Sex Determination from Scapular and Clavicular Bones Measurements by Computed Tomography in Egyptian Population Sample

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KEYWORDS
Scapula,
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ABSTRACT

Sex determination from skeletal remains is a principal step in any archeological or forensic study. This study aimed to evaluate the role of scapular and clavicular bones measurements for sex determination in Egyptian population sample using three dimensions computed tomography (3D CT) images and to obtain function equation for sex differentiation. This was a cross sectional study conducted on 135 CT images (66 males and 69 females) obtained from Radiology Department, Menoufia University Hospital. Five measurements of scapula and three of clavicle bilaterally were measured. All scapular measurements of males were significantly of higher values than those of females ($p < 0.001$). Maximum scapular height (MSH) and scapular breadth (SB) had the highest accuracy on the right side (84% each) where on the left side; MSH had the highest accuracy followed by SB (84% and 81% respectively). Male clavicles were significantly longer and had higher sagittal and vertical clavicular diameters (SCD and VCD respectively) at mid-clavicular point than female ones. Right clavicular length had the highest accuracy followed by SCD (81.5% and 79.9% respectively) while the left SCD had the highest accuracy followed by the left clavicular length (82.5% and 81.5% respectively). Bilateral symmetry of scapular and clavicular bones was present. Sex equations formulae using logistic regression analysis were obtained for all measurements. Scapulae and clavicles were useful bones for sex determination in this Egyptian population sample. CT was a reliable and an accurate method for sex determination from these bones. Application of the recovered equations from the current research is recommended.

Introduction

Estimation of sex, age, stature, and ethnic group are essential in order to establish the biological profile of skeletal remains (Boccone et al., 2010). Sex determination from skeletal remains is a principal step in any archeological or forensic study (Papaioannou et al., 2012). It depends on morphologic and metric methods and it is not a difficult task when examination is done on almost complete skeleton. However, it is significantly more difficult when isolated elements are present as in mass disasters (Giurazza et al., 2013). This is mainly resulted from a lack of required database that helps in a correct sex determination of analyzed skeletal parts (Gapert et al., 2009).

Sex assessment can be achieved from examination of various skeletal elements, some of which (e.g. skull and pelvis) provide high accuracy (Guyomarc'h and Bruzek 2011; Hayashizaki et al., 2015). But, these commonly dimorphic bones may be absent or too fragmented to give accurate information; so, researchers turned to other skeletal bones such as lumbar vertebrae, talus, patella, sternum etc. (Kandeel and Habib 2019; Zhan et al., 2020; Mohammed et al., 2021).

There is always a need to test the osteometric methods to different populations

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to make population specific standards to achieve precision and accuracy as standards developed from specific population cannot be applied on another group. So, developing methods for different skeletal remains is required for different populations (Novotny et al., 1993).

The human clavicle is considered as a long bone that has a curved shaft and two ends (sternal and acromial). It lies in the front of the chest wall and forms the anterior part of the shoulder girdle. It articulates medically with the sternum and with the acromial process of the scapula laterally and it varies in shape more than other long bones (Moore and Dalley, 2006). The clavicular bone shows much resistance to environmental changes and it has been confirmed that it has a reliable value in sex determination (Chavda et al., 2013).

Scapula is a flat short bone; has not received as much attention as other long bones (Torimitsu et al., 2016). Across the life the scapular changes are not notable after growth is completed (Scholtz et al., 2010). Researches has been concluded that metric analysis of the human scapula is of a useful value for sex determination in different populations (Dabbs and Moore‐Jansen 2010; Paulis and Samra 2015).

The aim of the current study was to evaluate the role of scapular and clavicular bones measurements for sex determination in Egyptian population sample using three dimensions computed tomography (3D CT) and to obtain function equations for sex differentiation.

Subjects and methods:

This study was a cross sectional study conducted on a total of 135 CT images (66 males and 69 females) of individuals aged 26 years and above (to ensure complete union of both selected bones) obtained from radiology department, Menoufia university hospital. The studied individual's demographic and radiological data were obtained from data bases of patients attended to Radiology Department and subjected to 3D multi - slice chest CT. Five measurements of scapula and three of clavicle bilaterally were measured in millimeter (mm). Exclusion criteria were fracture, deformity, neoplasm, or dislocation of scapula and or clavicle, and in diffuse bone lesions as Paget's disease and metabolic /connective tissue diseases.

