Identification of Sex from Clavicle Bone Morphometry through 3D CT in Libyan Population

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ABSTRACT

Background: Precise sex assessment relies over dimorphic dimensions measuring among unknown human remains is a necessary prerequisite for individuals' identification. Clavicle is a flat short bone appears to be better maintained than long bones. Anthropometric analyses of clavicles to determine the sex are evaluated in different populations with high accuracy. Three-dimensional computed tomography (3D-CT) pictures are an effective technique for this. **Objective:** The aim of the current study was to study sexual dimorphism of the clavicle, as well as establishment of sex prediction equation among Libyan people by utilizing measurements of the clavicle which obtained from 3D-CT images. **Subjects and methods**: A total of 50 males and 50 females sexes dimensions were measured from 3D CT scans of the left clavicle: C1, C2 and C3 maximum clavicular length, midshaft circumference, and maximum diameter of the midshaft. C4, C5 and C6 indicated minimum midshaft diameter, maximum sternal end, and acromial end widths, respectively. **Results**: All the studied measurements in the left clavicle showed a statistical significant increase in males compared to females. C4 was the most single sexually dimorphic dimension of the left clavicle with 90% accuracy. Stepwise discriminant analyses of clavicular variables (C2, C4, and C6) yielded high accuracy at the rate of 99 % (99 % cross-validated). **Conclusion:** 3D-CT morphomertric analyses of clavicle provide valuable data for identification of sex in modern Libyan population and can be used in forensic investigations.

Keywords: 3D CT, Libyan, Clavicle, Sex determination, Identification, Morphometry.

INTRODUCTION

The first and most crucial step in building a precise biological profile is gender assessment during the identification processes of the human skeleton. It is a main issue in the identification of persons in forensic cases [(1)]**.** Sex assessment is important as it affects the evaluation of other variables (e.g., age and stature) [(2)]**.** The idea behind sex identification is that male and female skeletons are dissimilar in form and size. This variation is called sexual dimorphism of bones [(3)]**.** Sex assessment methods can be generally classified as morphologic (non-metric) or metric approaches [(4)]**.**

The metric approach of sex assessment from skeletal remains is relies on anthropometric analysis of the bone measurements. Caliper measurements, radiologic (digital x-ray, computed tomography, magnetic resonance imaging) measurements and geometric morphometric analysis (uses landmark coordinates rather than linear measurements of bones) can be done for metric estimation [(3,5)]**.**

Metric studies mainly use several statistical methods as discriminant function analysis (DFA) to produce models or equations for sex prediction [(6)]. The best accurate method to assess sex from bone size is relied on pelvic bones or skull, However in many cases and after mass disasters they may be absent, so the development of approaches of sex identifications from other bones is vital [(7)]**.** Approximately 6 inches (15 cm) in length, the clavicle is an elongated, S-shaped bone that connects the shoulder blades to the chest wall. It sits horizontally on each side of the superior thorax [(8)]**.**

Variable studies about the value of the clavicle for sex assessment in different populations are published with encouraging results. The DFA equations for sex estimation have produced findings that are population-specific when compared across several population groups. Due to sexual dimorphism, there is a large demographic difference in how quickly people grow and develop.

The aim of the current study was to study sexual dimorphism of the clavicle, as well as establishment of sex prediction equation among Libyan people by utilizing measurements of the clavicle which obtained from 3D-CT images.

SUBJECTS AND METHODS

A total of 100 subjects, 50 men (group 1) and 50 women (group 2), were chosen randomly from those coming to radiology department of Zliten Medical Center and Tripoli Central Hospital, Libya, during the period from July 2021 to the end of December 2021. All the included subjects provided written informed consent.

Inclusion criteria:

- Age between 25 and 50 years.
- Males and females.
- From Libya.

Exclusion criteria

- Age less than 25 or more than 50 years.
- Any history of malignancies, metabolic bone disease, bone fractures, arthritis, deformities, pathological lesions, connective tissue disease or orthopedic surgery in the clavicle.

All participants were subjected to MDCT of the chest (TOSHIBA 128 slide – Japan) then using a 3D volume rendering method, 3D CT pictures were created.

