Original Article

Estimation of Sex Using Sacrum and Coccyx Computed Tomography of Libyan Population in Benghazi

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ABSTRACT

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Background: Sex identification of human skeleton is essential for bioarcheological and forensic studies. Determination of Sex is important to establish personal identity. Sex identification accurately depends on the presence of complete remains. Aim: This study aimed to estimate sex from measurements of sacrum and coccyx by computed tomography (CT) of Libyan population. **Subjects and methods:** A cross-sectional study was carried out in Radiological center of Aljala Hospital of Benghazi and Benghazi Medical Center, Libya on 120 subjects who were divided into 60 males and 60 females. Sex was determined through measuring anterior and posterior sacral lengths (ASL and PSL), anterior and posterior sacrococcygeal lengths (ASCL and PSCL), anterior sacral width (ASW), curved length of sacrum (CLS), length of auricular surface (LAS), mid-sagittal and maximum transverse diameters of base (MDB and MTDB) by using sacrum and coccyx CT. **Results:** There was very high statistical significant difference between the mean values of different studied parameters between males and females .All these parameters were higher in males except MTDB that was higher in females. Regarding ASW, there was no significant difference between the mean values of males and that of females. The most accurate sex parameters were CLS 99.0%, PSCL 98.3% and MDB 90.5%. **Conclusion:** Males were significantly higher than females regarding mean values of all studied parameters except MTDB that was higher in females. The most sexually dimorphic individual measurements for sex determination found in the study were CLS, PSCL and MDB. Recommendation: Other studies using different bones and techniques should be done.
Keywords: Sacrum, Coccyx, CT, ASL, PSL.

I. INTRODUCTION

Sacrum is a triangular bone located at the end of the spinal column. It is formed by the fusion of five sacral vertebrae from S1 to S5 and found at the upper posterior part of the pelvic cavity. Coccyx is formed of five vertebrae below the sacrum. The first coccygeal vertebra is the largest and looks like the final sacral segment. (Standring, 2015). Sacrum and Coccyx are supplied by lateral and median sacral arteries (Chenin et al., 2018). Spinal veins drain into venous plexuses located inside and outside the vertebral canal (Sattar and Guthrie, 2019). Sacral dimensions show high sexual dimorphism so it is important in estimation of sex (Zech et al., 2012). Identification of sex, age, and stature is highly important. Sex determination is one of the most important traits for assessment of personal identity as identification of age and stature depends on it. So, it is a routine practice in remains identification (Srivastava et al., 2012).

The skeletal features are different between males and females and these differences can be seen in hard and soft tissues**.** Sex determination can be done with ease in adults due to full expression of sex criteria. Some sexual characteristics appear in adolescence; however it is difficult to determine sex before puberty (Zech et al., 2012, Steyn, 2013). The accuracy of remains sexing is 100% in case of complete skeleton, pelvis alone 95% and skull alone 90%. (Chole et al., 2013). Computed tomography scan is an imaging procedure that produces multiple images according to different tissue structure (Liguori et al., 2015). CT is a useful imaging method which can be used in the process of human identification and has multiple advantages as compared to traditional radiographic methods (Kallalli et al., 2016). Therefore, this study aimed to determine forensic sex using sacrum and coccyx CT on a sample of Libyan population in Benghazi through measuring ASL, PSL, ASCL, PSCL, ASW, CLS, LAS, MDB and MTDB.

II. SUBJECT AND METHODS

A cross-sectional study was carried out in Radiological center of Aljala Hospital of Benghazi and Benghazi Medical Center, Libya on 120 subjects of both sexes .The period of the study was six months. Approval of the study was obtained from the Department of Forensic Medicine and Clinical Toxicology and Institutional Review Board (ZU-IRB#5785). IRB), Faculty of Medicine, Zagazig University. Written consent for participation was taken from every research subject.