Protocol of the study was approved by Ethical Committee of Faculty of Medicine, Menoufia University (The approval number was IRB/6/2022FORE/1). Patient's consents were not necessary as radiological data were obtained from data bases of patients attended to radiology department after obtaining approval from diagnostic radiology department director, and data were kept anonymous to ensure confidentiality.

Examination was done by 128 multi-slice CT scanner (GE). Routine CT chest was done with the upper limbs held up beside the head scout images were taken from level of cervical vertebra 7 to the level of kidneys. The following parameters were taken: 150 mAs, 120 kVp, 64 × 0.625 mm section collimation, 2 mm slice thickness, 1 mm reconstruction increment. Post processing was done in the workstation. Radiologists interpreted the images independently on workstation using multiplanar reformate and volume rendering Images. The used protocol for scan obtainment was the same for all patients in the study to abolish technical variations in the measured lengths.

- **Scapular measures**

1. Maximum height of scapular bone (MSH): It is the distance between the

highest point of the superior scapular angle and the lowest point of the inferior scapular angle) (A- line in figure 1).

2. Scapular breadth (SB) (From a point at center of lower border of the glenoid fossa till the end of scapula at vertebral border) (B- line in figure 1).
3. Scapular spine length (SS): (From the medial scapular border (vertebral border) till the most distal point of scapular spine (C- line in figure 1).
4. Glenoid cavity height (GH): (from the upper margin of the glenoid fossa to the lower margin of the glenoid fossa) (A- line in figure 2).
5. Glenoid cavity breadth (GB): distance between the anterior border and the posterior border of the glenoid fossa (at a right angle to the axis of glenoid cavity height) (B- line in figure 2).

- **Clavicular measures** (Figure 3)

1. Maximum clavicular length (MCL): It is the maximum distance between the medial and lateral clavicular ends (C- line).
2. Sagittal clavicular diameter (SCD): It is the maximum width at mid-diaphyseal point from anterior to posterior (A- line).
3. Vertical clavicular diameter (VCD): It is the maximum width at mid-diaphyseal point from superior to inferior (B- line).

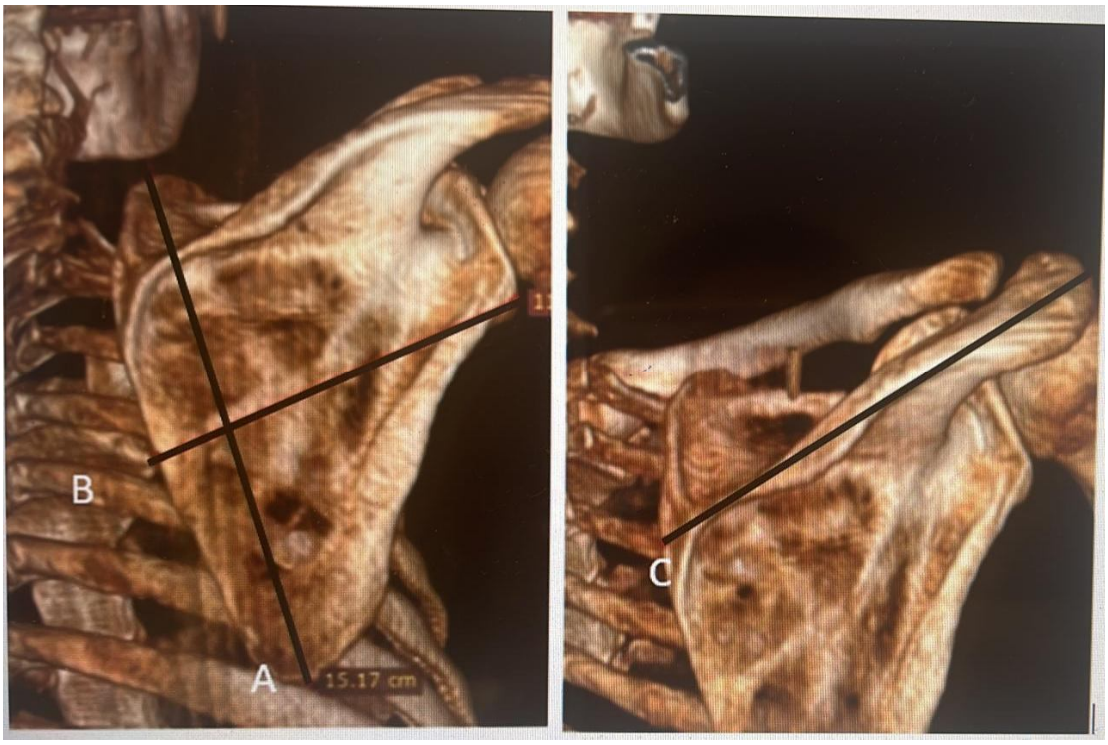

Fig. (1): Three dimensions chest CT scan bone window showing: A=Maximum scapular height (MSH), B=Scapular breadth (SB), C= Scapular spine length (SS)

