Reliability of Multi Slice Computed Tomography in Sex Identification from Lumbar Vertebrae on a Sample of Libyan Population

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ABSTRACT
Background: Because of how heavily sex plays into future techniques of estimating age and stature, determining a person's sex is a crucial biological factor in defining personal identity. It's crucial for narrowing down the list of possible IDs. As such, it is one of the common methods used in forensics, especially in cases involving unidentified human remains and in disaster victim identification (DVI).
Objective: The aim of the current study was to identify the human sex by lumbar vertebra multi-slice CT (MSCT) on a sample of Libyans.
Subjects and methods: A cross-sectional study was conducted on a total of 98 subjects (49 males and 49 females). Group I included 49 males aged between 0 and 60 years, and Group II included 49 females aged between 10 and 60 years. All individuals were subjected to lumber vertebras (L1-L5) measurements to determine sex using multi-slice CT.
Results: All measured parameters significantly increased in the first lumbar vertebrae to fifth lumbar vertebrae among males compared to females. Regarding detection of L1 to L5 parameters cut-off levels and their accuracy to estimate sex, males showed significantly higher parameters and the most accurate measurement was upper border (end plate) width (EPWu). **Conclusion:** sex can be reasonably determined from the first to the fifth in lumbar vertebrae for legal and humanitarian circumstances.
Keywords: Lumbar Vertebrae, Sex identification, Multi Slice Computed Tomography.

INTRODUCTION
Historically, forensic anthropologists and forensic morphologists have used morphological and anthropometric techniques to estimate sex from skeletal remains [(1)]. In forensic anthropology, determining a skeleton's gender is crucial since it cuts the number of potential matches in half [(1)].

Vertebral morphological changes, such as marginal bony lipping or osteophytes development, play a significant part in deciphering ageing patterns, complementing sexual dimorphism in other ways [(2)].

When anthropologists are confronted with a small number of bones from an unknown individual, or when several bones are missing or shattered as a result of environmental factors, they are sometimes asked to provide a reliable estimate of the age and sex of the individual. Disarticulation, dispersion, and commingling are all ways in which skeletal remains studied at archaeological or forensic sites might be damaged [(3)].

Five different measurements related to the vertebral body were shown to have an accuracy rate of over 80%, with the greatest contribution played by measurements collected from the first lumbar vertebra (L1) [(4)].

Forensic medicine has been greatly aided by recent advancements in cross-sectional imaging technology over the past decade. Computer tomography (CT) and magnetic resonance imaging (MRI) are just two examples of the 3D imaging technology that enable us to acquire high-resolution, high-quality virtual anthropology [(5)].

Post-mortem imaging with multi-slice computed tomography (MSCT) is gaining popularity [(6)]. To avoid offending religious beliefs or personal preferences, a virtual autopsy could be used in communities where performing one is socially unacceptable or outright illegal [(7)].

The aim of the current study was to identify the human sex by lumbar vertebra multi-slice CT (MSCT) on a sample of Libyans.

SUBJECTS AND METHODS
A cross-sectional study was conducted in the Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine at Zagazig University, and Judicial Expertise and Research Center (Libya), during the period from July to the end of December 2021. The estimated sample was 98 subjects, divided in to 2 groups; 49 males and 49 females.

Inclusion criteria:
- Age from 0 to 60 years.
- Males and females.
- Libyan populations.

Exclusion criteria:
- Age > 60 years.
- Presence of lumbar vertebra fracture or fixation.
- Lumbar vertebral deformity
- Presence of congenital or acquired lumbar vertebral diseases or trauma.
- Degenerative alterations in any vertebrae, especially those that are mild to severe, as these might cause distortion of borders and reading errors.
- Lumbar vertebrae showing pathological fusions.

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Groups of the study: The estimated sample was divided into two groups: Group I included 49 males aged between 0 and 60 years, and Group II included 49 females aged between 0 and 60 years.

Methods:

There were 98 Libyans participated in the study, ranging in age from 0 to 60. After receiving informed consent, patients in the Department of Radiology and the Orthopedic Trauma Center at Alkhums Hospital in Libya underwent an abdominal Computer tomography (CT) scan.

Patients at Alkhums Hospital's Orthopedic Trauma Center in Libya typically come from middle- and lower-income backgrounds. There were no signs of trauma or disease in the used vertebrae.

All individuals were subjected to lumbar vertebra (L1-L5) measurements to determine age and sex using multi-slice CT looking for variations in size as a function of sex and age along the lumbar vetebrae.

Researchers in Libya examined and evaluated the lumbar vertebrae (L1-L5) of people of all ages (0-60). All vertebral body heights, lengths, and widths are measured with a digital calliper.

Measuring methods:

Measurements were taken of the L1-L5 lumbar vertebrae. The following metrics were directly measured from each vertebral body and their ratios analysed: amid-sagittal heights of anterior and posterior vertebral bodies; lengths of the anterior and posterior (AP) vertebral bodies; widths of the superior, middle, and inferior vertebral bodies.

