SEX ESTIMATION FROM TRANSVERSE BREADTH OF TALUS BONE IN EGYPTIAN POPULATION

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ABSTRACT

Sex determination is the starting point in forensic anthropology (identification of an individual from skeletal remains) as it reduces the number of possible matches of unknown persons by 50%. The talus bone has an important role in human sex identification due to its durability as it is usually recovered in an intact state and it is readily distinguished from its characteristic morphology during the recovery of human skeletons. The aim of this study was to investigate the sex-discriminating potential of the Transverse Breadth (TB) of the talus in a sample of Egyptian Population.

Subjects and methods: This study was done using 320 computed tomography (CT) images of ankle joints (160 males and 160 females) obtained from Radiology Department, Menoufia University Hospital. Measurements were done in mid coronal sections. Sex dimorphism was evaluated using student t- test, demarking points (DPs), index of sexual dimorphism (ISD) and logistic regression analysis.

Results:- The Transverse Breadth of right and left talus in males were statistically significantly higher than those in females. ISD confirm sexual dimorphism with higher DPs in males than those of females. Sensitivity was 76.9%, specificity was 75.6 % and accuracy rate was 76.9%.

Conclusion:- It can be concluded that the transverse breadth of talus bone of this sample of Egyptian population is an important parameter for sex determination and CT is an accurate and reliable method for sex determination from talus bones.

Recommendations:- Further similar studies estimating the role of talus bones in sex differentiation from different regions of Egypt are required. Application of the equation derived from the present study for sex determination on Egyptian population is recommended.

KEY WORDS: Talus, Sex**,** Estimation, Egyptian, population

INTRODUCTION

Sex determination is the starting point in forensic anthropology (identification of an individual from skeletal remains) as it reduces the number of possible matches of unknown persons by 50%. **(DiGangi and Moore 2013; Singh and Chavali 2011).**

Generally, there are two methods for sex determination, either by visual observation of specific features of bone (morphologic method) or by measurements of certain parameters that has sexual dimorphism (metrical method). The morphologic method is quicker but need that the observer to have enough experience. On the other hand, the metrical method is more preferred due to its objectivity and repeatability **(Akhlagi et al., 2010, Bidmos and Asala 2003).**

The pelvis and skull bones are considered as the most accurate bones

for sex determination (**İşcan 2005)**. But these common bones that are traditionally used for determination of sex may be discovered in a fragmented state due to burial conditions, it has become necessary to develop new methods for sex estimation that rely on more denser bones that are commonly recovered in an intact state, like talus, calcaneus and patella **(Marlow and Pastor 2011).**

Talus is a composite, intra articular bone, has a unique structure designed to bear body weight with no muscular or tendinous attachments and is held in place by multiple ligaments and bony structures **(Mark 2005).** These factors make it more resistant to taphonomic factors (factors affecting decomposition and preservation), so increasing the chance of its preservation and field recovery **(Abd-elaleem et al., 2012).**

High-resolution Computed Tomography (CT) has more advantages over plain radiography in ankle measurements as it permits 3 dimensions (3D) evaluation of bone morphometry **(Hayes et al., 2006).** So CT technique for talus measurement was chosen.

The aim of this study was to investigate the sex -discriminating potential of the Transverse Breadth of the talus and obtain function equation for sex differentiation in a sample of Egyptian Population.

SUBJECTS and METHODS

This is a cross sectional study done on 320 computed tomography (CT) images of the ankle joint obtained from Radiology Department, Menoufia University Hospital for 160 male and 160 female patient aged from 20 to 70 years. Each sex sample was grouped into two equal separate subgroups (right and left talus).

The CT examination was done with a multi-detector scanner (Toshiba ,japan,16 detector) and the parameters for image acquisition were: collimation 0.5 mm, slice thickness 0.5 mm with a reconstruction overlap of 0.2 mm, mA 75 and kV 130.

Measurements were done in mid coronal sections. Two lines were drawn in longitudinal plan from both malleoli and parallel to each other and to the sagittal plane and the distance in centimeters between the two lines was measured (transverse breadth of the talus) (Fig 1). Only normal radiographs without any congenital or traumatic bone injury were included in this study.

