SEX IDENTIFICATION FROM RADIOLOGIC ANTHROPOMETRY OF SACRAL AND FIFTH LUMBAR VERTEBRAL MEASUREMENTS

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ABSTRACT

Forensic identification using new anthropological standards were developed to be applied to a specific population. Bone Computed Tomography (CT) reconstruction images have been reported in this forensic field. This study aimed to assess the sexual dimorphism by measuring the upper end plate width of fifth lumbar vertebra as well as anteroposterior diameter, transverse diameter, perimeter, area of the first sacral vertebra and width of sacral ala using abdominal computed tomography in 200 adult Egyptians. All measurements showed significant difference in sex identification except the width of sacral ala.

Key words: sex, sacrum, fifth lumbar vertebra, computed tomography

INTRODUCTION

Sex identification of suspect is an essential task in forensic science that minimizes the search population of suspects **(Wadhwa et al.; 2013)**. Many human body features have been used to estimate sex, some examples include foot print ratio, metatarsals, long bones of the arm, foot shape, femoral head, foot, shoe dimensions, patella, teeth, radial and ulnar bones **(Wang et al.; 2008).**

Sex determination can be conducted through two methods, morphologic and metric **(Ogawa et al.; 2013).** Metric method was preferred due to its easy repeatability, high accuracy, and no requirement for special skill **(Akhlaghi et al.; 2012).**

The lumbar vertebrae are the largest segments of the movable part of the vertebral column that can be distinguished by the absence of a foramen in the transverse process and by the absence of facets on the sides of the body (**Moore and Dalley, 2006).** The body of the first segment of the sacrum is the largest size while the succeeding ones diminish from above downward. Its form resembles that of a lumbar vertebra. Both L5 and S1 vertebrae can be used in sex determination **(Ludwikowski et al.; 2002 and Zheng et al. 2012).**

AIM OF THE WORK

This study is aiming to:

– Emphasize the role of pelvic bone, lumbar vertebral measurements in sex determination.

– Creating local identification standards for pelvis and fifth lumbar vertebra.

METHODOLOGY

The present study was performed on 200 adult Egyptian patients (109 males and 91 females), who presented to the Diagnostic and interventional

Radiological Department, Faculty of Medicine, Cairo University for abdomino-pelvic multi-slice computerized tomography (MSCT).

The Ethics Committee of Faculty of Medicine, Cairo University approved this study, and all the patients included in the study signed an informed consent document. The following exclusion criteria were used to ensure normal bone evaluation: skeletal immaturity, fracture, pathological lesions such as congenital developmental dysplasia, metabolic bone diseases or surgery, tumors and osteoarthritis.

Radiological CT technique:

The fifth lumbar vertebra and the first sacral segment measurements were determined by means of three dimensional image processing on an independent work station after doing a new recon with 1.5 mm slice width; bone window and sharpness B70 for optimum visualization using the software program analyze (Syngo VB 42). The patient was laid down in the supine position and no contrast was needed.

In this work six measurements; were assessed, one for the fifth lumbar vertebra and five for the first sacral vertebra. According to **Zech et al. (2012),** all measurements were in mm except the area in cm^2

1- Width of the upper end plate of the fifth lumbar vertebra (L5): the maximum distance between the most two lateral points **Fig. (1-A)**.

2- **First Sacral vertebra (S1):**

a. **Maximum transverse diameter (m.t.d):** the maximum distance between the two most lateral points **Fig. (1-B)**.

b. **Antero-posterior diameter (a.p.d):** the maximum distance between the two most anterior and posterior projecting points **Fig. (1-B)**.

c. **Area:** calculated by the software analyzer **Fig. (1-C)**.

d. **Maximum transverse diameter between the sacral ala:** the maximum distance between the farthest two points of the sacral ala **Fig. (1-D)**.

e. **Perimeter:** Calculated from the equation = $2 \times \pi \times \sqrt{\frac{r1^2 + r2^2}{2}}$

Where π: is Pi; approximately 3.14, r1 is the m.t.d and r2 is the a.p.d

Data analysis

The data was coded and entered using the statistical package SPSS version 15. The data was summarized using descriptive statistics: mean, standard deviation, minimal and maximum values for quantitative variables and number and percentage for qualitative values. Statistical differences between groups were tested using independent sample t test for quantitative normally distributed variables. Discrimination between males and females was evaluated by Receiver Operating Characteristic (ROC) curve analysis. Logistic regression analysis was used to test for significant predictors of individual sex. p-values less than or equal to 0.05 were considered statistically significant.

