Original article

Adult Sex Discrimination from Scapula in a Sample of Sohag Governorate Population Using Multi Detector Computed Tomography

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ABSTRACT

Introduction: Identifying individuals is one of forensic science's most difficult aspects. Accurate sex determination based on dimorphic dimension measurements in unidentified human remains is a critical first challenge towards identification of individual. **Aim**: to look into scapula sexual dimorphism. **Objectives**: to generate metric measurements for sex assessment in a Sohag community sample utilizing scapular metrics as maximum scapular length (MSL), maximum scapular breadth (MSB) and maximum length of spine (MLS) obtained from 3D CT images, aiming to meet the current demand for successful identification from skeletonized remains in forensic instances. **Subjects and methods**: the current study included 100 individuals (50 male and 50 female) who underwent thoracic CT (computerized tomography) scan examination as part of a pulmonary screening program. Images of each patient were analyzed and three parameters for both scapulae were measured. **Results**: The mean values increased by a statistically significant amount of the right and left MSL, MSB, and MLS in males in comparison to females. **Conclusion:** Among indices measured in the right and left scapulae, RT and LT MSL had the highest diagnostic accuracy while RT and LT MLS had the lowest accuracy in sexual dimorphism. Using CT scan, MSL, MSB and MLS were significant parameters in sex differentiation, Maximum scapular length in right and left scapulae was the most important parameter.

Keywords: Scapula, CT, Sex, Spine.

I. INTRODUCTION

The scapula connects the humerus to the clavicle and is also known as the shoulder blade. The rear of the shoulder girdle is formed by the scapula. It has a powerful triangular shape and a flat surface (Shrestha et al.,2022). It's a place of muscle attachment that's located on the posterolateral side of the thorax, overlaying ribs two through seven

(Baker& Al Janabi, 2022). Acromion process is a posterolateral extension of the scapular spine and a posterior shoulder landmark superior to the glenoid. It attaches to the clavicle and gives origin to the deltoid and trapezius muscles (kadi et al.,2017). The spine of scapula (SS) is a bone plate that offers support to the scapula. It emerges from the vertical (scapular) plane of the fossa and joins the scapular neck (Wang et al., 2015).

The assessment of sex is a critical first challenge in obtaining an accurate biological profile when assessing skeletal remains. Because there are obvious distinctions in ageing and growth differences among both sexes as well as morphological changes associated with ancestry, correct sex estimation is crucial in predicting age, ancestry, and stature **(**Krishan et al., 2016). The commonest sex estimation methods are either morphologic (non-metric) or metric in nature. Visual evaluation of sexually dimorphic traits is used in morphological approaches (Rúben Maranho et al.2022). Many physical features of sex evaluation can only be evaluated, such as glabellar prominence, pubic bone shape and mandibular ramus flexure. These traits are difficult to be quantified, have inter and intra-observer errors, difficult to be categorized and have analytical concerns (Garg and Goyal. 2021). These findings emphasize the fact that use of visual scoring systems has objective and reproducible limitations (Walrath et al., 2004). Because anatomical landmarks are easy to be established, skeletal measures used from CT scan images might be standardized. As a result of the ability to build 3D images of bones from multidetector computed tomography (MDCT), forensic scientists can gather existing statistics pertaining to a given demographic and develop standards for estimating of biological profiles in the skeleton regarding sex (Torimitsu et al., 2015).

Although these procedures are relatively expensive to be utilized, the findings in sex determination are encouraging. Past studies had revealed that using CT images rather than traditional approaches for developing a biological profile had improved accuracy and reproducibility (franklin et al., 2013). Furthermore, Ali et al. (2018) analyzed dry bone and CT scans and reported that CT scanning is a dependable technology that may be used for identification of humans especially in mass disasters. Because dry bone specimens are unavailable in many populations, the use of a CT scan as an alternative for sex estimate is incredibly beneficial and trustworthy. Despite the fact that several published studies show evidence of sexual dimorphism in the scapula, the validity of the scapula for sex estimate has not been thoroughly investigated in current populations, because there is a general absence of contemporary Osteometric databases (Papaioannou et al.,2012). In this work, the aim of this study is to determine the efficacy of scapula as a sex indication for forensic purposes.