Approval from the ethical committee at Menoufia university was obtained for this study and patients consents were not necessary.

Statistical analysis of the data

Data were analyzed using computerized IBM SPSS software package version 20.0. (**Kirkpatrick LA. and Feeney BC. 2013**). The Kolmogorov-Smirnov test was used to verify the normality of distribution. Quantitative data were described using mean, standard deviation(SD). Significance of results was judged at the 5% level.

Values for ISD were obtained from the formula (**Marin et al., 2006**):

$$ISD = \frac{\text{Male Mean}}{\text{Female Mean}} \times 100\%$$

Values for Calculated Range(CR) and Demarking point (DP) were obtained using the formula = mean ± 3 x Standard Deviation

The used tests were

1 - Student t-test:- which is used to compare between two quantitative variables.

2 - Receiver operating characteristic curve (ROC)

It is obtained by plotting specificity (FP) on X axis versus sensitivity (TP) on Y axis at different cut off values.

Diagnostic performance of the test is represented by the area under the ROC curve. Area higher than 50% gives acceptable performance while area about 100% is considered as the best result for the test.

3 - Sensitivity

The ability of the test to correctly identify the targeted case in a sample "TRUE POSITIVES". The higher the sensitivity, the lower the number of unidentified case "false negatives"

4 - Specificity

It is the ability of the test to correctly exclude individuals who are free of the detected parameter "TRUE NEGATIVES". The higher the specificity, the lower "false positives" will be detected.

5 - Positive Predictive value (PPV)

The probability of the detected parameter being present among those with positive test results.

6 – Negative Predictive value (NPV)

The probability that the detected parameter was absent among those with negative test results.

7 – Accuracy

Rate of Agreement = (True positives + True negatives) / Total tested x 100

8 – Regression :- To determine sex equation.

Figure 1: CT ankle bone window with mid coronal measurement of TB of right talus bone about 3.64 cm.

RESULTS

Table (1): Statistical significance of transverse breadth of talus bone in both sexes

	Male (n =160)		Female (n =160)	
	Mean SD(cm)±	**95% CL (cm)**	**Mean SD(cm)±**	**95% CL (cm)**
Transverse breadth of right talus	4.61 ± 0.45	4.51 - 4.71	4.19*** ± 0.30	4.12 – 4.25
Transverse breadth of left talus	4.50 ± 0.30	4.43 – 4.56	4.11*** ± 0.31	4.04 – 4.18

CM=Centimeter CL=Confidence Limit SD=Standard Deviation
***p= 0.001

Table (2): Statistical significance for transverse breadth between right and left talus in each sex

Gender	Right (n =160)		Left (n =160)	
	±Mean SD (cm)	**95% CL (cm)**	**±Mean SD (cm)**	**95% CL (cm)**
TB of males	4.61 ± 0.45	4.51 - 4.71	4.50NS ± 0.30	4.43 – 4.56
TB of females	4.19 ± 0.30	4.12 – 4.25	4.11NS ± 0.31	4.04 – 4.18

SD=Standard Deviation CL=Confidence Limit CM=Centimeter NS= Not Significant

Table (3): The DP and ISD for TB of the right and left talus in both sexes

	Male (n=160)			Female (n=160)			ISD
	±Mean SD(cm)	**CR(cm)**	**D.P(cm)**	**±Mean SD(cm)**	**CR(cm)**	**D.P(cm)**	
Right talus	4.61 ± 0.45	3.26-5.96	>5.09	4.19 ± 0.30	3.29-5.09	<3.26	110.0
Left talus	4.50 ± 0.30	3.60-5.40	>5.04	4.11 ± 0.31	3.18-5.04	<3.60	109.5

SD=Standard Deviation

ISD=Index of Sexual Dimorphism DP=Demarking Point

CM=Centimeter CR=Calculated Range

Table (4): Sex equation with logistic regression

	Constant	B	Sig.	OR	95% CI	
					LL	UL
TB of talus	-17.919	4.123	<0.001*	61.716	24.35	156.36