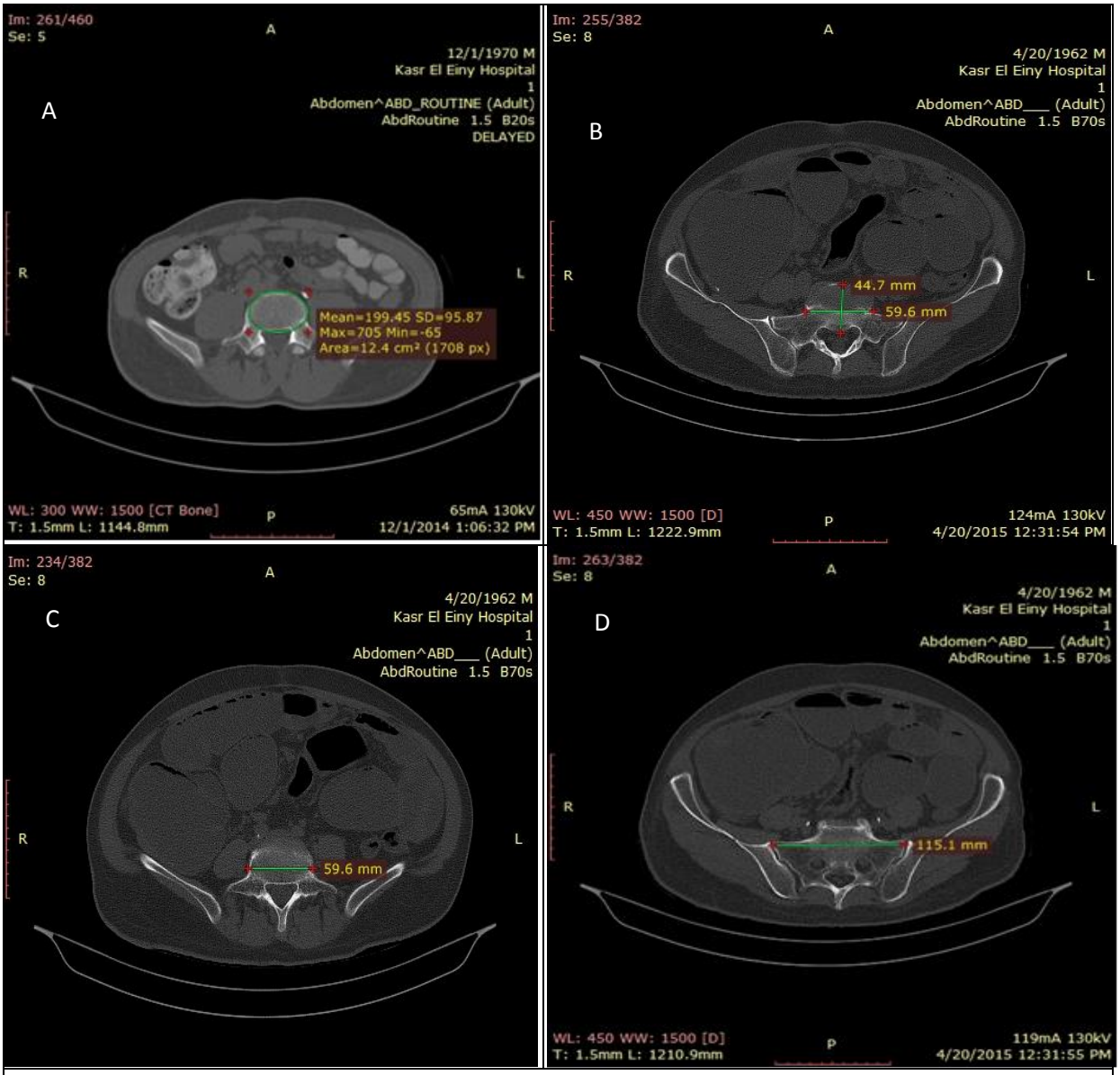

Figure (1): Abdominal C.T scan showing:
A: width of the upper end plate of L5,
B: the maximum transverse diameter and antero-posterior diameter of S1,
C: the area of S1and
D: the maximum breadth of the sacral ala

RESULTS

The sample in the present study consisted of 109 males (54.5%) and 91 females (45.5%) with mean ages of (46.4±11.9 years) and (42.67±11.85 years) respectively **(Table 1)**.