II.1. Subjects:

This study included 120 libyian subjects (60 males and 60 females).Inclusion criteria included libyian populations of both sex aged from $\geq$ 21 to 60 years. Exclusion criteria included Age < 21or >60 years, patients with known congenital or acquired skeletal diseases or pelvic trauma, , pelvic bony malformation, pelvic bone tumor, sacra showing pathological fusion and presence of lumbar vertebral fracture or fixation.

II.2. Methods:

Computed tomography was done on 128 slice CT Machine by Siemens Germany Ltd. The scanning area includes the region of the whole pelvis. The imaging protocol was: column 1 mm, voltage of tube of 120 kV and tube current 110 mA. Measurements used mid-sagittal plane and 3D images were also taken (Zhan et al., 2018). Along the period of the study, sex was determined through measuring ASL, PSL, ASCL, PSCL, ASW, CLS, LAS, MDB and MTDB. ASL, PSL, ASCL, PSCL and CLS were measured from mid-sagittal plane images, while ASW, MDB, MTDB and LAS were measured from 3D reconstructed images (Torimitsu et al., 2014).

II.3. Statistical Analysis:

Data were analyzed using Microsoft Excel software. Data were then imported into SPSS (version 20.0) *(*IBM, 2017). P value was set at <0.05 for significant, P <0.01 for high significant, P <0.001 for very high significant and P >0.05 for non-significant results. Student -t –test was used for comparison of means of two independent groups. Receiver operating characteristic (ROC) curve is a graphical plot which illustrates the performance of a binary classifier system .It was used to determine sex by plotting the fraction of true positives out of the positives (TPR = true positive rate) vs. the fraction of false positives out of the negatives (FPR = false positive rate), at various threshold settings. Multivariate logistic regression was used to determine independent predictors of sex estimation

III.RESULTS:

   III.1. Demographic data of the studied groups*:* The results of the present study showed no significant difference between the mean age of males (44.43±7.88) and that of females (41.86±8.3) (Figure 1).

III.2. Sex determination from sacral and coccygeal parameters:

III.2.1. Comparison between males and females as regard sacral and coccygeal CT parameters: There was very high significant difference (p<0.001) between the mean values of ASL, PSL, ASCL, PSCL, CLS, LAS and MDB for males (10.92±0.66, 10.99 ±0.44, 12.66±0.62, 13.38±0.52, 14.94±0.24, 7.33± 0.32 and 4.40± 0.80, respectively) and that for females (10.07±0.48, 10.10±0.58, 11.18±1.37, 11.74±0.71, 13.71 ±0.246, 6.54±0.53 and 3.41± 0.34, respectively) using student-t test. Regarding MTDB, there was very high statistical significant difference (p<0.001) between the mean values for males (11.48±0.37) and that for females (12.09±0.45).Females were higher than males. Regarding ASW, there was no significant difference (p>0.05) between the mean values of males (11.26±0.45) and that of females (11.17±0.33) (Table 1, Figure 2 and Figure 3).

III.2.2. Detection of sacral and coccygeal parameters cutoff levels, validity and its accuracy to determine sex: Demarking points (cutoff levels) were calculated using the mean values of males and females. The calculated value is a point above it an individual is considered a male and below it is considered a female. Measurements that showed high sexual dimorphism were CLS 99.0%, PSCL 98.3% and MDB 90.5% using ROC curve (Table 2, Figure 4).