B: Unstandardized Coefficients OR: Odds ratio

CI: Confidence interval LL: Lower limit

UL: Upper Limit *: Statistically significant at $p \leq 0.05$

Sex equation = -17.919 + measured x 4.123

Table (5): ROC analysis results

	Youden index	Cutoff point	Sensitivity	Specificity	P .value	NPV	PPV	Accuracy	AUC
TB of talus	0.537	-0.025	76.9	75.6	<0.001*	76.6	75.9	76.9	76.3

AUC: Area Under a Curve p value: Probability value

NPV: Negative predictive value PPV: Positive predictive value

*: Statistically significant at $p \leq 0.05$

If value > cutoff point = male

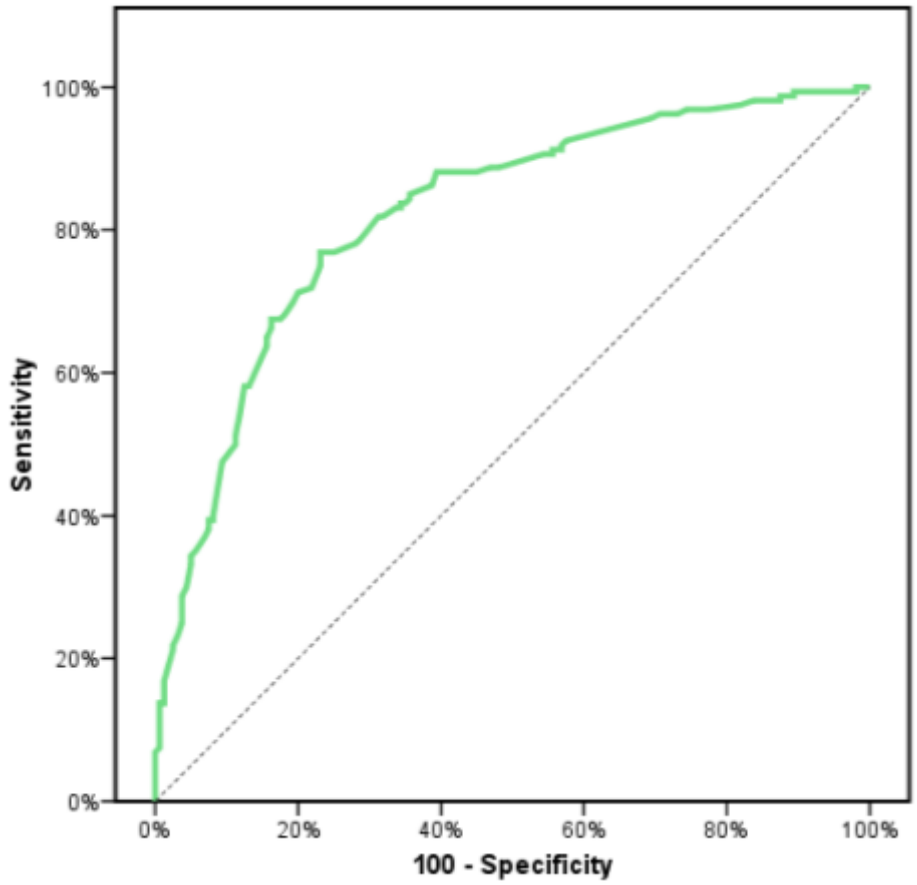

Figure (2): ROC curve

Statistical significance of transverse breadth of talus bone in both sexes:-

The Transverse Breadth of right and left talus in both sexes was compared. It was showed that the mean TB was higher in males on both sides (4.61 cm and 4.50 cm on right and left sides respectively) than those in females (4.19 cm and 4.11 cm on right and left sides respectively)and the difference was statistically highly significant (p value =0.001) **(Table 1).**

Statistical significance for transverse breadth between right and left talus in each sex:-

Analyzing transverse breadth of right and left talus in males, It was found that the TB measured of the talus bones was slightly greater on the right side (4.61) than on the left one (4.50), but the difference was found to be statistically insignificant (P value >0.05)**(Table 2).**