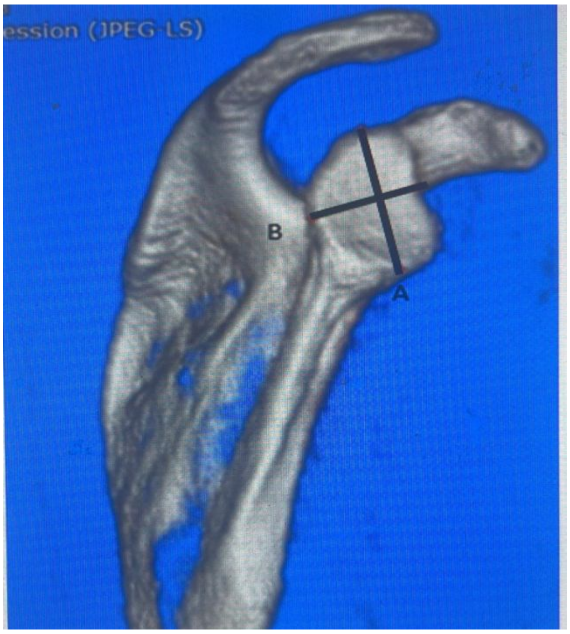

Fig. (2): Three dimensions chest CT scan bone window showing: A = glenoid cavity height; B= Glenoid cavity breadth.

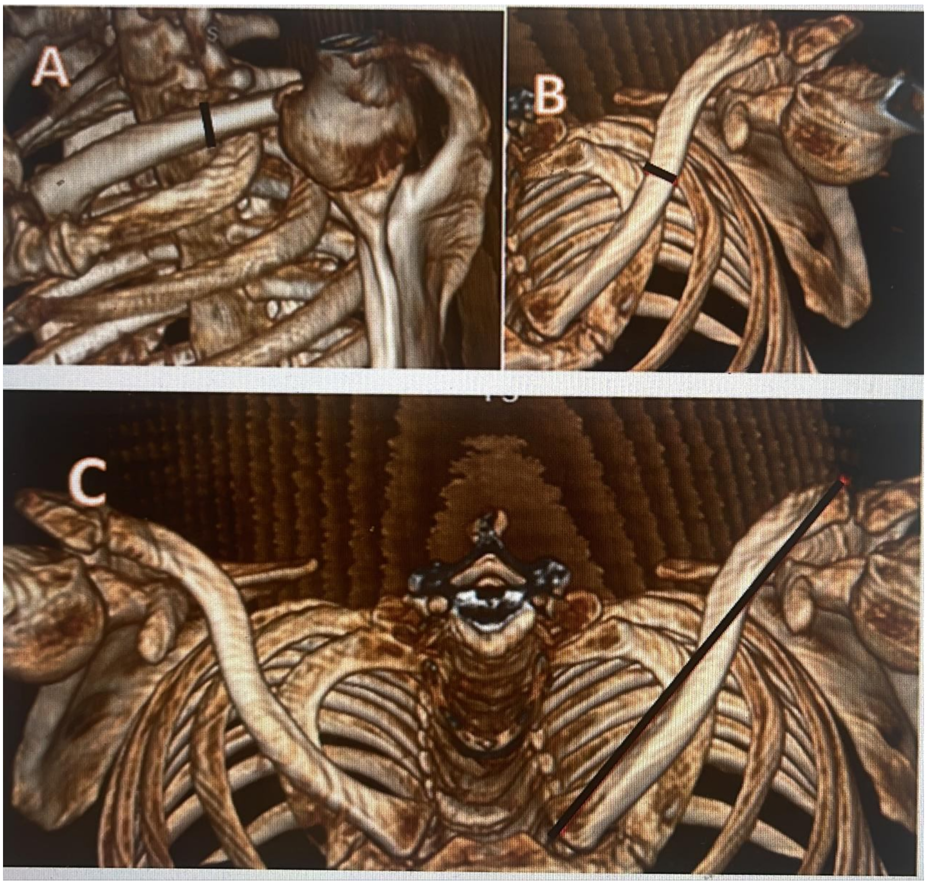

Fig. (3): Three dimensions chest CT scan bone window showing: A=Sagittal clavicular diameter (SCD), B= Vertical clavicular diameter (VCD), C= Maximum clavicular length (MCL)