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The following measurements were taken from 3D reconstructed pictures of the patient's left clavicle: **(Figures 1, 2 and 3)** according to **Papaioannou *et al.*** [(9)]**:**

1. Maximum clavicular length (C1): The distance between the most extreme ends of the clavicle (Figure 1).

2. Midshaft circumference (C2): The midpoint of the shaft was established then circumference was measured (Figure 2).

3. Midshaft maximum diameter (C3): The maximum diameter of the bone shaft was measured at midshaft point (Figure 2).

4. Midshaft minimum diameter (C4): The minimum diameter of the bone shaft was measured at midshaft point (Figure 2).

5. Maximum breadth of sternal end (C5): The maximum anterior to posterior length of the sternal end was measured (Figure 3).

6. Maximum breadth of acromial end (C6): The acromial end's articular surface's maximal anterior-posterior length assessed (Figure 3).

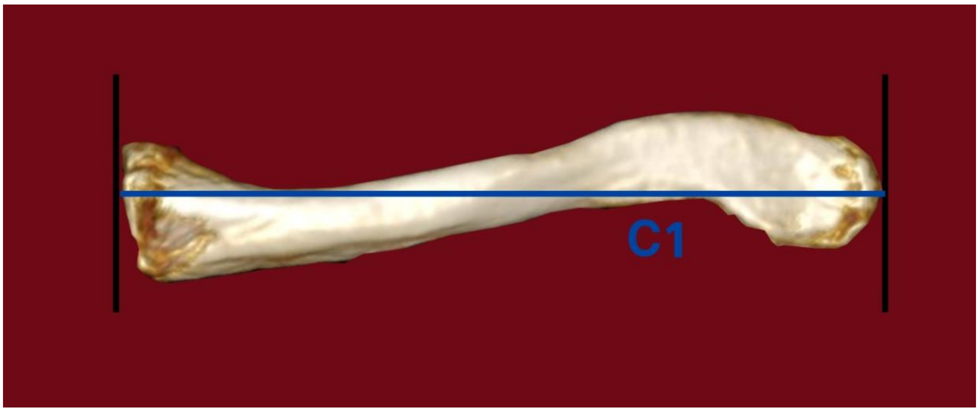

Figure (1): 3D CT image showing maximum clavicular length (C1).

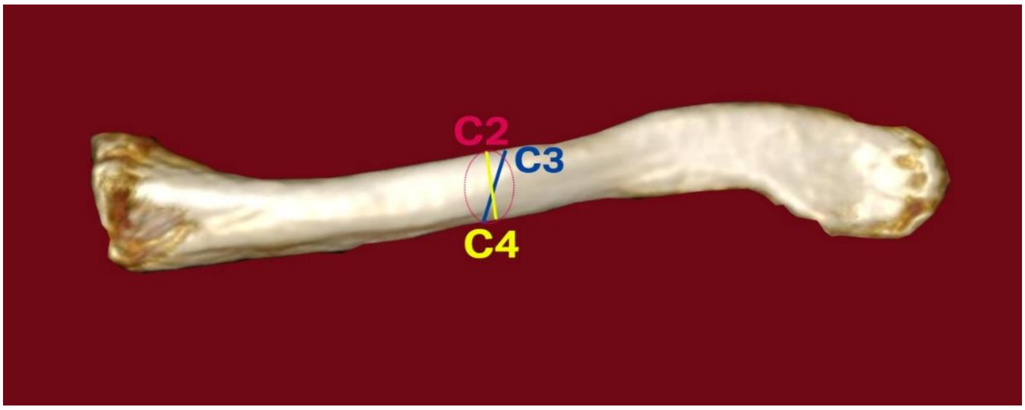

Figure (2): 3D CT image showing midshaft circumference (C2), midshaft maximum diameter (C3) and midshaft minimum diameter (C4).