Table (1): Demographic data of the studied subjects

Sex	Number	(%)	Age (Mean ± SD)
Males	109	(54.5%)	46.4±11.9
Females	91	(45.5%)	42.67±11.85
Total cases	200	(100%)	44.7±12.02

A-CT measurements in the studied groups (Student (t) test):

1- Width of the upper end plate of L5:

Regarding the width of the upper end plate of L5; females had statistically significant lower values compared to males; their values ranged between 41.6 mm and 66.9 mm with a mean of 51.57±4.59 mm (p<0.001**) **(Table 2)**.

Table (2): Student (t) test evaluating the difference in L5 measurements between the studied female and male groups

	Female group			Male group			Student (t) test	p-value
	Max.	Min.	Mean ±SD	Max.	Min.	Mean ±SD		
L5	66.9	41.6	51.57±4.5	69.8	45.5	54.74±5.3	-4.4	<0.001**

**Significance was set at p≤0.05

2- First sacral vertebra:

Descriptive statistics for the first sacral vertebra measurements were presented in (**Table 3)**. It is apparent that all S1 measurements were lower in females than males. Four measurements; m.t.d, a.p.d, area and perimeter showed significant difference in sex identification (p≤0.05)**.**

Table (3): Student (t) test evaluating the difference in five S1 measurements between the studied female and male groups

	Female group			Male group			Student (t) test	p value
	Max.	**Min.**	**Mean ±SD**	**Max.**	**Min.**	**Mean ±SD**		
m.t.d	61.4	39	51.71±5.1	74.6	35.5	54.79±6.0	-3.8	<0.001**
a.p.d	59.2	30.6	40.57±5.5	59.6	30.5	42.4±5.23	-2.4	<0.015**
Ala breadth	118.7	90.3	107.59±6.3	127.1	76.2	108.3±7.6	-0.6	<0.504
Area	26.8	10.5	16.5±3.1	31.8	9.9	18.2±3.63	-3.6	<0.001**
Perimeter	18.8	11.8	14.5±1.3	20	11.1	15.3±1.6	-3.8	<0.001**

m.t.d (maximum transverse diameter of S1), a.p.d (the anteroposterior diameter of S1), ** Significance was set at p≤0.05

Receiver Operating Characteristic (ROC) curve:

Area under this curve measures the ability of the tested parameter to correctly discriminate between two groups (males & females). Area under the ROC curve is divided into four zones; A(0.9-1:excellent), B (0.8-0.89:good), C (0.7-0.79: fair), D(0.6-0.69: poor) and E (0.5-0.59: failure). Regarding the Roc curve values in our study; all measurements were in the D zone except the breadth of the sacral ala was in E zone. **(Table 4 and Fig. 2)**.

Table (4): Area under the ROC curve for all studied measurements

Variables	Area	Sig.	95% confidence interval	
			Lower bound	Upper bound
L5	0.665	< 0.001**	0.591	0.740
a.p.d	0.609	< 0.008**	0.530	0.687
m.t.d	0.652	< 0.001**	0.576	0.727
Area	0.648	< 0.001**	0.572	0.724
Perimeter	0.657	< 0.001**	0.582	0.733
Ala breadth	0.523	0.574	0.443	0.603