II. SUBJECTS AND METHODS

II.1 Subjects: The current research was carried out on 100 patients (50 males and 50 females), who had a chest CT scan assessment during program of pulmonary screening for various reasons in the department of radiodiagnosis and imaging at Sohag university hospital. their ages were between 25 and 80 years.

II.2 Exclusion criteria:

Those having a history of fractures of vertebra or scapula, growth problems, severe osteoporosis, dysplasia, tumors, or arthritis, history of orthopedic surgery, other anomalies affecting the scapula's form and growth were excluded from the study.

11.3 Apparatus: - All participants were subjected to Siemens SOMATOM CT scanner spirit (Siemens Germany Ltd.), after taking written informed consent and describing the study's objectives to examine the following measurements: maximum scapular length, maximum scapular breadth, and maximum length of the spine.

II.4 Methods: The thorax was CT-scanned using the conventional approach on an MDCT Brilliance 64 slice Phillips. Patients undergoing thoracic CT were positioned supine on the CT couch, supporting the upper limbs next to the head, with a breath-hold on the inspiration and Anatomical scannogram obtained in the Posterior-Anterior (PA) position. Scanning protocol was performed with the following securing parameters: 120 kV tube voltage, 150 effective mA, 1 mm slice thickness, 5 mm slice increment, 1.0 s rotation time and scan direction from head to feet parameters. The filter used was hard. These settings are technically approved for Thoracic CT scans on a regular basis and give adequate 3D reconstruction image quality as well as morphometric measurements. The patients were appropriately taught how to eliminate motion artefacts. On a General Electric (GE) workstation image data were processed to yield orthogonal multiplanar reconstruction images and volume-rendered views. Once the imaging was complete, a single radiologist examined the CT scans for three specific measures on both scapulae **(Figure 1)** according to El Morsi et al 2017:

Maximum scapular length (MSL): The distance between the superior angle's highest point and the inferior angle's lowest point.

Maximum scapular breadth (MSB): The distance between the middle of the glenoid fossa's dorsal border and the vertebral border, where the spinal axis ends.

Maximum length of the spine (MLS): distance from the scapular spine's most lateral point to the scapula's medial margin at the spinous axis.

To increase measurement reproducibility, 3D reconstructed bones were obtained, enabling the alignment of virtual bones and the parameter's maximum length to be determined was in the screen's frontal plane.

II.5 Statistical analysis: -

All statistical evaluates were carried out on an individual computer with SPSS version

26.0 and Excel software (Microsoft Office 2019, Redmond, WA, USA). Quantitative data in tables and graphs were expressed as mean and standard deviation. The P value was computed as follows:-P value < 0.05 » regarded as significant.

-P value < 0.01 » regarded as moderately significant.

-P value <0.001 » regarded as highly significant.

In order to determine the best cutoff points for the examined measures in predicting male gender, a receiver operating curve (ROC) was developed. The area under the ROC curve value with a 95% confidence interval (CI) was then computed. It had been determined the ideal cut-off values, sensitivity, and specificity.

Wilks' lambda test was employed in the multivariate analysis of variance MANOVA to see if there were differences in the means of different groups of participants on a set of dependent variables. Wilks' lambda was also used to determine whether there are statistically significant variations between groupings of individual predictor variables. Wilks' lambda test scale spans from 0 to 1, with 0 indicating total discrimination and 1 indicating no prejudice. The smaller Wilks' lambda value, the better the outcome (Mohamed et al.,2020).