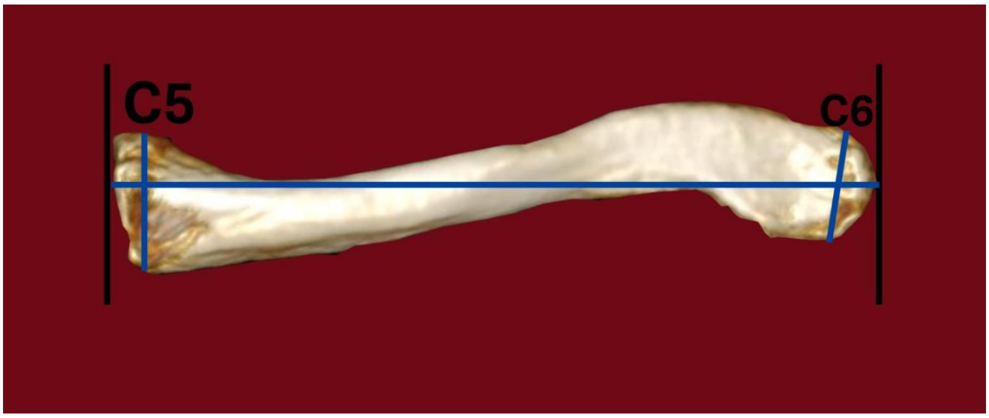

Figure (3): 3D CT image showing maximum breadth of sternal end (C5) and maximum breadth of acromial articular (C6).

Ethical Approval:

The study was approved from the Faculty of Medicine, Zagazig University Ethics Committee for Scientific Research of Institutional Review Board (IRB), Egypt (ZU-IRB#7036/30-6-2021). After explaining our research objectives, written informed consent was obtained from all study participants. This study was conducted in compliance with the code of ethics of the world medical association (Declaration of Helsinki) for human subjects.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) application, version 27.0 (IBM, 2020), was used to analyze the collected data. Qualitative data were defined as numbers and percentages. Quantitative data were tested for normality by Kolmogorov-Smirnov test. Normal distribution of variables was described as mean and standard deviation (SD), and independent sample t-test was used for comparison between groups.

Limits of detection for various metrics that maximize both specificity and sensitivity for sex prediction were determined using Receiver operating characteristic (ROC) curves. The Stepwise Discriminant Analysis was used to establish sex predicting equation. P value $\leq$0.05 was considered significant.

RESULTS

The age range in each group was between 25-50 years. No significant differences were found regarding age **(Table 1).**

Table (1): Demographic data of the studied groups.

Variable	Group I (Male) (*n*=50)	Group II (Female) (*n*=50)	*t-test*	P-value
Age: (years) *Mean ± SD* *Range*	37 ± 7.94 25 - 50	36.26 ± 7.70 25- 50	0.47	0.64 NS

SD: Standard deviation, t: Independent t test, NS: Non significant (P>0.05).

Al parameters measured in the left clavicle were highly significantly different of males compared to females **(Table 2).**

Table (2): Comparisons of all measurements of the left clavicle in both sexes.

Variable in cm	Group I (Males) (*n*=50)	Group II (Females) (*n*=50)	*t-test*	P-value
Maximum clavicular length C1 ***Mean ± SD*** ***Range***	**15.65±2.08** **11.7-19.8**	**13.78±1.86** **10.2-16.5**	**4.73**	**<0.001****
Mid shaft circumference C2 ***Mean ± SD*** ***Range***	**3.92±0.43** **3.18-4.58**	**3.42±0.43** **2.71-4.16**	**5.84**	**<0.001****
Mid shaft maximum diameter C3 ***Mean ± SD*** ***Range***	**1.31±0.13** **1.02-1.51**	**1.2±0.11** **1-1.42**	**4.26**	**<0.001****
Mid shaft minimum diameter C4 ***Mean ± SD*** ***Range***	**1.02±0.06** **0.93-1.12**	**0.85±0.07** **0.75-0.98**	**12.77**	**<0.001****
Maximum breadth of sternal end C5 ***Mean ± SD*** ***Range***	**2.69±0.19** **2.35-3**	**2.47±0.18** **2.15-2.8**	**5.72**	**<0.001****
Maximum breadth of acromial end C6 ***Mean ± SD*** ***Range***	**1.74±0.10** **1.59-1.87**	**1.63±0.09** **1.49-1.81**	**5.14**	**<0.001****

The current study showed that the accuracy of C1 in determining male sex at cut off more than 13.95 mm was 64%, C2 at cut off more than 3.48 mm was 65%, C3 at cut off more than 1.25 mm was 66%, C4 at cut off more than 0.94 mm was 90%, C5 at cut off more than 2.55 mm was 67% and C6 at cut off more than 1.63 mm was 63% **(Table 3 and Figure 4).**

Table (3): Validity of left clavicle measurements in sex determination.