**Significance was set at p≤ 0.05

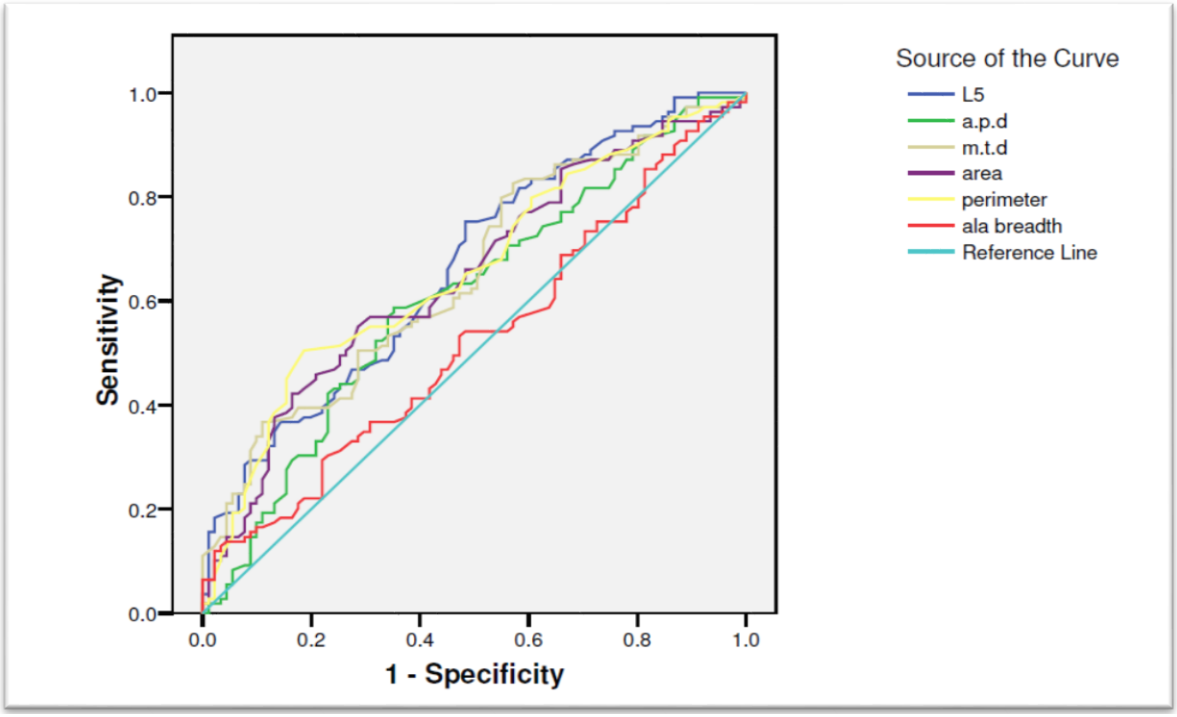

Fig. (2): ROC curve for all studied parameters

Moreover, cut off values, their specificity and sensitivity in correct sex classification for males and females using L5 and S1 measurements were represented in **(Table 5)**. A subject is considered male if his measurements are above the mentioned values and vice versa.

Table (5): Cut off values, their sensitivity and specificity of measured parameters indicating male sex

Measured parameters	Cut off value	Sensitivity	Specificity
L5	51.1	71%	52%
a.p.d	40.1	63%	53%
m.t.d	52.4	62%	52%
Area	16.5	66%	52%
Perimeter	14.6	65%	52%

In the logistic regression statistics using age, we found that the width of the upper end plate of L5 was the only significant variable in sex determination **(Table 6)**

Table (6): Logistic Stepwise Regression Statistics depending on L5 as variable

Step	B	Sig.	95% confident interval	
			Lower	Upper
L5	0.130	0.000**	1.069	1.213
Constant	-6.7			

****Significance was set at p≤0.05**

The accuracy of L5 in sex determination was found to be 59.5% **(Table 7)**.

Table (7): The accuracy of the logistic regression using L5 analysis in sex prediction

Sex		Predicted sex Count (%)				Total
		Male		Female		
		N	%	N	%	
Actual sample	Male	69	63.4%	40	36.6%	109(100%)
	Female	41	45%	50	55%	91(100%)
Overall percentage						59.5%

DISCUSSION

Human identification depending on radiological image technique analysis is a practice and a proper method in forensic science field **(Franklin, 2010). Sex** determination from skeleton remains is essential forensic step, as this helps in identification of missing person **(Stavrianos et al.; 2009).** Metric data of the S1 measurements, (a.p.d), (m.t.d), area, perimeter and ala breadth, and width of the upper end plate of L5 were used in this study. All measurements showed higher males values and statistically significant difference between male and female subjects ($p<0.05$*) except the sacral ala breadth.