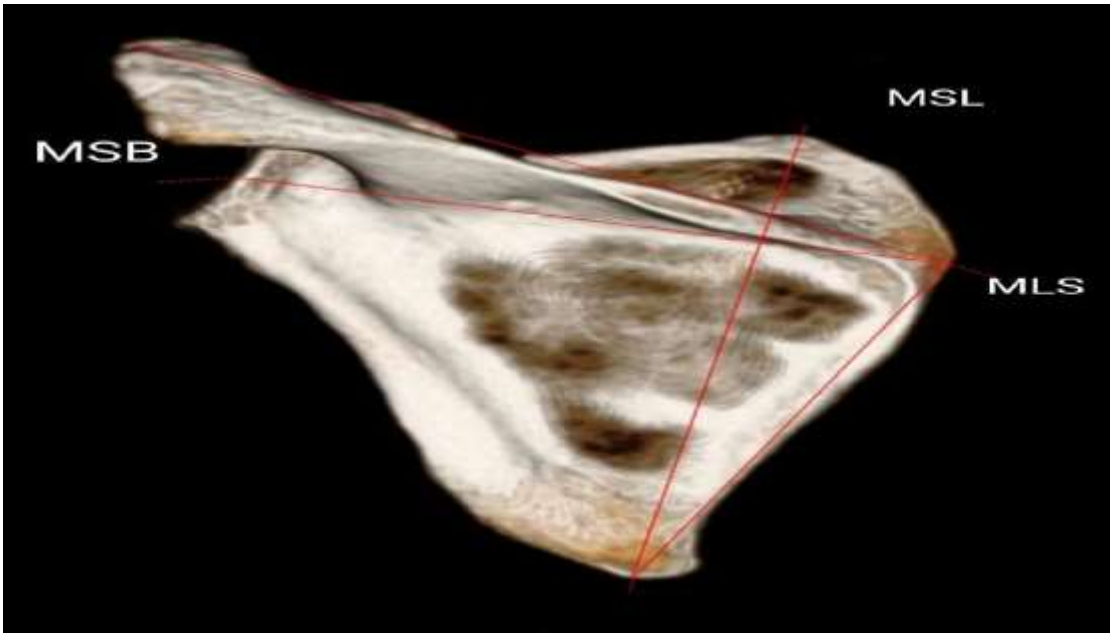

Figure 1: MSL, MSB, and MLS measurements on the posterior view of a 3-D picture of the left scapula (Er et al., 2020). MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine.

II. 6 Ethical consideration:

Prior to study the ethics committee for medical research of Sohag Faculty of Medicine approved the study under IBR registration number Soh-Med-21-07-15.

III. RESULTS

Regarding table (1), there was no statistically significant difference between the mean values of any of three measurements (MSL, MSB and MLS) between right and left scapulae in male subjects with p-value 0.395, 0.817 and 0.756 respectively. There was no statistically significant difference between the mean values of any of three measurements (MSL, MSB and MLS) between right and left scapulae in female subjects with p-value 0.622 ,0.713 and 0.220 respectively**.**

Concerning right scapula, there was marked statistically significant increase in the mean values of all of males' parameters MSL, MSB and MLS in comparison to females with P-value <0.001**.**

In left scapula, there was statistically significant increase in the mean values of all of mal**es'** parameters MSL, MSB and MLS in comparison to females with p- value <0.001 (table 2).

Regarding table (3), shows that RT MSL cut-off value of >138.2 for sex assessment was equating to 98% sensitivity and 66% specificity. Thus, values less than 138.2 suggested that the person was most likely female. Cut-off value for RT MSB of > 88.2 for sex assessment corresponds to 86% sensitivity and 62% specificity. Thus, values below 88.2 therefore strongly suggested that the person was most likely female.

Cut-off value for RT MLS of > 119.9 regarding sex assessment, corresponding to 80% sensitivity and 66% specificity. Thus, values fewer than 119.9 showed that the person was most likely female. Cut-off value for LT MSL of > 140.2 for sex assessment corresponds to 92% sensitivity and 86% specificity. Thus, values fewer than 140.2 suggested that the person was most likely female (Table 3).

Cut-off value for LT MSB of > 89.65 for sex assessment corresponds to 84% sensitivity and 66% specificity. Thus, values fewer than 89.65 suggested that the person was most likely female. Cut-off value for LT MLS of > 119 for sex assessment corresponds to 78% sensitivity and 60% specificity. Thus, values fewer than 119 suggested that the person was most likely female (Table 3).

In the right scapula, RT MSL exhibited the highest diagnostic accuracy (82%) and Wilks' lambda 0.492 among indices assessed, whereas RT MLS had the lowest accuracy (73%) and Wilks' lambda value of 0.766. In left scapula, LT MSL had the best diagnostic accuracy (89%) and Wilks' lambda 0.438, whereas LT MLS had the lowest diagnostic accuracy (69%) and Wilks' lambda 0.738. (Table 4).

Using the most consistent dimensions of both scapulae, the correct classification for males was 86%, 94% for females, and 90% for both. (Table 5).