MSCT protocol for image acquisition:

MS-CT scanner was used to acquire the MS-CT images. Three-dimensional (3D) models of the first five lumbar vertebrae were linearly measured.

Position and Technique:

When using a scanner, patients often lie supine. About 0.625 mm CT-slices were acquired through the scanning process. The number of lumbar vertebrae was used to identify the vertebra. The lumbar vertebrae were modelled in 3D and then rotated, clipped, and measured.

All patients followed the same scan acquisition protocol to eliminate the possibility of technical differences in length measurements. All measures were obtained twice, at 2-week intervals, throughout the course of two separate times. The averages were computed so that the data could be analysed further. The same radiologist performed all of the examinations.

Reconstruction and post-processing considerations: High-quality 3D model reconstruction was accomplished on the workstation with commercially-available software employing surface shaded display and the volume rendering technique (Syngo 3D).

Measurements on the vertebrae 3D-CT images: Scans were optimised for visibility using the imaging equipment and software (Syngo VB 42), with settings of bone window, sharpness B70, and slice width of 1.5 mm.

Maximum intensity projection (MIP) pictures were used for the vast majority of the measurements to reduce the chance of error. To minimise the possibility of technical difficulties, all subjects followed the aforementioned routine.

In the workstation, a forensic pathologist who had been trained and supervised by a senior consultant radiologist took ten linear vertebral measurements, starting at the first lumbar vertebra and ending at the fifth.

The 10 parameters included vertebral body dimensions such as **(EPDu)** (end plate) of Upper border depth. **(EPWu)** (end plate) of Upper border**.** **(EPDl)** (end plate) of Lower border. **(EPWl)** (end plate) of Lower border. **(VBHa)** Vertebral body height as measured by the height of the anterior border. **(VBHp)** Vertebral body height, measured from the posterior. (**PW)** (Width) Pedicle dimensions. **(PH)** (Height) Pedicle dimensions. **(SPL)** (length) Spinous process, and **(SPH)** (Height) Spinous process.

These numbers were borrowed from **Zheng *et al.*** [8] with one key difference: instead of using 2D images of CT scans, these researchers used 3D images.

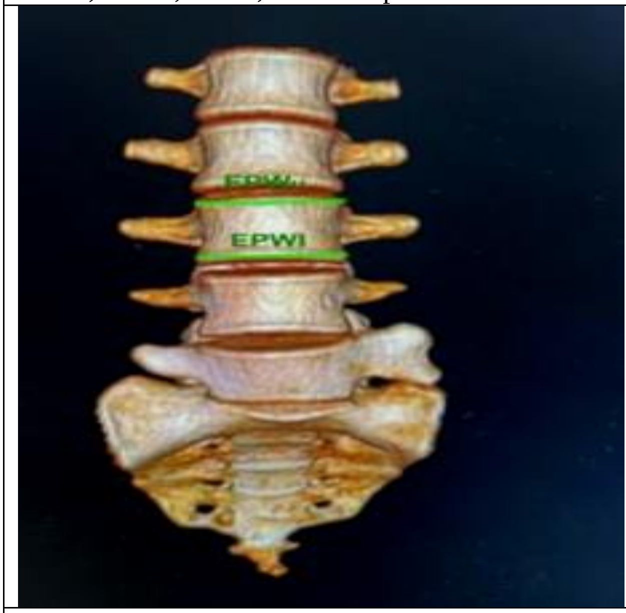
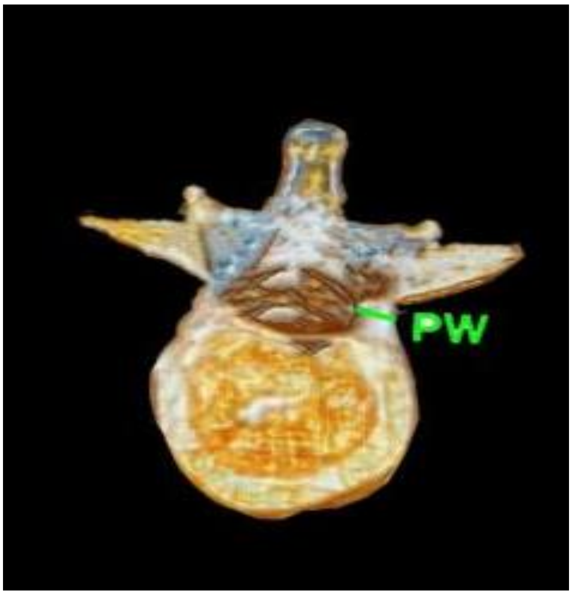
	
CT lateral view of lambar vertebrae showing EPDu, EPDl ,VBHa, and VBHp	CT lateral view of lambar vertebrae showing SPH, SPL and PH
	
CT anterior view of lambar vertebrae showing EPWu, and EPWi	CT superior view of lambar vertebrae showing PW

Figure (1): CT views of Lumbar vertebrae.

Ethical Consent:

This study was ethically approved by the Institutional Review Board of the Faculty of Medicine, Zagazig University (IRB Approval No. #:7033-30-6-2021). Written informed consent was obtained from all participants. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS) version 27.0 for windows. 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 non-parametric data was described as median and range. Independent sample student's t-test was used for comparison between groups. P value ≤0.05 was considered to be statistically significant.