Analyzing transverse breadth of right and left talus in females, It was found that the TB measured of the talus bones was slightly greater on the right side (4.19) than on the left one (4.11), but the difference was found to be statistically insignificant (P value >0.05)**(Table 2).**

The Demarking points and Index of sexual dimorphism for TB of the right and left talus in both sexes:-

ISD was 110 and 109.5 on right and left sides respectively.

with higher DP in males (> 5.09 and > 5.04 on right and left sides respectively) than those of the females (< 3.26 and < 3.6 on right and left sides respectively**) (Table 3).**

Sex equation formula was generated from the results using logistic regression analysis for sex differentiation from the TBs of talus bones in Egyptian population **(Table 4).** The Equation is: -17.919 + measured x 4.123.

Receiver operating characteristic curve (ROC) analysis was used to estimate the maximum value for sex determination. The optimum cut-off point was determined from sensitivity and specificity values. with cutoff point -0.025 (If value > cutoff point = male).

The sensitivity and specificity of TBs of talus measurement was used for sex determination. Sensitivity was 76.9%, specificity was 75.6 % and accuracy rate about 76.9% **(Table 5 and fig2).**

DISCUSSION

Sex determination is an early important step in skeletal remains analysis as it makes the further analysis more sex specific. Architectural differences and size of bones between both sexes can be used to differentiate them **(Agnihotri and Kaur 2016).**

The talus bone is the second largest tarsal bones that has an important role in human sex identification due to its durability as it is usually recovered in an intact state and it is readily distinguished from its characteristic morphology during the recovery of human skeletons **(Javia et al., 2013)**.

The present study showed that the mean TB of right and left talus bones was greater in males than in females and the differences were statistically highly significant (p value = 0.001). These results were in consistence with those noted by **Lee et al., 2012** (Koreans), **Gualdi-Russo 2007** (northern italians), **Murphy 2002** (New zealand).

In the present study, Index of sexual dimorphism (ISD) confirm the significant difference of the TB of the talus between males and females as it was greater than 100 in both right and left sides. DPs showed a similar trend which confirm presence of sexual dimorphism with higher demarking points in males than those of the females. This was in agreement with that observed by **Otong et al., 2016** (Nigerians).

Sex Identification of the individual can be estimated with 100% accuracy by the use of demarking point. The value of DP may differ significantly in bones from different zones even within the same population, so it should be calculated separately for each region of population**.(Singh and Gangrade 1968).**

Generally, sex difference can be as a result of genetic, environmental and developmental factors affecting growth of bones (nutrition, physical activities, hormones like growth hormones, estrogens for females and testosterone for male), or the interaction of these factors **(Kafa et al., 2009).** On the other hand male skeleton is usually longer and more robust than the average female one, although the difference magnitude varies from population to population. Occupationally, males are usually more involved in hard jobs like manual work than females. These make bones of males to develop and become more larger and remain as that for a long time than those of females. Beside degenerative changes which are observed in bones in females as a result of earlier decrease in steroid

hormones at age of menopause that usually occur at age of 50 years **(Zaki et al., 2015; Giles and Elliot (1963).** This is supported by previous studies on athletes which noted that bone tissues responds to increased mechanical loads by increasing bone mass **(Karlsson and Rosengren 2012; Bass et al., 2002).**

Suspected sexual dimorphism of talus bone is strengthened by the fact that it is a weight-bearing bone and during locomotion both sexes will show at least some sexual dimorphism in bone parameters due to different types of activities in both sexes **(Barret et al., 2001).**

Experimental studies noticed localized skeletal adaptation to mechanical loading changes. As these mechanical loadings affected bone shape and size. **(Lanyon and Skerry 2001).**

The current study showed that measured TB for the talus was slightly greater on the right side than on the left one in both sexes, but the differences were found to be statistically insignificant (P value >0.05). These findings were in consistence with other studies that confirm non significant side differences of talar parameters as **Agnihotri and Kaur 2016** in north Indians, **Otong et al., 2016** (Nigerians), and **Koshy et al 2002** in south Indians.

While **Ari and Kafa 2009** (Turkey) noted a significant side differences in two parameters (the length and breadth of sulcus tali) of talus bones ($p<0.01$).