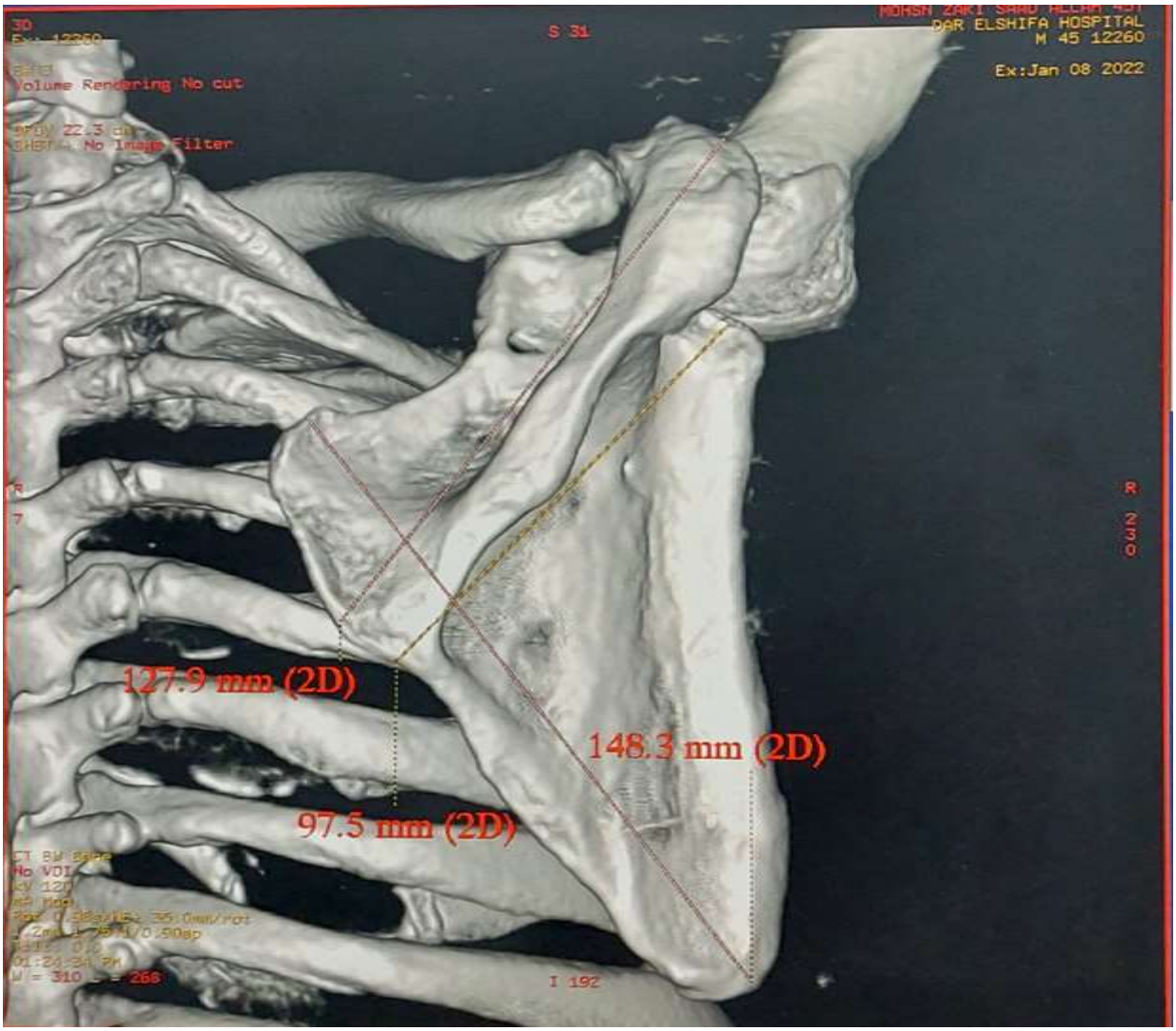

Fig. (2): CT scan showing MSL, MSB and MLS on the right side in one of the males. MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine.