Statistical analysis of the data

Computerized data were analyzed by using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Distributed data were expressed as range (minimum and maximum), mean, and standard deviation. Student t-test was used to compare two groups for normally distributed quantitative variables. Significance of the obtained results was judged at the 5% level. Cut off values and accuracy for each variable was obtained using receiver operating characteristic curve. Sex equation formula was obtained using logistic regression analysis for sex differentiation.

Results:

There was no significant difference between males and females in relation to age. The mean age of males was 44.72 ± 11.33 years (Range = 26-70 years) and that of females was 45.17 ± 11.59 years (Range = 26-73 years). There were significant differences between males and females regarding the five used scapular bone measurements bilaterally (males had longer measurements than females) (all p-values <0.05). While there were no significant differences between right and left measurements in both sexes; indicating bilateral symmetry of the scapular bones (p-value >0.05) (Table 1).

Table (1): Comparison between the five chosen bilateral scapular measurements (in mm) in both sexes (n=135)

	Gender		t	p
	Male (n = 66)	**Female (n = 69)**		
Age (years)				
Mean ± SD Range	44.72 ± 11.33 (26-70 years)	45.17 ± 11.59 (26-73 years)	0.226	0.821
Maximum scapular height (MSH)				
Right (Mean ± SD)	159.11±8.31	145.32±6.12	11.013	<0.001*
Left (Mean ± SD)	159.07±8.33	145.26±6.14	10.999	<0.001*
p_1	0.983	0.956		
Scapular breadth (SB)				
Right (Mean ± SD)	113.11±9.79	97.94±7.39	10.177	<0.001*
Left (Mean ± SD)	113.06±9.84	97.72 ±7.01	10.467	<0.001*
p_1	0.979	0.860		
Scapular spine length (SS)				
Right (Mean ± SD)	139.27±12.09	123.30 ±11.04	8.018	<0.001*
Left (Mean ± SD)	139.03±12.04	123.14 ±10.92	8.034	<0.001*
p_1	0.908	0.932		
Glenoid cavity height (GH)				
Right (Mean ± SD)	40.67 ±6.62	31.42±4.38	9.605	<0.001*
Left (Mean ± SD)	40.50 ±6.54	31.37±4.28	9.635	<0.001*
p_1	0.885	0.953		
Glenoid cavity breadth (GB)				
Right (Mean ± SD)	32.58 ±3.93	26.65 ±3.42	9.363	<0.001*
Left (Mean ± SD)	32.44 ±3.84	26.58 ±3.34	9.483	<0.001*
p_1	0.840	0.900		

SD: Standard deviation. t: Student t-test, p: p value for comparing between Male and Female, p1: p value for comparing between Right and Left. *: Statistically significant at p ≤ 0.05. n: number of cases

The measured three clavicular measurements (maximum clavicular length, sagittal clavicular diameter, vertical clavicular diameter) showed significant sexual dimorphism on both sides right and left (all p - values <0.05). Where, all measurements were larger in males than in females. While there were no significant differences between right and left measurements in both sexes; indicating bilateral symmetry of the clavicular bones (p- value >0.05) (Table 2).

Table (2): Comparison between the bilateral three chosen clavicular measurements (in mm) in both sexes (n=135)

	Gender		t	p
	Male (n = 66)	**Female (n = 69)**		
Maximum clavicular length (MCL)				
Right (Mean ± SD.)	148.68 ±8.58	132.40±7.69	11.610	<0.001*
Left (Mean ± SD.)	148.86±8.76	132.59±7.71	11.468	<0.001*
p_1	0.904	0.886		
Sagittal clavicular diameter (SCD)				
Right (Mean ± SD.)	13.36 ±1.84	10.78 ±1.41	9.175	<0.001*
Left (Mean ± SD.)	13.56 ±1.67	10.88 ±1.39	10.128	<0.001*
p_1	0.521	0.671		
Vertical clavicular diameter (VCD)				
Right (Mean ± SD.)	11.39 ±1.05	9.43 ±1.40	9.172	<0.001*
Left (Mean ± SD.)	11.45 ±1.17	9.55 ±1.39	8.579	<0.001*
p_1	0.754	0.627		

SD: Standard deviation. t: Student t-test. p: p value for comparing between Male and Female.
p1: p value for comparing between Right and Left. *: Statistically significant at $p \leq 0.05$. n: number of cases.