III.2.3. Multivariate logistic regression for independent predictors for sex estimation: The results showed that PSCL, CLS and MDB were very high statistically significant (P <0.001) independent predictors for sex at a confidence interval 95% of study (Table 3).
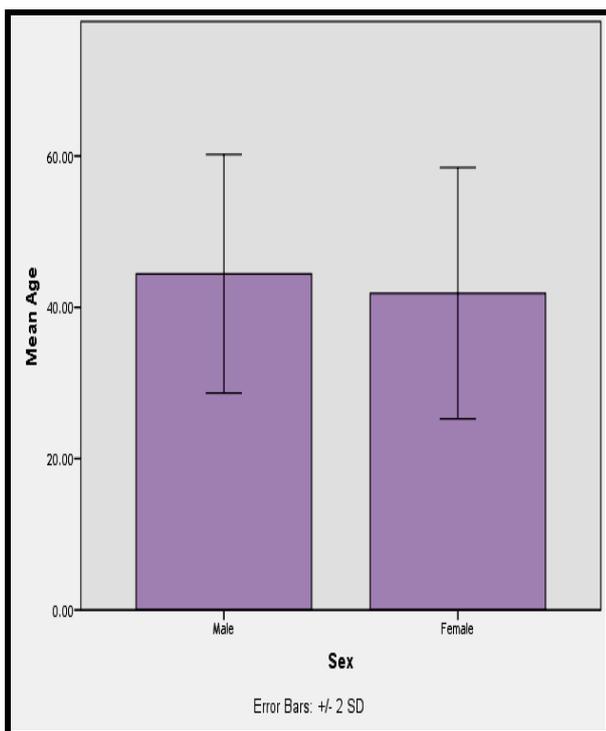
Figure. (1): Distribution bars showing the mean values of age in both males and females.
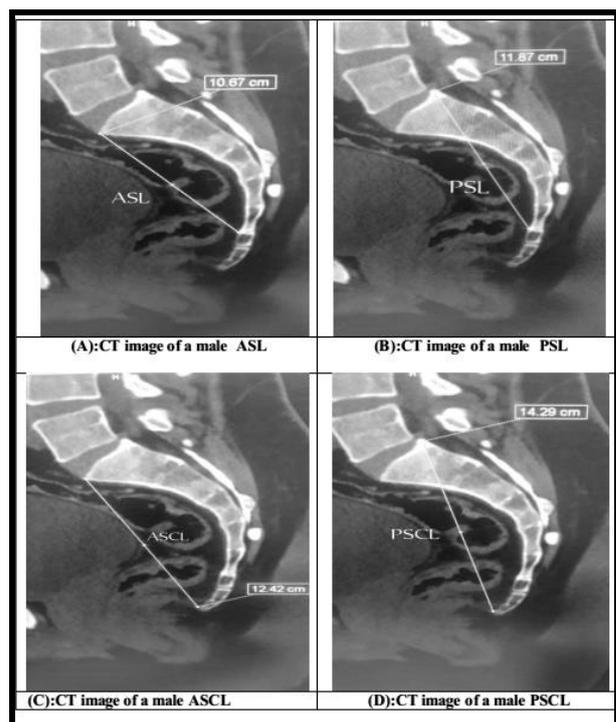
Figure (2): CT images showing a male ASL, PSL, ASCL and PSCL.

Table (1): Sacrum and Coccyx CT parameters distribution between males and females using student -t- test:

N=60	Sex	Mean	SD	T	P
ASL	Male	10.9250	0.66059	8.077	0.00**
	Female	10.0727	0.48143		
PSL	Male	10.9935	0.44489	9.317	0.00**
	Female	10.1065	0.58812		
ASCL	Male	12.6695	0.62804	7.580	0.00**
	Female	11.1875	1.37798		
PSCL	Male	13.3800	0.52578	14.334	0.00**
	Female	11.7420	0.71209		
ASW	Male	11.2653	0.45216	1.288	0.211
	Female	11.1720	0.33280		
CLS	Male	14.9465	0.24125	38.365	0.00**
	Female	12.5105	0.23214		
LAS	Male	7.3360	0.32700	9.745	0.00**
	Female	6.5450	0.53702		
MDB	Male	4.4095	0.80391	8.813	0.00**
	Female	3.4130	0.34769		
MTDB	Male	11.4842	0.37985	-8.045	0.00**
	Female	12.0965	0.45092		

. P: Probability**: Very high significant   t: Student -t-Test SD: Standard deviation. N: Number of subjects in each group.ASL: Anterior sacral length/ PSL: Posterior sacrococcygeal length/ ASCL: Anterior sacrococcygeal length /PSCL: Posterior sacrococcygeal length / CLS: Curved length of sacrum / LAS: Length of the auricular surface/ MDB: Mid-sagittal diameter of base / MTDB: Maximum transverse diameter of base.