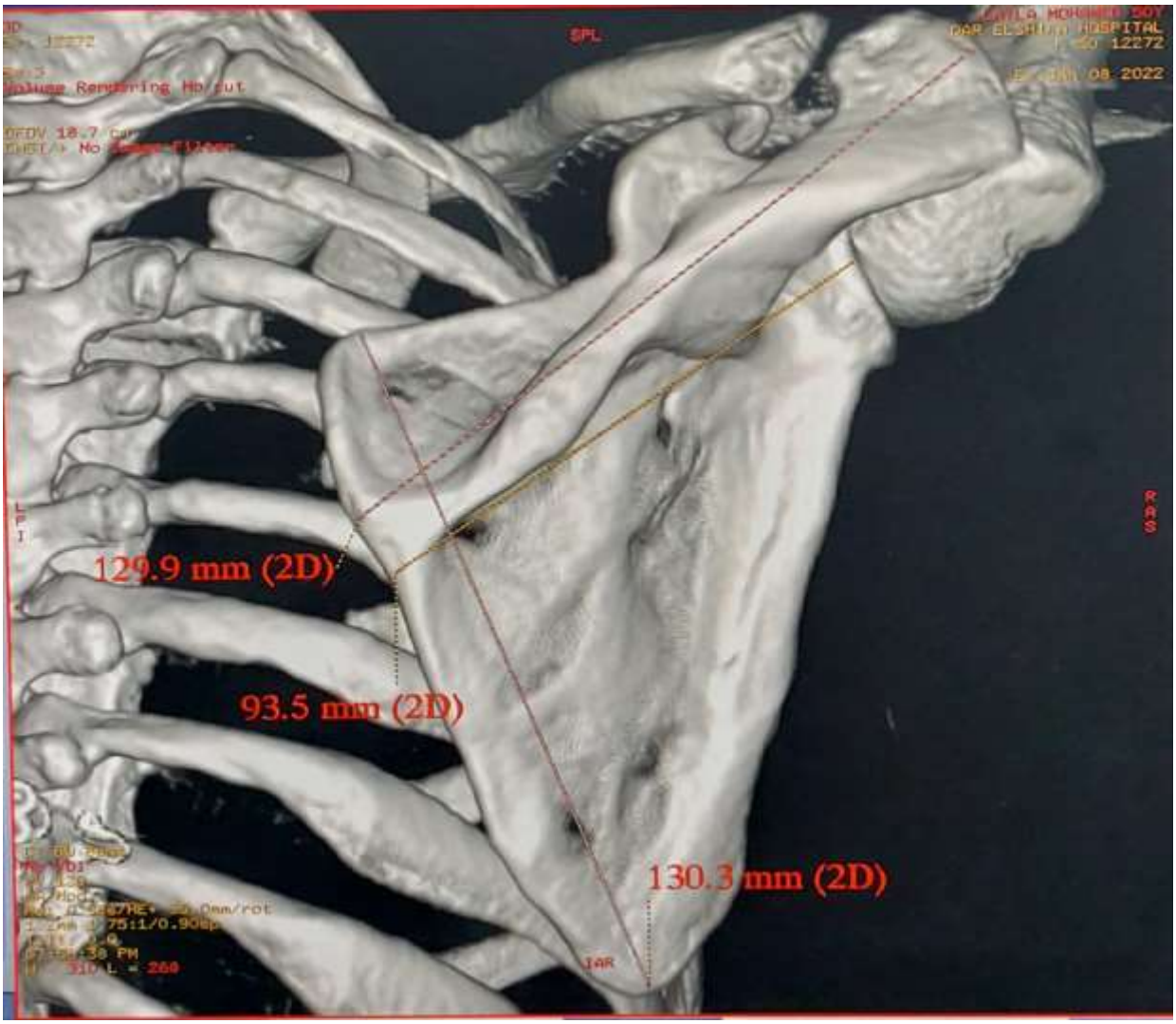

Figure 3: CT scan showing MSL, MSB and MLS on the right side in one of the females. MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine.

Table (1): The mean values and ±SD of MSL, MSB, and MLS on both right and left sides in males (N=50) & females (N=50).