Regarding cut off values and accuracy for all measured scapular and clavicular measurements in both sides and of both sexes, scapular measurements showed that the maximum scapular height and the maximum scapular breadth had the highest accuracy for sex determination on the right side (84% each) where on the left side, the maximum scapular height had the highest accuracy followed by maximum scapular breadth (84% and 81% respectively). Regarding the clavicular measurements on the right side, the maximum clavicular length had the highest accuracy for sex determination followed by sagittal clavicular diameter (accuracy was 81.5% and 79.9% respectively). On the left side, the sagittal clavicular diameter had the highest accuracy for sex determination followed by the maximum clavicular length (accuracy was 82.5% and 81.5% respectively) (Table 3).

Table (3): Accuracy and cut off values for each measurement in right and left sides (n=135)

	AUC	Cutoff	Sensitivity (%)	Specificity (%)	Accuracy (%)
		Right			
Maximum scapular height (MSH)	0.908	Males>148.5 mm>females	89.4	78.3	84
Scapular breadth (SB)	0.904	Males> 99.5 mm>females	92.4	75.4	84
Scapular spine length (SS)	0.850	Males >132 mm >females	81.8	73.9	77.9
Glenoid cavity height (GH)	0.868	Males > 34.5 mm>females	80.3	79.7	80
Glenoid cavity breadth (GB)	0.0858	Males > 28.5 mm>females	84.8	72.8	78.8
Maximum clavicular length (MCL)	0.915	Males > 139.5 mm>females	81.8	81.2	81.5
Sagittal clavicular diameter (SCD)	0.857	Males >12.5 mm >females	74.2	85.5	79.9
Vertical clavicular diameter (VCD)	0.858	Males > 10.5 mm>females	77.3	79.3	78.3
		Left			
Maximum scapular height (MSH)	0.908	Males>148.5 mm>females	89.4	78.3	84
Scapular breadth (SB)	0.906	Males > 100.5 mm>females	86.4	75.4	81
Scapular spine length (SS)	0.851	Males >132.5 mm>females	80.3	75.4	77.8
Glenoid cavity height (GH)	0.867	Males >34.5 mm>females	78.8	79.7	79.3
Glenoid cavity breadth (GB)	0.860	Males > 28.5 mm>females	83.3	78.3	80.8
Maximum clavicular length (MCL)	0.911	Males >139.5 mm>females	81.8	81.2	81.5
Sagittal clavicular diameter (SCD)	0.885	Males >11.5 mm>females	92.4	72.5	82.5
Vertical clavicular diameter (VCD)	0.842	Males > 10.5 mm>females	74.2	73.9	74

AUC: Area Under a Curve, n: number of cases.

Sex equations formulae from the results using logistic regression analysis for sex differentiation from all measurements in scapula and clavicle in both sides in Egyptian population sample were obtained where if the value of the equation is more than zero the person is male; otherwise is female (Table 4).

Table (4): Sex equation with logistic regression (n=135)