(A): CT image of a female CLS   (B): CT image of a female ASW   (C): CT image of a female MDB   (D): CT image of a female MTDB

Figure (3): CT images , (A) is a CT image showing a female CLS. (B, C, D) are 3D CT images showing a female ASW, MDB and MTDB.

Table (2): Area under curve, cutoff, validity and accuracy parameters to determine the sex:

Test Result Variable(s)	Area	Cutoff	P	Sensitivity	Specificity	Accuracy
ASL	0.793	>10.320	0.00**	62.5%	59.8%	60.0%
PSL	0.912	>10.520	0.00**	80.0%	70.0%	73.3%
ASCL	0.820	>12.080	0.00**	60.0%	60.0%	60.0%
PSCL	0.979	>12.590	0.00**	98.8%	97.5%	98.3%
CLS	0.998	>13.222	0.00**	99.0%	99.0%	99.0%
LAS	0.847	>6.950	0.00**	75.0%	60.0%	72.0%
MDB	0.973	>3.750	0.00**	82.0%	98.8%	90.5%
MTDB	0.800	<11.77	0.00**	65.0%	58.6%	61.7%

**: Very high significant (P value<0.001; %: percent; ASL: Anterior sacral length/ PSL: Posterior sacrococcygeal length/ ASCL: Anterior sacrococcygeal length/ PSCL: Posterior sacrococcygeal length / CLS: Curved length of sacrum /LAS: Length of the auricular surface/ MDB: Mid-sagittal diameter of base / MTDB: Maximum transverse diameter of base.
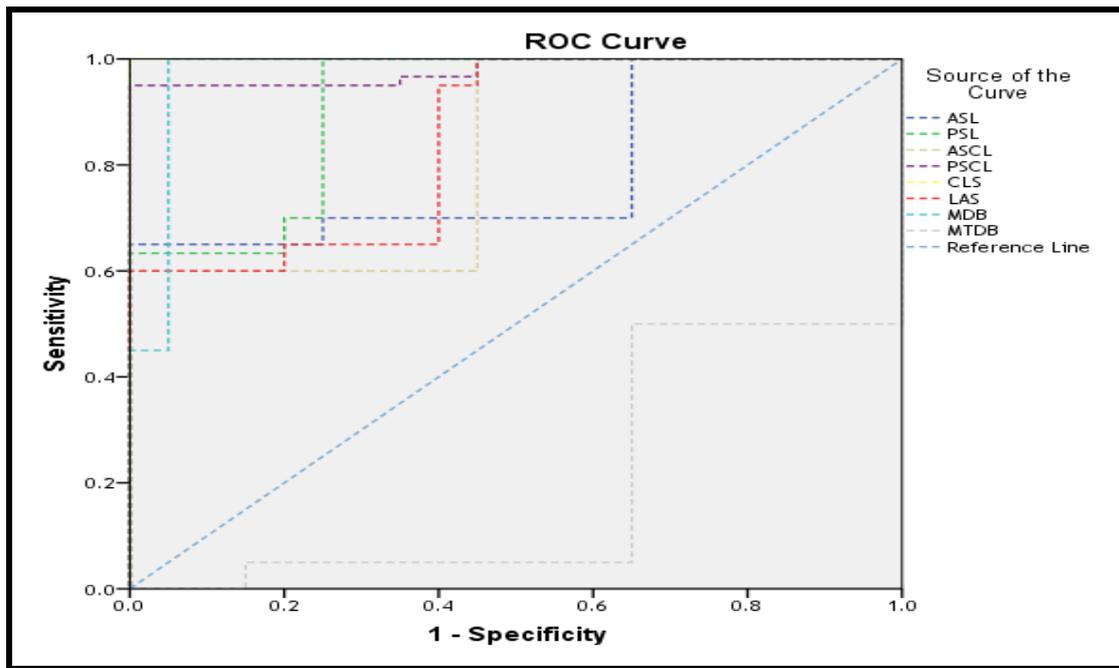
Figure (4): ROC curve for detection of cutoff regarding sex determination in males and females.