	Right scapula Mean ± SD	Left scapula Mean ± SD	P-value by t test
Male			
MSL	154.86 ± 10.315	152.98 ± 9.609	0.395
MSB	97.16 ± 7.619	96.79 ± 8.22	0.817
MLS	127.77± 11.05	127.08 ±11.18	0.756
Female			
MSL	133.44± 10.73	132.53 ± 8.6	0.622
MSB	87.278± 6.76	86.79 ± 6.34	0.713
MLS	117.38 ± 7.628	115.398 ± 8.433	0.220

* Significant statistical difference at P< 0.05, ** high significant statistical difference at P <0.01 *** very high significant statistical difference at P < 0.001, SD=standard deviation MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine.

Table (2): The mean values ± SD of right and left maximum scapular length, maximum scapular breadth, and maximum length of spine in males and females (N=100).

	Males (n=50) mean± SD	Females (n=50) mean± SD	P value by t test
RT scapula			
MSL	154.68± 10.315	133.44 ± 10.73	< 0.001***
MSB	97.16 ± 7.619	87.278 ± 6.76	< 0.001***
MLS	127.77 ± 11.05	117.38 ± 7.628	< 0.001***
LT scapula			
MSL	152.982 ±9.609	132.534± 8.607	< 0.001***
MSB	96.794± 8.22	86.79 ± 6.34	< 0.001***
MLS	127.086 ± 11.18	115.398± 8.344	< 0.001***

*** P < 0.001 indicates a very high significant statistical difference, SD=standard deviation, MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine.

Table (3): Receiver operating Curve (ROC) analysis of the studied measurements of right and left maximum scapular length, maximum scapular breadth, and maximum length of spine of both males and females for optimum cut-off points predicting sex.

Measurement	Cutoff	AUC	95%CI	Sensitivity (%)	Specificity (%)	P-value
RT MSL	>138.2	0.926	0.877-0.975	98%	66%	< 0.001
RT MSB	>88.2	0.842	0.766-0.918	86%	62%	< 0.001
RT MLS	>119.9	0.783	0.687-0.879	80%	66%	< 0.001
LT MSL	>140.2	0.948	0.908-0.988	92%	86%	< 0.001
LT MSB	>89.65	0.837	0.758-0.916	84%	66%	< 0.001
LT MLS	>119	0.784	0.693-0.875	78%	60%	< 0.001

CI = confidence interval, AUC =area under the ROC curve, MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spine

Table (4): The degree to which scapular measurements on the right and left sides can be predicted for determining sex.

Parameter	Wilks' lambda	The correct predictive rate for males (%)	The correct predictive rate for females (%)	Overall accuracy (%)
RT MSL	0.492	98	66	82
RT MSB	0.676	86	62	74
RT MLS	0.766	80	66	73
LT MSL	0.438	92	86	89
LT MSB	0.679	84	66	75
LT MLS	0.738	78	60	69

MSL: maximum scapular length, MSB: maximum scapular breadth, MLS: maximum length of spin

Table (5): Multivariate logistic regression on both scapulae for correctly classified sex.

Observed	Original	Male predicted	Predicted Female	Corrected percentage
Male	50	43	7	86%
Female	50	3	47	94%
Overall percentage				90%

IV. DISCUSSION

Despite the fact that several published studies show evidence of sexual dimorphism in the scapula, the validity of the scapula for sex estimate has not been thoroughly investigated in Egyptian populations because there is a general absence of contemporary Osteometric databases. So the aim of the study was to investigate scapular sexual dimorphism and create metric standards for sex assessment in Sohag population sample utilizing scapular parameters such as maximum scapular length, maximum scapular breadth and maximum length of spine derived from 3D CT scans.

According to Stull et al. (2014) for anthropologists, CT scan is a viable alternative due to the distinction between the CT image and virtual bone is only 2mm which is seen as a near approximation. The use of CT scans for sex differentiation is extremely beneficial and dependable, especially since dry bone specimens are restricted in many cultures. CT was utilized to determine sex from distinct scapula features in Caucasians by Giurazza et al. (2013), Mexican by Hudson et al. (2016) Japanese by Torimitsu et al. (2016) and Turkish by Atamtürk et al. (2019).

In present research, there is no significant difference between two scapulae of both sides of male and female, indicating that the scapula is bilaterally symmetrical in males and females. Several investigations on bilateral scapular symmetry discovered There is no discernible difference between the left and right scapula, which agrees with Giurazza et al. (2013) in the Caucasian people; Torimitsu et al. (2016) in the Japanese people; peckmann et al. (2017) in Thai people; Ahmidan et al (2022) in Libyan people and Ülkir et al. (2023) in Turkish people.