The optimum cutoff values of several factors for maximal sensitivity and specificity in sex prediction were determined using receiver operating characteristic (ROC) curve analysis. The area under the ROC curve is a statistical measure of accuracy and looks like this: 0.90-1 for excellent (A), 0.80-0.90 for good (B), 0.70-0.80 for fair (C), 0.60-0.70for poor (D), and 0.50-0.60 for fail (F).

Reliability data were calculated using: Accuracy = (true positive + true negative)/ Total no. Demarking points (cut-off levels): which are determined by taking the average of male and female measurements; the resultant figure represents the cut-off at which a person is considered male and the cut-off for female status, respectively.

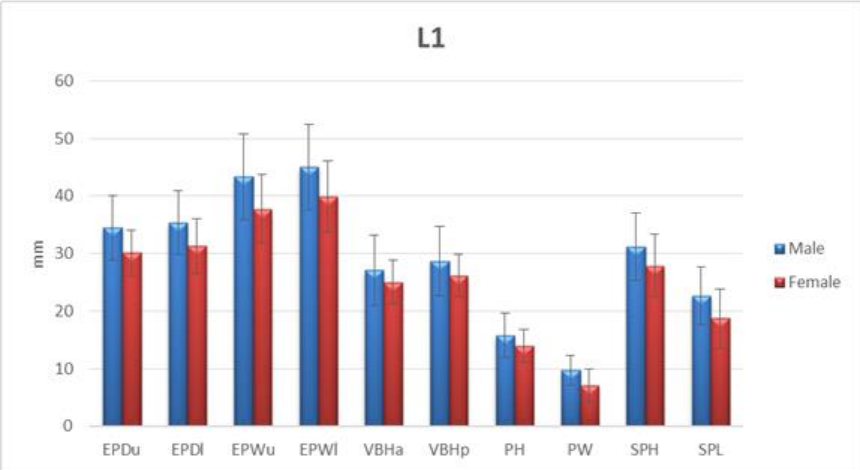
RESULTS

The average ages of the studied groups did not differ significantly from one another (**Table 1**).

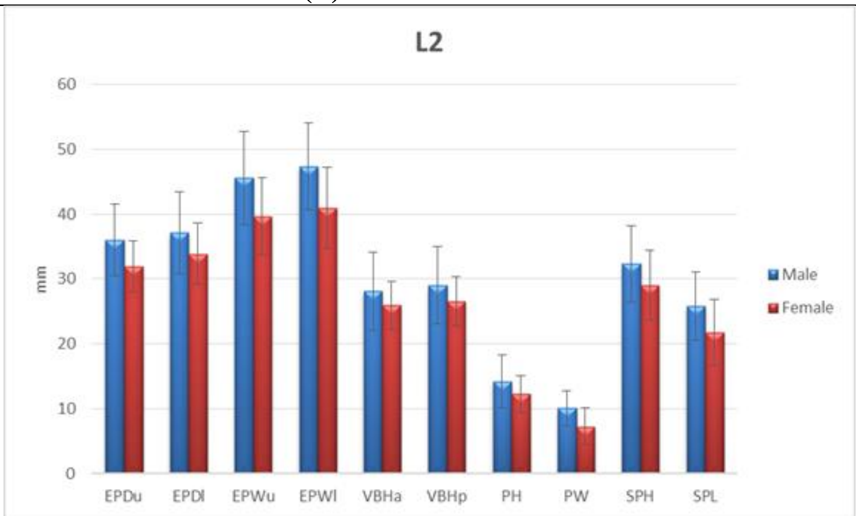
Table (1): Demographics characteristics of the studied groups.

Variable	Group I (Male; n =49)	Group II (Female; n =49)	t-test	P-value
Age: (years) Mean ± SD Range	37.06±15.69 10-60	35.24±15.97 10-60	0.57	0.57 NS

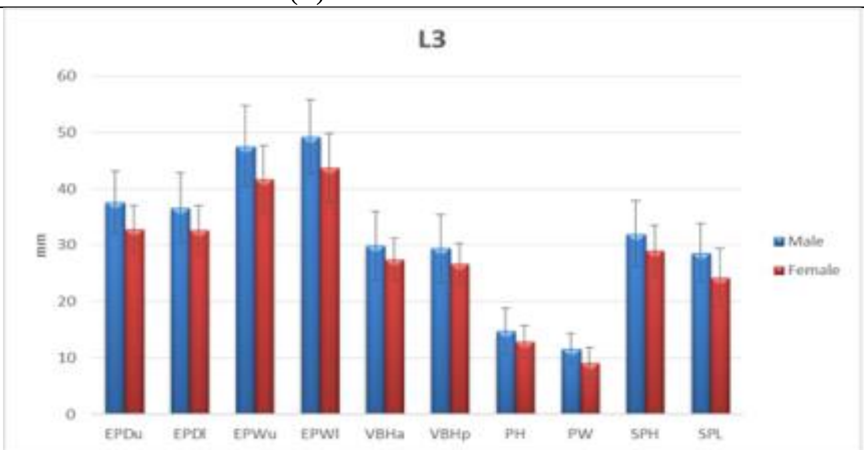
All measured parameters increased significantly in the first, 2nd, 3rd, 4th and 5th lumbar vertebrae among males compared to females (**Figure 1**).