Table (3): Multivariate logistic regression for independent predictors for sex estimation:

Variable (s)	Wald test	P	OR	CI (95%)
ASL	1.7957	0.1254	2.123	(0.687-6.36)
PSL	2.1456	0.0987	2.514	(0.927-8.63)
ASCL	1.8412	0.1185	2.213	(0.745-5.21)
PSCL	6.2514	0.00**	4.231	(1.87-10.25)
CLS	7.2145	0.00**	5.123	(2.14-18.52)
LAS	1.9654	0.1023	2.312	(0.95-10.23)
MDB	5.9854	0.0002**	4.123	(1.25-9.252)
MTDB	1.8123	0.1121	0.189	(0.847-5.21)

P: Probability OR: Odds ratio CI: Confidence interval. **: Very high significant; ASL: Anterior sacral length/ PSL: Posterior sacrococcygeal length/ ASCL: Anterior sacrococcygeal length/ PSCL: Posterior sacrococcygeal length / CLS: Curved length of sacrum / LAS: Length of the auricular surface / MDB: Mid-sagittal diameter of base / MTDB: Maximum transverse diameter of base.

IV. DISCUSSION

Morphometric estimation of sex from pelvic bones is important especially in cases of fragmented remains. Accuracy of sex determination helps completeness of full biological profile. (Berg, 2012). CT scanning is useful in forensic work especially in postmortem anthropology (Thali et al., 2010). Post mortem CT scan is valuable in cases of charred bodies. CT can be used to detect age, body height and cause of death. CT scans create databases for forensic anthropology (Zech et al., 2012). This study aimed to estimate sex from measurements of the sacrum and coccyx by CT in Libyan population. In the present study, sex was determined through the measurement of ASL, PSL, ASCL, PSCL, ASW, CLS, LAS, MDB and MTDB by using sacrum and coccyx CT. Regarding the demographic data of the present study, there was no significant difference between the mean age of males and that of females. The results of this study showed high significant increase in mean values in males regarding ASL, PSL, ASCL, PSCL CLS, LAS and MDB. While females were higher than males regarding the mean values of MTDB .There was no significant difference regarding ASW between males and females. In the line with the results of the present study, Mishra et al. (2003) observed that the mean values of maximum length, curved length of sacrum and length of auricular surface of sacrum were higher in males than females. Additionally,

Torimitsu et al. (2017) found that the mean values of ASL, PSL, ASCL and PSCL were higher in males than females. Consistent with the results of the present study, Zhan et al. (2018) demonstrated that the mean values for males were higher than females considering ASL, PSL, ASCL, PSCL, CLS, LAS and MDB while MTDB was higher in females. To explain the differences between the mean values of male and female parameters, Lazarevski (2004) stated that the aging process causes backward and downward displacement of the sacrum so the height of sacrum decreases with age in females.

In contrast with the results of the present study Zhan et al. (2018) founded that the mean values of the ASW were higher in females than males. To explain that Torimitsu et al. (2017) found that similar methods produce different results in different races.

The result of present study showed measurements that showed accurate sex determination were CLS 99.0%, PSCL 98.3% and MDB 90.5%using Roc curve .These parameters were high significant independent predictors for sex at a confidence interval 95% of study.Sexual dimorphism is physical and behavioral differences found between males and females. (Franklin et al., 2012). The age at which these changes appear depends on genetic and environmental factors. As its occurrence varies between populations, sex determination is population specific (Torimitsu et al., 2017). In the line with the results of the present study, Torimitsu et al. (2017) and Zhan et al.(2018) who found that the most significant sex difference was PSCL . In contrast with the results of the present study, Etli et al. (2019) found that the most dimorphic parameter was PSL. Populations show frequent variations in biological traits, so to develop standard measurement from collection of bones, these measurements should be repeated at regular intervals (Ross et al., 2011). Franklin et al. (2014) observed a sex accuracy rate of < 70% of sacrum in Australian population. Zech et al. (2012) reported that sacral CT showed accuracy < 80% in a Swiss people while in American citizens, the transverse diameter of the base had accuracy rate 91% in black and 84% in white people.