In contrast to this study, Dabbs and Moore-Jansen (2010) proposed that the scapula's size and shape can be bilaterally asymmetric in English people. Hudson et al. (2016) asymmetry in the right and left scapulae was found to be bilateral, this disparity could be due to population differences.

The current study revealed that the scapula's mean values for all anthropometric measurements including MSL, MSB and MLS were considerably larger in males in comparison to females on both sides right

and left with statistically significant difference ($p< 0.001$), this means that the scapula exhibits sexual dimorphism.

This is in line with the results of Giurazza et al. (2013), who investigated 200 healthy Italian adults (100 healthy males and 100 healthy females). For both scapulae, two parameters were measured: longitudinal scapular length (LSL), which represents maximum scapular length (MSL) and transverse scapular length (TSL), which represents maximum scapular breadth (MSL). Every anthropometric characteristic differed significantly between male and female individuals.

The same for Torimitsu et al. (2016) that had found similar results utilizing 218 known-age and gender Japanese cadavers, on which PMCT (postmortem computed tomography) scanning followed by a forensic autopsy which were carried out in the legal medical department. ANOVA revealed that for all variables, male participants' mean values were substantially higher than those of female individuals.

In addition, Zhang et al. (2016) conducted research on the Chinese people; the study sample consisted of 414 Chinese people, 190 females and 224 males and assessed six parameters for both scapulae: morphological length (ML), morphological breadth (MB), Longitudinal scapular length (LSL), longitudinal Maximum length (LML) and transverse scapular length (TSL). For all variables, the male sample had higher mean values than the female sample. the student's t-test findings showed that for all linear dimensions, the gap between mean values of males and females was very significant.

Furthermore, the present results of the discriminating function analysis of all metrics revealed male and female sex classification accuracy of 90%. In addition, maximum scapular length (82%) has the best accuracy on the right side, maximum scapular breadth (74%) is the next and maximum spine length (73%) is the last; while on the left side the maximum scapular length has the best accuracy (89%) followed by the maximum scapular breadth (75%) and the maximum length of the spine (69%).

Similarly, in a modern Greek population, Papaioannou et al. (2012) reported that the maximum scapular height (MSH) was the most effective single dimension with an accuracy of 91.2%. Ozer et al. (2006) revealed that in an Anatolian population only 82.9% of MSH's sex predictions were accurate.

In the Egyptian population, a descriptive comparison research was performed by Paulis and Abu Samra (2015) including Longitudinal (LL) and transverse scapular lengths (TL) were taken from 200 CTs chest (100 of each sex) in both the right and left sides, in every measure the values of males were considerably higher than those of females. The estimation of both male and female sexes yielded an accuracy of 87% for males and 95% for females when both dimensions were employed, for an overall accuracy of 91%. The TL exceeded the LL in sex determination when only one dimension was used.

El Morsi et al. (2017) reported that the accuracy of the right maximum scapular height and breadth was highest (82%) whereas the accuracy of maximum breadth of the left scapula was highest (80%), followed by the accuracy of the maximum scapular height and the maximum length of spine (78% each).

On contrary to present results, Giurazza et al. (2013); Zhang et al. (2016); Paulis and Abu Samra (2015); El Morsi et al. (2017) and Ülkir et al. (2023) in Turkish people noted that the most accurate measure was transverse length or morphological breadth.

The disparities between this study and earlier research could be attributed to growth hormone-induced anatomical changes in scapula between populations which is influenced by genes and environmental factors (Capellini, et al 2010), Employing various sample sizes, inclusion criteria, measurement methodologies and areas or points of reference (Sharan et al., 2008).

V. CONCLUSION

When comparing males to females, there is a statistically significant rise in the mean values of all left and right parameters. Based on the results of this study, the most sensitive and specific measure for predicting gender is the mean value of the left maximum scapular length. Therefore, the findings of this study are anticipated to aid in the sex determination research in the Egyptian population.

VI. RECOMMENDATION

It's crucial to remember that this study is preliminary due to the small sample size, but it's still significant because it creates a foundation for additional investigations on larger samples and in various communities and populations.