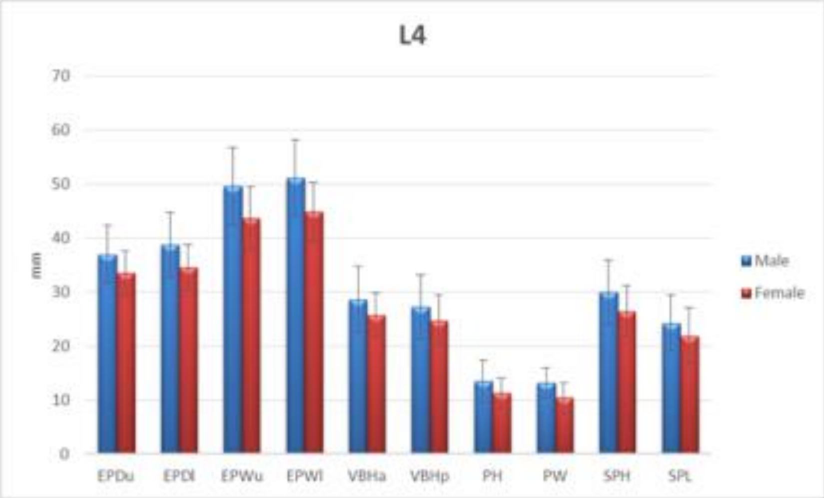
(A) first lumbar vertebrae



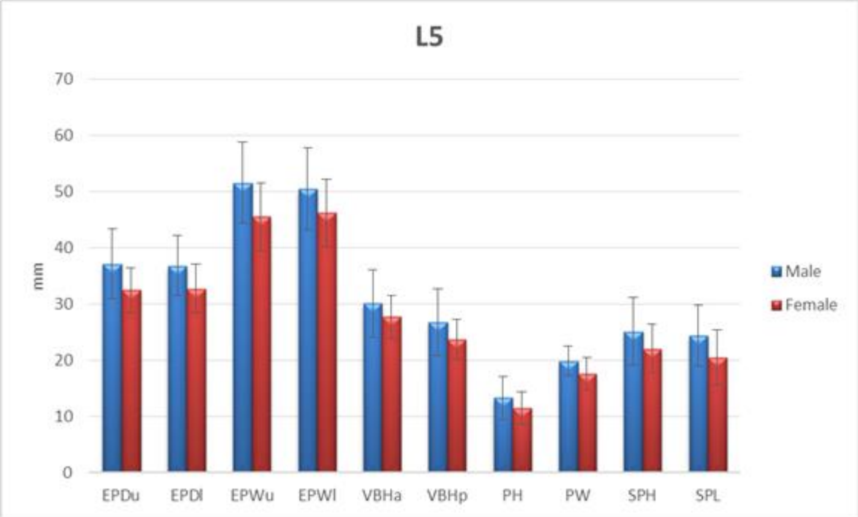
(B) second lumbar vertebrae



(C) third lumbar vertebrae



(D) forth lumbar vertebrae



(E) fifth lumbar vertebrae

Figure (1): Comparing between male and female among different measured parameters of lumbar vertebrae from L1 to L5.

Upper border (end plate) depth (EPDu), Lower border (end plate) depth (EPDl), Upper border (end plate) width (EPWu), Lower border (end plate) width (EPWl), Height of anterior border of the body of the vertebra (VBHa), Height of the posterior border of the body of the vertebra (VBHp), Pedicle dimensions (Height) (PH), Pedicle dimensions (Width) (PW), Spinous process (Height) (SPH), Spinous process (length) (SPL).

Table 2 shows that the accuracy of EPDu, EPDl, EPWu, EPWl, VBHa, VBHp, PH, PW, SPH and SPLof L1 in determination of male sex was 78.6%, 75.5%, 78.6%,73.5%, 66.3%, 67.3%, 69.4%, 73.5%, 70.4% and 72.4% respectively.

Table (2): Validity of first lumber vertebra parameters in sex determination.

Variable	Cut off	AUC (95% CI)	Accuracy	P-value
EPDu	**>35.21**	**0.74 (0.63-0.84)**	**78.6**	**<0.001****
EPDl	**>36.32**	**0.72 (0.61-0.82)**	**75.5**	**<0.001 ****
EPWu	**>46.16**	**0.74 (0.63-0.84)**	**78.6**	**<0.001 ****
EPWl	**>48.25**	**0.71 (0.61-0.82)**	**73.5**	**<0.001 ****
VBHa	**>27.06**	**0.62 (0.50-0.73)**	**66.3**	**0.04 ***
VBHp	**>27.9**	**0.64 (0.53-0.76)**	**67.3**	**0.02 ***
PH	**>16**	**0.65 (0.54-0.77)**	**69.4**	**0.01***
PW	**>9.15**	**0.71 (0.61-0.81)**	**73.5**	**<0.001 ****
SPH	**>31.24**	**0.68 (0.57-0.79)**	**70.4**	**0.002 ***
SPL	**>21.99**	**0.70 (0.60-0.80)**	**72.4**	**0.001 ***

AUC: Area under curve, CI: Confidence interval, *: Significant (P<0.05), **: Highly Significant (P<0.001).