	Constant	B	Sig.	OR	95% CI		Equation
					LL	UL	
Right							
Maximum scapular height (MSH)	-43.399	0.287	<0.001*	1.333	1.202	1.477	Sex equation= -43.399 + MSH× 0.287
Scapular breadth (SB)	-18.233	0.174	<0.001*	1.190	1.126	1.258	Sex equation= -18.233 + SB × 0.174
Maximum length of the scapular spine (SS)	-14.245	0.108	<0.001*	1.144	1.074	1.155	Sex equation= -14.245 + SS× 0.108
Glenoid cavity height (GH)	-9.156	0257	<0.001*	1.294	1.190	1.406	Sex equation= -9.156 +GH× 0.257
Glenoid cavity breadth (GB)	-11.295	0.382	<0.001*	1.465	1.297	1.653	Sex equation= -11.295 + GB× 0.382
Maximum clavicular length (MCL)	-30.662	0.219	<0.001*	1.244	1.161	1.334	Sex equation= -30.662 + MCL× 0.219
Sagittal clavicular diameter (SCD)	-10.767	0.895	<0.001*	2.447	1.832	3.268	Sex equation= -10.767 + SCD× 0.895
Vertical clavicular diameter (VCD)	-12.495	1.192	<0.001*	3.292	2.226	4.870	Sex equation= -12.495+ VCD× 1.192
Left							
Maximum scapular height (MSH)	-43.135	0.285	<0.001*	1.330	1.201	1.474	Sex equation= -43.135 + MSH × 0.285
Scapular breadth (SB)	-19.219	0.184	<0.001*	1.202	1.134	1.274	Sex equation= -19.219 + SB× 0.184
Scapular spine length (SS)	-14.311	0.108	<0.001*	1.114	1.074	1.156	Sex equation= -14.311 + SS × 0.108
Glenoid cavity height (GH)	-9.300	0.262	<0.001*	1.300	1.194	1.415	Sex equation= -9.300 + GH× 0.262
Glenoid cavity breadth (GB)	-11.710	0.397	<0.001*	1.487	1.312	1.686	Sex equation= -11.710+ GB× 0.397
Maximum clavicular length (MCL)	-30.019	0.214	<0.001*	1.238	1.157	1.326	Sex equation= -30.019 + MCL× 0.214
Sagittal clavicular diameter (SCD)	-13.281	1.089	<0.001*	2.972	2.097	4.213	Sex equation= -13.281 + SCD× 1.089
Vertical clavicular diameter (VCD)	-11.461	1.086	<0.001*	2.962	2.052	4.274	Sex equation= -11.461 + VCD× 1.086

OR: Odd`s ratio, C.I: Confidence interval, LL: Lower limit, UL: Upper Limit, n: number of cases.

Discussion

The sex determination is an important aspect of forensic and osteological investigations as being the initial step to skeletal or biological identification (Scholtz et al., 2010; Papaioannou et al., 2012; Oliveira Costa et al., 2016). Steele (1976) concluded that sex differentiation using a single measurement had a limited utility as there was a large overlap of the ranges between males and females. So, in the present study five scapular measurements and three clavicular measurements were chosen.

All male scapular measurements in the current study showed considerably greater values than female scapular measurements ($p < 0.05$) on both right and left sides, demonstrating scapular sexual dimorphism. In terms of right and left scapula symmetry, the current work found that there was no significant difference between both sides in Egyptian population sample. Sexual dimorphism may be due to difference of development and physical activity in males than females (El Morsi et al., 2017). In addition to the effects of genes and environmental factors including diet, stress at work, and medical care, may be linked to sexual dimorphism (Papaioannou et al., 2012).

These results corroborate with data reported in the studies for Egyptian populations (Paulis and Samra, 2015; El Morsi et al., 2017). Also, many researchers in other populations found the same results; Patel et al. (2013) in Indian population, Omar et al. (2019) in Malaysian population, Er et al. (2020) in Turkish.

In contrast to the point of symmetry of scapular bones, Peckmann et al. (2016) showed that there was a minor bilateral asymmetry between left and right scapula in the Chilean population, but this minor variation had a negligible impact on affecting sex determination.

In addition, the present work showed that the highest percent of accuracy for sex determination on the right side was achieved by the maximum scapular height and the maximum scapular breadth (84% each), where on the left side, the maximum scapular height was the most accurate for sex determination followed by maximum scapular breadth (84% and 81% respectively).

El Morsi et al. (2017) discovered that the accuracy of the right scapular breadth and maximum scapular height were both 82%, followed by the height and breadth of the glenoid cavity (76% each). On the other side, the accuracy of the left scapular breadth was 82%, followed by the length of the spine and maximum scapular height (78% for each). Er et al. (2020) concluded that the best overall estimation rate was achieved by measuring the glenoid cavity breadth (92.1% accuracy), followed by maximum scapular height and maximum length of the spine (90.1% accuracy).

The present work also studied sexual dimorphism of clavicular bone; male clavicles were significantly longer than female ones and had longer vertical clavicular diameter and sagittal clavicular diameter dimensions at mid diaphyseal point (p value <0.05). These results were in consistence with those revealed by Demir et al. (2022) (Eastern Turkish population) and Ahmidan et al. (2023) (Libyan Population).