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الملخص العربي

تحديد جنس البالغين من لوح الكتف في عينة من سكان محافظة سوهاج

باستخدام التصوير المقطعي المحوسب ثلاثي الأبعاد متعدد الكواشف

عصام محمد عبد الله، مها عبد الحميد هلال، داليا محمد خلف، أحمد محمد سعيد، وفاء عبد الغفار على

قسم الطب الشرعي والسموم الإكلينيكية، كلية الطب ،جامعة سوهاج، مصر

المقدمة :إن تحديد هوية الأفراد هو من أصعب مجالات علم الطب الشرعي. حيث يعد التقدير الدقيق للجنس بناءً على قياسات الأبعاد ثنائية الشكل في البقايا البشرية الغير معروفة خطوة أولى حاسمة نحو تحديد الهوية الفردية. **الهدف** من هذا البحث: تم تقديم دراسة من أجل اختبار فعالية لوح الكتف ليكون بمثابة مؤشر لتحديد الجنس لأغراض الطب الشرعي. **الاشخاص و الطريقة**: هدفت الدراسة إلى التحقيق في إزدواج الشكل الجنسي للكتف ووضع معايير قياسية لتقدير الجنس في عينة من سكان محافظة سوهاج باستخدام قياسات كتفيه مثل أقصى طول لعظمة الكتف، وأقصى اتساع لعظمة الكتف وأقصى طول للعظمة الشوكية الكتفية وذلك عن طريق صور ثلاثية الأبعاد بالأشعة المقطعية، بهدف تغطية الاحتياج الحالي من الرفات الهيكلية في حالات الطب الشرعي. **طريقة الدراسة**: أجريت الدراسة الحالية على 100 شخص (50 ذكر و50 أنثى) خضعوا لتقييم التصوير المقطعي للصدر خلال برنامج فحص الرئة لأسباب مختلفة. تمت الموافقة على الدراسة من قبل اللجنة العلمية والأخلاقية بكلية الطب بسوهاج وتم الحصول على الموافقة الخطية المستنيرة من جميع المرضي.تم تحليل صور كل مريض وتم قياس ثلاث معاملات لكلا الكتفين:

الحد الأقصى لطول عظمة لوح الكتف: الطول بين أعلى نقطة من الزاوية العليا وأدنى نقطة من الزاوية السفلية، **الحد الأقصى للاتساع الكتفي**: من منتصف الحدود الظهرية للحفرة الحقانية إلى نهاية المحور الشوكي على الحدود الفقرية، **الحد الأقصى لطول عظمة الشوكة الكتفية**: من الحدود الإنسية للكتف عند المحور الشوكي إلى النقطة الأكثر جانبية على عظمه الشوكة الكتفية.

النتائج: كشفت هذه الدراسة ما يلي:

1- عدم وجود فروق ذات دلالة إحصائية بين الجانبين الأيمن والأيسر فيما يتعلق بجميع المعاملات الكتفية المقاسة لدى الذكور والإناث.

2- حدثت زيادة إحصائية ذات دلالة في متوسط قيم أقصي الطول الكتفي اليمين واليسار لدى الذكور مقارنة بالإناث.

3- وجود فروق ذات دلالة إحصائية في متوسط قيم الاتساع الكتفي الأقصى الأيمن والأيسر بين الذكور والإناث.

4- حدثت زيادة ذات دلالة إحصائية في متوسط قيم أقصى طول لعظمة الشوكة الكتفية الأيمن والأيسر لدى الذكور مقارنة بالإناث.

الخلاصة: أظهرت نتائج دراستنا أنه يمكن استخدام لوح الكتف لتحديد الجنس. وأن قياس أبعاد الكتف باستخدام الأشعة المقطعية في سكان سوهاج يمكن أن يكون موثوقاً فيه ودقيقاً لتحديد الجنس وهذه النتائج مفيدة في الطب الشرعي.

التوصيات: من المهم أن نتذكر أن هذه الدراسة أولية نظرًا لصغر حجم العينة، لكنها لا تزال مهمة لأنها تخلق أساسًا لإجراء تحقيقات إضافية على عينات أكبر وفي مجتمعات ومجموعات سكانية مختلفة ولذلك ننصح بعمل مزيد من الدراسات على عينات أكبر حجماً للوصول لنتائج أكثر دقة.