Variable	Cut off	AUC (95% CI)	Sens	Spec	PPV	NPV	Accuracy %	P-value
Maximum clavicular length C1	13.95	0.73 0.63-0.83	76	52	61.3	68.4	64	**<0.001****
Mid shaft circumference C2	3.48	0.79 0.70-0.87	78	52	61.9	70.3	65	**<0.001****
Mid shaft maximum diameter C3	1.25	0.73 0.63-0.83	74	58	63.7	69	66	**<0.001****
Mid shaft minimum diameter C4	0.94	0.97 0.94-1	90	90	90	90	90	**<0.001****
Maximum breadt of sternal end C5	2.55	0.78 0.69-0.87	76	58	64.4	70.7	67	**<0.001****
Maximum breadth of acromial end C6	1.63	0.76 0.67-0.85	76	50	60.3	67.6	63	**<0.001****

Sens: Sensitivity, Spec: Specificity, PPV: Positive predictive value, NPV: negative predictive value.

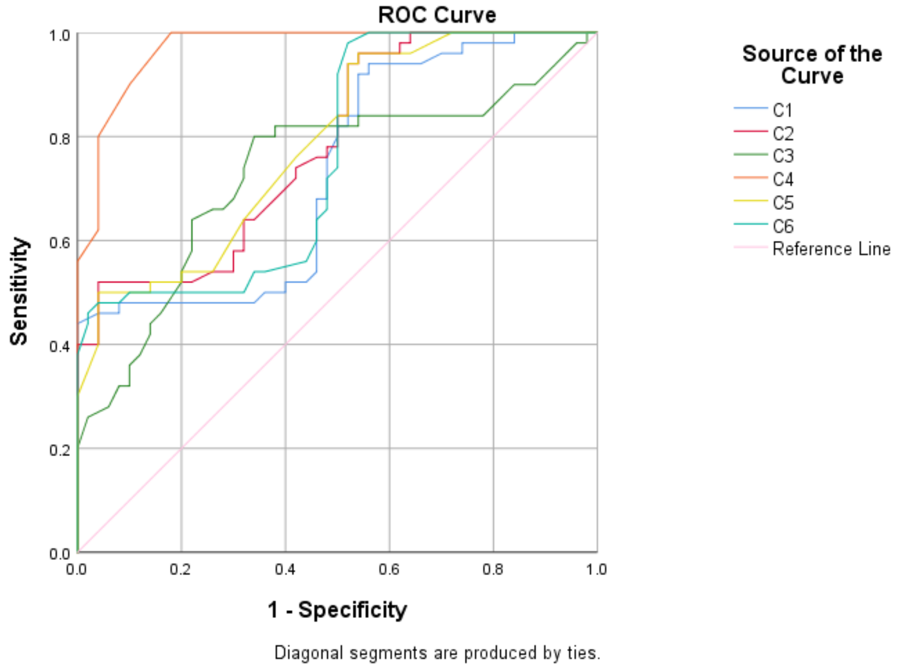

Figure (4): Roc curve for validity of left clavicle measurement in sex determination.

Table 4 shows that the clavicle parameters 3 of 6 measurements were selected in the stepwise discriminant analysis: C2, C4, and C6; cross-validated sex classification accuracy was 99%. This equation could be unutilized for sex prediction:

Sex= 47.18+ **10.91*C2 + 89.47*C4+ -101.26*C6.** If the value is greater than or equal to 0.18, it is highly likely that the clavicle belongs to a man, and if it is less than or equal to 0.18, it is quite likely that the clavicle belongs to a female with accuracy about 99%.

Table (4): Stepwise discriminant analysis of clavicle parameters to detect sex.

Variable	Canonical Discriminant Function Coefficients		Wilks' Lambda	Functions at Group Centroids	Sectioning point	Accuracy
	Un-standardized	Standardized				
Mid shaft circumference C2	10.91	4.69	0.04	Male = 5.07	0.18	99%
Mid shaft minimum diameter C4	89.47	5.82				
Maximum breadth of acromial end C6	-101.26	-9.99		Female = -5.01		
Constant	47.18	----				

DISCUSSION

The clavicle bone showed relatively high accuracy in sex assessment studies. Metric analysis of the clavicle bone measurements by the assessment of sex may benefit from data from 3D-CT. While the pelvis and skull—two crucial sex indicators—are frequently missing or injured, the clavicle may be recovered intact from scavenged and decomposed bones. Identifying the gender of skeletal remains is a crucial component in forensic anthropology [10, 11]. Some studies were done on estimation of sex from the clavicle bones in different population groups which either used bone remains, digital photographs, 3D-CT or geometry morphometry analysis using different measurements and different age groups. **Papaioannou *et al.*** [9] **and Koukiasa *et al.*** [12] clavicle sexual dimorphism in a Modern Greek population was investigated using bone calliper measurements. Also, **Kharuhadetch *et al.*** [6] used the same approach of clavicular parameters in modern Thai population.