Furthermore, the current work revealed that the maximum clavicular length had the highest accuracy for sex determination followed by sagittal clavicular diameter on the right side (accuracy was 81.5% and 79.9% respectively). While on the left side, the sagittal clavicular diameter had the highest accuracy for sex determination followed by the maximum clavicular length (accuracy was 82.5% and 81.5% respectively).

Ahmidan et al. (2023) found that the most sexually dimorphic measurements were mid-shaft diameter 90% accuracy. Doshi and Reddy (2017) concluded in their analysis that the single most useful variable was the mid clavicular circumference with 89.4% accuracy. Ishwarkumar et al. (2016) reported an accurate sex prediction of 89% from the mid-shaft circumference and the maximum length of adult human clavicle for KwaZulu-Natal population (South Africa).

Akhlaghi et al. (2012) reported an accuracy ranging from 73.3%-88.3% using the maximum length and midshaft circumference of the clavicles in Iranian population.

Logistical regression analysis is a good method for sex determination as it has a higher accuracy rate and a lower sex bias ratio (Macaluso, 2011; Torimitsu et al., 2016; Atamtürk et al., 2019). So, sex equations formulae from the results using logistic regression analysis of all measurements in scapula and clavicle in this Egyptian population sample were obtained. As we may be encountered with fragmented bones so we can identify sex from the available parts measurements where if the value of the equation is more than zero the person is male; otherwise is female.

Conclusion:

Scapula and clavicle are good discriminators for sex determination and could be used in this Egyptian population sample. Bilateral symmetry was present regarding these two bones. Skeletal measurements using CT stored images are a good method for sex identification because it is easy and accurate and available at any time as it is digitally stored.

Recommendations: Application of the recovered equations from the current research for sex estimation on Egyptian population is recommended. CT scanning should be used in the variable aspects of forensic medicine as it is a reliable and accurate modern imaging technique.

Conflict of interest: No conflict of interest.

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تحديد الجنس من قياسات عظام الكتف والترقوة باستخدام التصوير المقطعي في عينة من الشعب المصري

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تحديد الجنس من الهيكل العظمي هو خطوة رئيسية في أي دراسة أثرية أو شرعية. وقد كان الهدف من هذه الدراسة هو تقييم دور قياسات عظام الكتف والترقوة في تحديد الجنس في عينة من الشعب المصري باستخدام التصوير المقطعي ثلاثي الأبعاد والحصول على معادلة وظيفية للتمايز الجنسي.

أجريت هذه الدراسة المقطعية على إجمالي ١٣٥ صورة تصوير مقطعي لأفراد يبلغون من العمر ٢٦ عامًا فما أكثر (٦٦ ذكرًا و٦٩ إناثًا) تم الحصول عليها من قسم الأشعة بمستشفى جامعة المنوفية. تم قياس خمس قياسات لعظمة الكتف وثلاثة قياسات لعظام الترقوة للجانبين الأيمن والأيسر. تم الحصول على صيغة معادلة الجنس باستخدام تحليل الانحدار اللوجستي للتمايز بين الجنسين.

وقد كانت جميع القياسات لعظمة الكتف للذكور ذات قيم أعلى من تلك الخاصة بالإناث في كلا الجانبين الأيمن والأيسر. أقصى ارتفاع لعظمة الكتف وأقصى اتساع لها كان لهما أعلى دقة لتحديد الجنس على الجانب الأيمن (٨٤٪) حيث كان أقصى ارتفاع كتفي أعلى دقة على الجانب الأيسر متبوعًا بأقصى اتساع كتفي (٨٤٪ و٨١٪ على التوالي). كانت عظمة الترقوة في الذكور أطول من الترقوة الإناث وأعرض على الجانبين. تم الحصول على معادلات الجنس باستخدام تحليل الانحدار اللوجستي لجميع القياسات في عظام الكتف والترقوة في كلا الجانبين في هذه العينة السكانية المصرية. يمكن الاستنتاج أن عظمتي الكتف والترقوة مفيدة لتحديد الجنس في هذه العينة السكانية المصرية. كان التصوير المقطعي المحوسب طريقة موثوقة ودقيقة لتحديد جنس هذه العظام. ويوصى بتطبيق المعادلات المسترجعة من البحث الحالي لتقدير الجنس على السكان المصريين. كما يجب استخدام التصوير المقطعي المحوسب في الجوانب المختلفة للطب الشرعي لأنه تقنية تصوير حديثة موثوقة ودقيقة.