6 compares the results of the present study against previous studies.

Discussion

The talus bone in the postcranial skeleton was selected to verify the discriminant power of the weight of bone in sex differentiation. The most sexually dimorphic bones i.e., pelvis and skull were not always available whenever bone remains are recovered, though their morphological study makes it possible to determine sex with a high rate of reliability. Different approaches and new studies on other bones in the postcranial skeleton are necessary to verify the percentage of accurate classification which can be achieved on the basis of the study variables, taking into account both the bone in its entirety and in parts, because bones are not always recovered in the best state of preservation.[11] For a variable to be dimorphic, and therefore a good discriminator of sex, not only should the average value for each sex be different, but also the distribution of measurements should overlap as little as possible.[12]

Mean weight of both sides for each talus was found to be significantly larger in males than in females ($p < 0.001$), suggesting that all of these measurements have potential as sex indicators (Table 1). The significant differences between male and female 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.[8-10,13] Weight of talus was also used as a parameter for sexual dimorphism by Singh et al.[14], Ahmad et al.[15] and Patel et al.[16]. Findings of present study are tabulated, compared and discussed with findings of these researchers (Table 6).

The male tali are heavier than the female tali, for both right as well as left side, in all the population and studies compared to present one (Table 6). Also, the mean weight of right talus is marginally higher than the left talus, for males as well as females. However, mean weight of talus of Gujarati population[16], for both right as well as left side, is less as compared to weight of talus of Varanasi[14], Pakistani[15] and present population. The percentage of tali classified by identification point in this study is less than the study conducted by Singh et al.[14] and Ahmad et al.[15] but more than Gujarati population (Table 6). Moreover, the percentage of tali classified correctly by demarcating point is less than Pakistani population but more than other two studies conducted in India. The percentage of female tali classified by demarcating point is comparatively far less than that of male and this observation is same in other studies also. Other three studies did not classify their results by using limiting point, which proved to be most successful in discriminating sex in talus bone in the current study.

This preliminary study is perhaps the first work done on ascertaining the sexual dimorphism of weight of talus by using discriminant and logistic regression as tool for analysis. The most common used means for sex discrimination in unidentified skeletal remains is Discriminant function analysis. But, as discriminant function equations are population specific, [8,9,11-19] the equations derived in the present study can be used for determination of sex from the talus weight available specifically from the study population. By applying univariate discriminant analysis, the overall sex classification result came out to quite similar for both the variables i.e., right and left tali as 89% with similar male and female accuracy rates (Table 2). There was no use of application of multivariate discriminant analysis in this study as the variables used were very few and also showed same results in all the different methods.

Various simulations have shown that the difference in results between logistic regression and discriminant analysis is negligible when sample sizes are over 50,[17] as is the case in the present study, and therefore the results of this study should still be comparable to those produced by others using discriminant analysis. Logistic regression also has the advantage of relatively simple calculation of the probability of belonging to one sex or the other. Logistic regression equations that include two or more measurements for an individual bone improve the allocation accuracy about half the time in the reduced sample, when compared to the best single measure from the same bone.[18] The overall classification result by logistic regression analysis is almost similar to the classification result of discriminant analysis i.e., 89%.

The fact that no statistical difference was found in both the variables after applying paired t-test, implies that both left and right side of talus weight can be used individually if any of the sides is not available for sex differentiation in routine forensic practice. This proposition was further strengthened in different statistical analytical results conducted by authors in which all the classification results showed almost similar results for both the variables. Our finding is in concordance with the observations concluded by Islam et al.[19] and Mediavilla et al.[11]

Conclusion

The mean value of the male talus bone for the weight parameter was more when compared to the value of female bone bilaterally. The identification and demarcating points were of limited use in sex determination whereas limiting point showed significant classification accuracy. The accuracy percentage of correct sex estimation in univariate discriminant function analyses was 89% and it was similar as compared to logistic regression analysis. The statistical analysis of weights of talus bilaterally showed similar results, which is in agreement with the results of other bones of hands and feet and thus, any side of talus, could be used independently for sex determination if the other is not available. Also, for estimating sex in any bone, single parameter may not be sufficient to decide the sex of the bone and it becomes crucial to include other parameters before deciding the sex from an unknown talus bone.

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