Table 3 shows that the accuracy of EPDu, EPDl, EPWu, EPWl, VBHa, VBHp, PH, PW, SPH and SPL of 2nd lumber vertebra in determination of male sex was 77.6%, 71.4%, 79.6%, 82.7%, 52%, 68.4%, 51%, 77.6%, 75.5% and 76.5%, respectively.

Table (3): Validity of Second lumber vertebra parameters in sex determination.

Variable	Cut off	AUC (95% CI)	Accuracy	P-value
EPDu	**>35.55**	**0.73 0.63-0.83**	**77.6**	**<0.001 ****
EPDl	**>35.23**	**0.65 0.54-0.76**	**71.4**	**0.009 ***
EPWu	**>44.86**	**0.74 0.64-0.84**	**79.6**	**<0.001 ****
EPWl	**>44.22**	**0.77 0.68-0.87**	**82.7**	**<0.001 ****
VBHa	**>26.95**	**0.61 0.50-0.72**	**52**	0.06 NS
VBHp	**>27.34**	**0.62 0.50-0.73**	**68.4**	**0.05***
PH	**>13.05**	**0.60 0.48-0.72**	**51**	0.09 NS
PW	**>9.4**	**0.73 0.63-0.83**	**77.6**	**<0.001 ****
SPH	**>31**	**0.70 0.59-0.81**	**75.5**	**0.001 ***
SPL	**>23.55**	**0.71 0.60-0.81**	**76.5**	**<0.001 ****

AUC: Area under curve, CI: Confidence interval.

Table 4 shows that the accuracy of EPDu, EPDl, EPWu, EPWl, VBHa, VBHp, PH, PW, SPH and SPL of L3 in determination of male sex was 77.6%, 74.5%, 78.6%,73.5%, 67.3%, 67.3%, 67.3%, 76.5%, 71.4% and 72.4%, respectively.

Table (4): Validity of Third parameters in sex determination.

Variable	Cut off	AUC (95% CI)	Accuracy	P-value
EPDu	**>36.68**	**0.73 0.63-0.84**	**77.6**	**<0.001 ****
EPDl	**>34.18**	**0.72 0.61-0.83**	**74.5**	**<0.001 ****
EPWu	**>45.52**	**0.74 0.64-0.84**	**78.6**	**<0.001 ****
EPWl	**>47.37**	**0.72 0.62-0.83**	**73.5**	**<0.001 ****
VBHa	**>28.27**	**0.65 0.54-0.77**	**67.3**	**0.01 ***
VBHp	**>27.34**	**0.65 0.54-0.77**	**67.3**	**0.01 ***
PH	**>13.38**	**0.65 0.54-0.77**	**67.3**	**0.009 ***
PW	**>10.2**	**0.73 0.63-0.83**	**76.5**	**<0.001 ****
SPH	**>30.45**	**0.69 0.58-0.80**	**71.4**	**0.002 ***
SPL	**>26.51**	**0.72 0.62-0.82**	**72.4**	**<0.001 ****

AUC: Area under curve, CI: Confidence interval.

Table 5 shows that the accuracy of EPDu, EPDl, EPWu, EPWl, VBHa, VBHp, PH, PW, SPH and SPL of L4 in determination of male sex was 72.4%, 724%, 76.5%,80.6%, 67.3%, 52%, 67.3%, 77.5%, 73.5% and 68.4%, respectively.

Table (5): Validity of Fourth parameters in sex determination.

Variable	Cut off	AUC (95% CI)	Accuracy	P-value
EPDu	**>35.30**	**0.69 0.59-0.80**	**72.4**	**0.001 ***
EPDl	**>36.55**	**0.70 0.60-0.80**	**72.4**	**0.001 ***
EPWu	**>46.61**	**0.74 0.64-0.84**	**76.5**	**<0.001 ****
EPWl	**>47.94**	**0.77 0.67-0.86**	**80.6**	**<0.001 ****
VBHa	**>26.83**	**0.65 0.54-0.76**	**67.3**	**0.009 ***
VBHp	**>25.86**	**0.61 0.50-0.72**	**52**	0.06 NS
PH	**>12.08**	**0.62 0.50-0.73**	**67.3**	**0.048 ***
PW	**>11.7**	**0.73 0.63-0.83**	**75.5**	**<0.001 ****
SPH	**>27.71**	**0.71 0.60-0.81**	**73.5**	**<0.001 ****
SPL	**>23.41**	**0.62 0.51-0.73**	**68.4**	**0.04 ***