The slight increase in the transverse breadth of talus bone on the right than the left side may be due to increased physical activities of the right side in relation to the left one (**Harma and Karakaş 2007**).

Singh and Mohanty 2005 stated that the overall incidence of bones parameters were increased on right lower limb bones than those of the left one. This can be explained by the fact that dominant hemisphere leads to dominance of the extremities on the contra lateral side and majority of the population are with dominant left cerebral hemisphere.

Gautham et al., 2013 explained the reason for that non significant side variations of transverse breadth of talus bones to be returned to differences in gait or may be influenced by habit.

In the current study the degree of accuracy for sex determination from TB of talus bone was 76.9%. This means that TB of talus is a useful parameter for sex determination in Egyptians. This was in accordance with the study done by **Abd-elaleem et al., (2012**), on another sample of Egyptian population (110 tali (67 male & 43 female) of skeletal remains in upper Egypt region). They concluded that the talus of Egyptian population is useful for sex determination and all measures of talus were statistically significant higher in males with 81.8% degrees of accuracy of talar width (transverse breadth).

Similar results that confirm role of TB of talus bone for sex determination in a different population detected by **Peckmann et al., (2015)** who detected 77.0- 88.9 % degrees of accuracy for Greek population using transverse breadth of talus bone.

Others as **Bidmos et al., 2003** detected 80–88% degrees of accuracy for South African whites and **Bidmos and Dayal 2004** detected 80–89% for South African Blacks but they use multiple measures of talus bone.

Obtained results from discriminant function analysis of different studies are population specific and cannot be applied to other population due to racial, geographical, environmental differences **(Wankhede et al., 2015).**

CONCLUSION

It can be concluded that the transverse breadth of talus bone of this sample of Egyptian population is important and reliable for sex determination and CT is an accurate and reliable method for sex determination from talus bone.

RECOMMENDATIONS

Further similar studies estimating the role of talus bones in sex differentiation from different regions of Egypt are required.

Application of the gender equation derived from the present study for sex determination on Egyptian population is recommended.

Further studies are required on the talus bone for estimating its role in stature determination.

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الملخص العربي

تحديد الجنس عن طريق قياس عرض عظمة الكاحل في الشعب المصري

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ألمقدمة: يعد تحديد الجنس نقطة البداية في علم الأنثروبولوجي الشرعي (علم تحديد الجنس من البقايا العظمية) لأنها تقلل الاحتمالات بنسبة 50%. وتلعب عظمة الكاحل دورا مهما في تحديد الجنس في الإنسان نتيجة صلابتها ومتانتها ولأنها تكتشف غالبا في صورة سليمة بالإضافة إلى سهولة تمييزها نتيجة شكلها المميز. ويهدف هذا البحث إلى دراسة دور عظمة الكاحل فى تحديد الجنس فى عينة من المواطنين المصريين.

مواد وطرق البحث :هذه دراسة مستعرضة تم إجراؤها على320 أشعة مقطعية علي الكاحل لمواطنين مصريين بالغين من محافظه المنوفية والذين حضروا للمستشفى الجامعى بالمحافظة حيث تم قياس عرض عظمة الكاحل الخاصة بهم. و قد تم استبعاد أي حالات لديها تشوهات أو إصابات في عظمه الكاحل.

النتائج: وقد أظهرت النتائج وجود فروق ذات دلالة إحصائية بين الذكور والإناث على الجانبين الأيمن والأيسر. كما انه تبين أن قياس عرض عظمة الكاحل من القياسات المهمة في تحديد الجنس حيث بلغت درجه حساسيتها 76,9% و نوعيتها حوالي**75,6**% ومعدل دقة **76,9**%.

الملخص: يمكن استخدام قياس عرض عظمه الكاحل عن طريق الأشعة المقطعية في تحديد الجنس.

التوصيات: ضرورة وجود دراسات أخرى باستخدام الأشعة المقطعية لتحديد الجنس من خلال عظمة الكاحل في محافظات أخري في مصر .كما يوصي باستخدام معادله قياسات عظمه الكاحل الناتجة عن الدراسة في تحديد الجنس.