The results of the present study matched with **Steyn & Iscan (2008)**, **Benazzi et al. (2009), Zech et al. (2012)** and **Franklin et al. (2014),** while it did not match with **Steyn & Patriquin (2009**) who found a statistically significant difference between males and females regarding measurements of ala breadth. This may be due to different research method and population **(Table 8).**

Table (8): Comparison of the present study with previously published studies regarding sex determination using S1 measurements

Authors	Population (No)	Research method	Measured parameters	Accuracy
Present study	Egyptians (200)	CT	m.t.d, a.p.d, area, perimeter and ala breadth	Perimeter (69.6%)
Benazzi et al. (2009)	Italian (114)	Digital camera	m.t.d, area, perimeter and ala breadth	Area (86.9%)
Steyn & Patriquin (2009)	South Africa (white and black (399), and Greeks (193)	Bone	ala breadth, pubic length, ischial length, greater sciatic notch breadth and greater sciatic notch depth	Ala breadth& pubic length in white, black and Greeks (80.3%, 85.6% and 82.6%)
Zech et al. (2012)	Swiss (95)	CT	m.t.d, a.p.d, area, perimeter and ala breadth	Perimeter& a.p.d (78.9%)
Franklin et al. (2014)	Australian (400)	CT	m.t.d, a.p.d, pelvic inlet and outlet	Sacral data (69%) All data (100%)
Steyn & Iscan (2008)	Greeks (192)	Bone	m.t.d, a.p.d, pubic length, ischial length, greater sciatic notch (breadth& depth) and acetabular diameter	m.t.d& a.p.d (60.9%)

(No): number

By applying the ROC curve, we found that the most significant parameter in sex determination from S1 measurements is the "perimeter" parameter with an accuracy of about 69.6%. The forward stepwise regression analysis of all parameters didn't show any significant improvement as it showed 68.8% prediction probability, while using the a.p.d showed 66% accuracy; the area showed 68% prediction probability, while the m.t.d showed 68.9% prediction probability accuracy.

Table (9): Comparison of the present study with previously published studies regarding sex determination using L5 measurement

Authors	Population (No)	Research subjects	Measured parameters	Accuracy
Present study	Egyptians (200)	CT	Width of upper end plate L5	Width of upper end plate (60%)
Zheng et al. (2012)	Chinese (210)	CT	Width of upper and middle end plate. Moreover height of the left pedicle.	Width of upper end plate (85%) All data (89%)
Tan et al. (2002)	Asian (60)	Bone measuerments	Width, area and depth of both upper and lower end plate. Moreover spinal canal and pedicle measurements.	Not determined

The present findings were on the same line with those of **Tan et al. (2002) and Zheng et al. (2012)**, They concluded that, lumbar vertebrae could be used in determination of sex among the studied

groups. Moreover the accuracy rate in **Zheng et al. (2012) study is** 25% higher thanthe precent in the present work . This difference may be due to different sample type and size.

CONCLUSION

CT scan was a valuable method in measuring the selected pelvic sacral dimensions (maximum transverse diameter, antero- posterior diameter, area, perimeter, length of sacral ala) as well as fifth lumbar vertebral dimension (upper end plate width). The most accurate dimension in estimating sex is the perimeter of S1 with accuracy 69.6% then the upper end plate width of L5with accuracy60%

RECOMMENDATIONS

1- More researches are needed to coup with the increasing numbers of unidentified skeletons all over the world.

2- More parameters should be tested to increase the accuracy of sex determination

3- Logistic regression is population specific; that need more researches on different populations.

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الملخص العربى

تحديد الهوية الجنسية باستخدام الاشعة المقطعية عن طريق استخدام معايير انثروبولوجية على الفقرة القطنية الخامسة والعجزية

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تم تحديد الهوية باستخدام معايير أنثروبولوجية جديدة ليتم تطبيقها على مجموعة سكانية محددة وذلك بإستخدام الأشعه المقطعيه علي العظام فى مجال بالطب الشرعي.

هدفت الدراسة لتقييم دور بعض قياسات الفقرة الخامسة القطنية والفقرة العجزية الأولي (آلا) في تحديد الجنس و تم استخدام القياسات التاليه:عرض الطبقة العليا للفقرة القطنية الخامسة ، محيط الفقرة العجزية الأولي ، طول الفقرة العجزية الأولي من الأمام للخلف ، مساحه الفقرة العجزية الأولي ، عرض الفقرة العجزية الأولي وقياس الألا العجزية .

تم أخذ القياسات بواسطه الأشعه المقطعيه لعدد ٢٠٠ شخص من قسم الأشعه بالقصر العيني وقد وقع جميع المرضى التي شملتهم الدراسة وثيقة الموافقة المسبقة.

وكانت كل القياسات ذات دلاله احصائيه ما عدا قياس الالا العجزيه