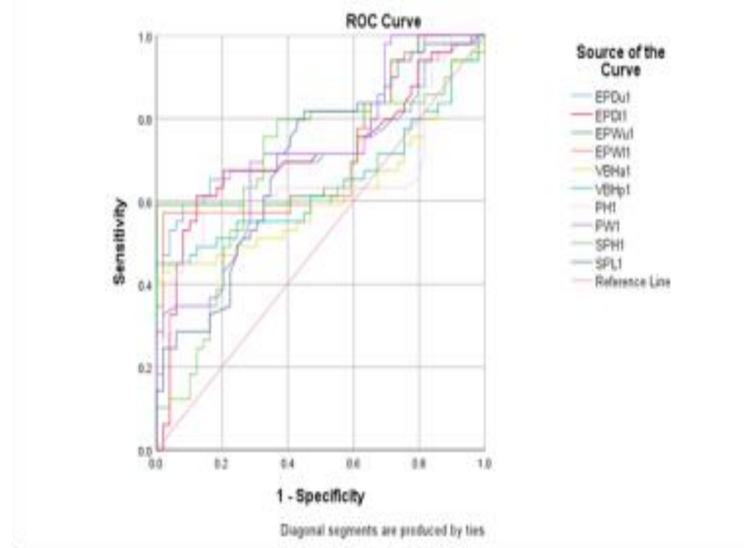
AUC: Area under curve, CI: Confidence interval.

Table 6 shows that the accuracy of EPDu, EPDl, EPWu, EPWl, VBHa, VBHp, PH, PW, SPH and SPL of L5in determination of male sex was 76.5%, 76.5%, 78.6%,72.4%, 67.3%, 69.4%, 67.3%, 73.5%, 70.4% and 72.4%, respectively.

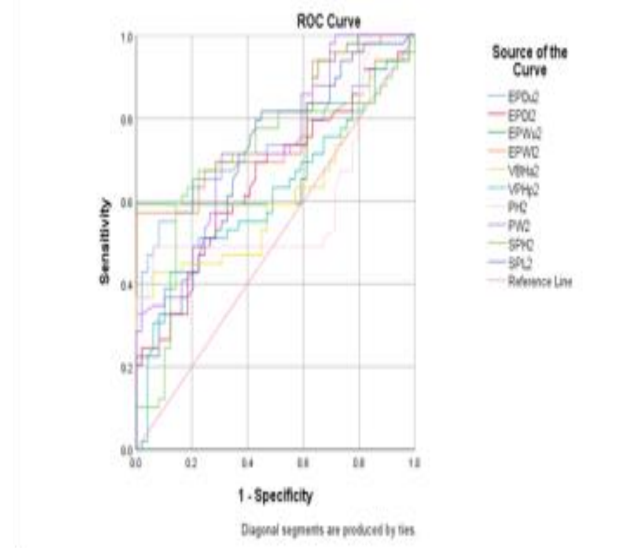
Table (6): Validity of 5th lumber vertebra parameters in sex determination.

Variable	Cut off	AUC (95% CI)	Accuracy	P-value
EPDu	**34.74**	**0.72 0.62-0.83**	**76.5**	**<0.001 ****
EPDl	**34.22**	**0.72 0.61-0.83**	**76.5**	**<0.001 ****
EPWu	**48.08**	**0.75 0.65-0.85**	**78.6**	**<0.001 ****
EPWl	**47.91**	**0.70 0.59-0.81**	**72.4**	**0.001 ***
VBHa	**28.52**	**0.65 0.53-0.76**	**67.3**	**0.01 ***
VBHp	**25.51**	**0.67 0.55-0.78**	**69.4**	**0.004 ***
PH	**12.93**	**0.65 0.54-0.77**	**67.3**	**0.01 ***
PW	**18.53**	**0.70 0.60-0.80**	**73.5**	**0.001 ***
SPH	**23.79**	**0.68 0.57-0.79**	**70.4**	**0.002 ***
SPL	**22.3**	**0.70 0.60-0.80**	**72.4**	**0.001 ***

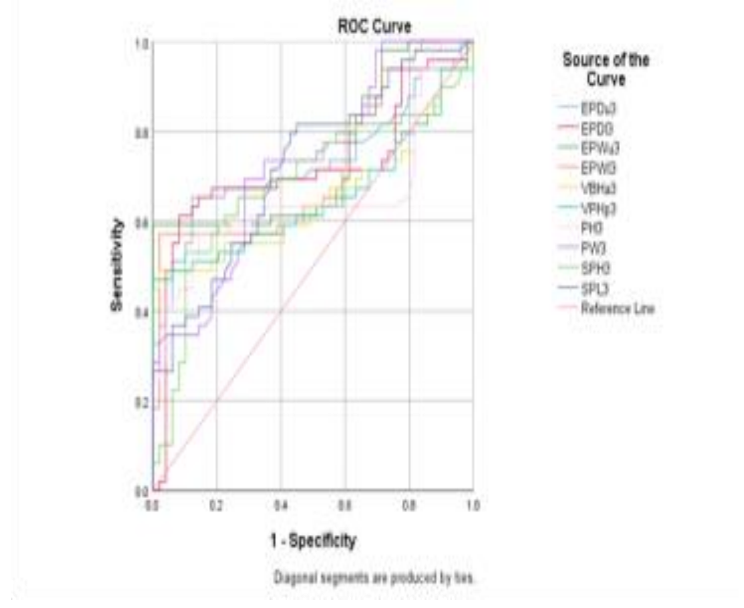
AUC: Area under curve, CI: Confidence interval.