Shirley's [13] geometry-based morphometric technique to define clavicular sexual dimorphism yielded 92% cross-validated accuracy rates. 3D-CT scan is an amazing objective non-invasive radiographic procedure for the study of bone morphometry [14]. Thus, investigating sexual dimorphism was the goal of the current work. from the clavicle and establish sex predicting equations in Libyan population by using six left clavicular measurements obtained from 3D CT images of living adults. 100 subjects (50 males and 50 females) were randomly chosen from those coming to Radiology Department of the Zliten Medical Center and Tripoli Central Hospital, Libya for chest CT scan for diagnostic purpose. The age ranged of the selected persons from 25-50 years in males and in females. Degree of sexual dimorphism in bones can be affected by age. We picked the same age range for both sexes since methods based on bone dimensions may be influenced by the relative age of the adult. There was little distinction between males and females as regarding age (in males 37 ± 7.94 years and in females was 36.26 ± 7.70 years). This age range was chosen as sexual dimorphisms of bones do not come to be surely visible until maturity. Growth plates of the clavicle bone may not close until between 20 to 25 year of life [15].

All the included persons were subjected to multidetector CT of the chest, after that, 3D volume rendering technology was used to obtain 3D-CT pictures. The full left clavicle's 3D reconstruction image was created to assess the following 6 parameters in our study. **Papaioannou *et al.*** [9] study on the skeletal material of contemporary Greek population and recent study done by **Kharuhadetch *et al.*** [6] on modern Thai population showed high statistically significant sexual dimorphism of all clavicular variables measured. The same outcomes were observed in many investigations comparing the mean value of clavicular parameters between sexes in other populations, e.g., American [16], Iranian [17], Indian [18], Mexican [19] and Greek [12]. Sexual dimorphic characters of the clavicle bone might have more to do with testosterone and male development than with female muscle activity [20].

Regarding the validity of left clavicular measurement in sex determination of Libyan population, the current study found that all the variables showed high accuracy percentage >60% (the least was maximum breadth of acromial end (C6) 63% and the greatest was mid shaft minimum diameter (C4) 90%. The most sexually dimorphic measurements were mid shaft minimum diameter (C4) 90% followed by maximum breadth of sternal end (C5) 67% and mid shaft maximum diameter (C3) 66%.

Like our study, using a clavicle, a prior study was undertaken by **Kaewma and colleagues** [21] among Thai people found that C4 parameter provided high accuracy 90.55 % followed by C3, C2 and C1. Whereas C5 and C6 were as not being precise enough for sex assessment. While in the study of **Kharuhadetch *et al.*** [6] also in Thai population, due to their statistical significance in producing a sex equation, C5 and C6 parameters were unquestionably chosen. They came to the conclusion that, method of bone collecting distribution of sex and age, the sample size, as well as other factors may have contributed to the inconsistent results.

In our study, Stepwise discriminant analyses of clavicular variables (C2, C4 and C6) yield high accuracy at the rate of 99% (99% cross-validated). With comparison to others, statistic result by the study of **Kharuhadetch *et al.*** [6] showed that clavicular parameters stepwise analysis yields 90.7% for overall accuracy. DFA is a simple useful statistical method to assess the sex of skeletal remains. Although the DFA equation of sex determination is trustworthy, reduces the examiner's subjectivity, and can be replicated, it can only be used with data from a single community due to the wide variation in skeletal structure between human populations [22].

CONCLUSION

Clavicle bone measurements can be used for assessing sex in contemporary Libyan population. Sex can be predicted from the left clavicle in Libyan population from the following equation: Sex= 47.18+ 10.91*C2 + 89.47*C4+ -101.26*C6. If the result ≥0.18, the person is male and if <0.18, the person is female (accuracy 99%). MDCT scans are useful tool for metric analysis of bones for sex identification in forensic cases.

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