V. CONCLUSION

There was no significant difference between mean values of age of males and females. Males were higher than females regarding mean values of ASL, PSL, ASCL, PSCL, CLS, LAS and MDB. While, females were higher than males regarding mean value of MTDB. The most sexually dimorphic individual measurements for sex determination found in the study were CLS 99.0%, PSCL 98.3% and MDB 90.5%.

VI. RECOMMENDATION

The results of this study can be used in forensic identification. These formulae are specific to Libyan population. Sex determination standards expressed in the present study can be applicable in criminal cases and forensic investigations. Other studies on other bones and techniques should be done.

VII. CONFLICTS OF INTEREST:

There were no conflicts of interest in the study.

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تقدير الجنس باستخدام الأشعة المقطعية للعظم العجزي والعصعصي للسكان الليبيين في بنـغـازي

الهام الشوادفى عبدالسميع مجاهد١، فاطمة يوسف فرحات١ ، أحمد علي أحمد حمد٢

١ أقسام الطب الشرعى والسموم الإكلينيكية-كلية الطب جامعة الزقازيق- مصر. ٢طبيب شرعى بمركز الخبرة القضائية والبحوث اجدابيا – ليبيا ،

المقدمة: يعد تحديد الجنس ضروريًا لدراسات علم الآثار البيولوجية والطب الشرعي. كما أنه هام لتحديد الهوية الشخصية ويعتمد تحديده بدقة على وجود بقايا كاملة . **هدف البحث**: هدف هذا البحث إلى تحديد الجنس من قياسات العجز والعصعص بواسطة التصوير المقطعي للسكان الليبيين.**الطريقة والأشخاص ا**: أجريت هذه الدراسة المقطعية في مركز الأشعة بمستشفى الجلاء في بنغازي ومركز بنغازي الطبي بليبيا على ١٢٠ شخصًا تم تقسيمهم إلى ٦٠ ذكرًا و ٦٠ أنثى. تم تحديد الجنس من خلال قياس الأطوال العجزية الأمامية والخلفية، أطوال العجز العصعصى الأمامي والخلفي، العرض العجزي الأمامي، الطول المنحني للعجز، طول السطح الأذني، القطر منتصف السهمي والقطر العرضي الأقصى للقاعدة باستخدام التصوير المقطعي للعجز والعصعص.**النتائج**: كان هناك فروق ذات دلالة إحصائية عالية جدًا بين متوسطات قيم المتغيرات المدروسة بين الذكور والإناث ، حيث كانت جميع هذه القياسات أعلى في الذكور باستثناء القطر العرضى الأقصى للقاعدة الذي كانت قيمه المتوسطة أعلى عند الإناث. فيما يتعلق بالعرض العجزي الأمامي ، لم يكن هناك فرق كبير بين متوسط القيم للذكور والإناث. كانت القياسات الجنسية الأكثر دقة هي الطول المنحني للعجز والطول العجزي العصعصي الخلفي والقطر منتصف السهمي .**الخلاصة:** كانت نسبة الذكور أعلى من الإناث فيما يتعلق بالقيم المتوسطة لجميع المتغيرات المدروسة باستثناء القطر العرضي الأقصى للقاعدة الذي كانت قيمه المتوسطة أعلى في الإناث. كانت القياسات الجنسية الأكثر دقة هي الطول المنحني للعجز والطول العجزي العصعصي الخلفي والقطر منتصف السهمي . **التوصيات** : يجب إجراء دراسات أخرى باستخدام تقنيات وعظام مختلفة.