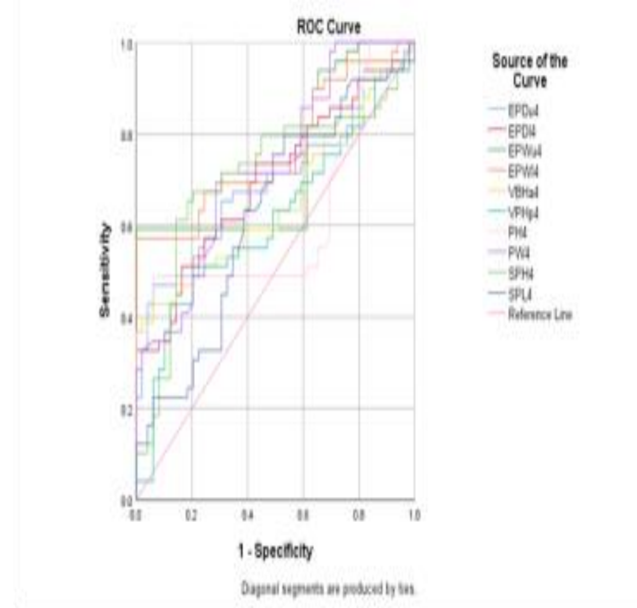
(A) first lumbar vertebrae



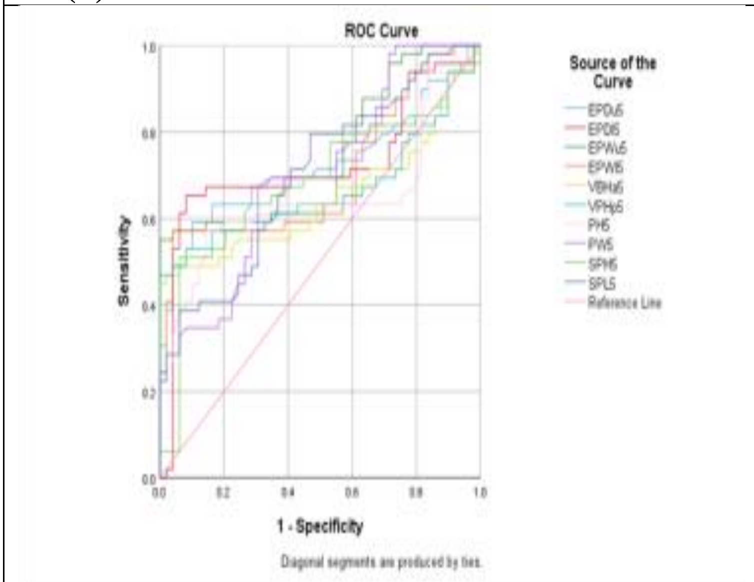
(B) second lumbar vertebrae



(C) third lumbar vertebrae



(D) forth lumbar vertebrae



(E) fifth lumbar vertebrae

Figure (2): Roc curves for validity of 1st, 2nd, 3rd, 4th and 5th lumbar vertebrae parameters in sex determination.

DISCUSSION

When creating a biological profile from unidentified human bones, sexually dimorphic skeleton characteristics are crucial. Parts of bones are frequently found in real forensic cases. Different bones in the pelvis, skull, and upper and lower extremities, there have been efforts to create sex and age determining equations using bones [9].

Studies comparing vertebral dimensions across populations based on sex and age have been conducted, although most vertebral morphometric research is conducted with a clinical or descriptive focus [10].

MSCT is the previous generation of CT equipment. It has transformed CT from a transaxial cross-sectional technique to a true 3D imaging modality with many clinical applications, especially in musculoskeletal imaging. Additionally, it permits maintaining the integrity of the remains while investigating the anatomy and macroscopic material. When the geometry of a bone needs to be measured fast along any axis, the resulting photographs are quite similar to the source photos. Measurements of the lumbar vertebrae's shape, awareness of any variances in height, and careful consideration of the screw's entry point angle and depth are all necessary for a smooth application. Understanding the factors that affect morphometric data is crucial for making the right screw choice [11].

Previous research has shown that the first, second, third, fourth, and fifth lumbar vertebrae show sexual dimorphism; however, the usefulness of these bones for sex determination in the Libyan population has not been investigated.

Regarding the demographic data of the studied groups, Males had a mean age of 37.06 (SD 15.69) years (range: 0–60 years) and females, 35.24 (SD 15.97) years (range: 0–60 years). In terms of age, there was no statistically significant difference between the male and female groups.

In comparison between male and female participants regarding first to fifth lumbar vertebrae parameters, the current study documented males were significant larger in mean of all measurements of first to fifth lumbar vertebrae in than females. These findings were very similar to those found by **Zheng *et al.*** [8]**,** who similarly found that men generally had significantly bigger indices than women.

Güleç *et al.* [12] using the 2D CT approach, the researchers analysed the morphology of lumbar vertebrae in the Turkish population and came to some interesting conclusions. There was a statistically significant difference between the sexes, with males having higher mean values.

In line with this, **Ostrofsky and Churchill** [13] found that males in South Africa were larger than females in most measurements of the lumbar vertebrae.

Badr El Dine and El Shafei [9] did research on Egyptians and found that only 7 out of 24 measurements of L1 differed substantially across sexes with only 68% success rate. While **Zheng *et al.*** [8] employed 3D images for their measurements, which were different from this study's use of 2D photos, it is unlikely that this distinction explains the discrepancy in results; however, future investigations on larger Egyptian samples should evaluate the accuracy of 2D and 3D images. In addition, the findings of the current study differ with those of **Badr El Dine and El Shafei** [9]**,** who concluded that EPDu is the most reliable measurement.

However, **Ruhli *et al.*** [14] identified a little gender difference in L1 intervertebral foramen widths in his original Swiss sample. Differences in methodology, potential changes between populations, and the age of the sample all had a role in producing these findings.

Regarding detection of L1 parameters cut-off levels and their accuracy to estimate sex, the current study revealed that EPDu accuracy of L1 in male sex determination was at a cut-off >35.21 mm was 78.6%, EPDl at a cut-off >36.32 mm was 78.5%, EPWu at a cut-off >46.16 mm was 78.6%, EPWl at a cut-off >48.25 mm was 73.5%, VBHa at a cut-off >27.06 mm was 66.3%, VBHp at a cut-off >27.9 mm was 67.3%, PH at a cut-off >16 mm was 69.4%, PW at a cut-off >9.15 mm was 73.5%, SPH at a cut-off >31.24 mm was 70.4%, and SPL at a cut-off >21.99 mm was 72.4%.

Regarding detection of L2 parameters cut-off levels and their accuracy to estimate sex, the current study revealed that EPDu of L2 accuracy of in male sex determination was at a cut-off >35.23 mm was 77.6%, EPDl at a cut-off >35.23 mm was 71.4%, EPWu at a cut-off >44.86 mm was 79.6%, EPWl at a cut-off >44.22 mm was 82.7%, VBHa at a cut-off >26.95 mm was 52%, VBHp at a cut-off >27.34 mm was 68.4%, PH at a cut-off >13.05 mm was 51%, PW at a cut-off >9.4 mm was 77.6%, SPH at a cut-off >31 mm was 75.5%, and SPL at a cut-off >23.55 mm was 76.5%.

Regarding detection of L3 parameters cut-off levels and their accuracy to estimate sex, the current study revealed that EPDu of L3 accuracy for male sex determination was at a cut-off >36.68 mm was 77.6%, EPDl at a cut-off >34.18 mm was 74.5%, EPWu at a cut-off >45.52 mm was 78.6%, EPWl at a cut-off >47.37 mm was 73.5%, VBHa at a cut-off >28.27 mm was 67.3%, VBHp at a cut-off >27.34 mm was 67.3%, PH at a cut-off >13.38 mm was 67.3%, PW at a cut-off >10.2 mm was 76.5%, SPH at a cut-off >30.45 mm was 71.4%, and SPL at a cut-off >26.51 mm was 72.45%.

Regarding detection of L4 parameters cut-off levels and their accuracy to estimate sex, the current study revealed that EPDu of L4 accuracy for male sex determination was at a cut-off >35.30 mm was 72.4%, EPDl at a cut-off >36.55 mm was 72.4%, EPWu at a cut-off >46.61 mm was 76.5%, EPWl at a cut-off >47.94 mm was 80.6%, VBHa at a cut-off >26.83 mm was 67.3%, VBHp at a cut-off >25.86 mm was 52%, PH at a cut-off >12.08 mm was 67.3%, PW at a cut-off >11.7 mm was 75.5%, SPH at a cut-off >27.71 mm was 73.5%, and SPL at a cut-off >23.41 mm was 68.4%.

Regarding detection of L5 parameters cut-off levels and their accuracy to estimate sex, the current study revealed that EPDu of L5 accuracy for male sex determination was at a cut-off >34.74 mm was 76.5%, EPDl at a cut-off >34.22 mm was 76.5%, EPWu at a cut-off >48.08 mm was 78.6%, EPWl at a cut-off >47.91 mm was 72.4%, VBHa at a cut-off >28.52 mm was 67.3%, VBHp at a cut-off >25.51 mm was 69.4%, PH at a cut-off >12.93 mm was 67.3%, PW at a cut-off >18.53 mm was 73.5%, SPH at a cut-off >23.79 mm was 70.4%, and SPL at a cut-off >22.3 mm was 72.4%.

Ramadan *et al.* [(4)] similar to the current study, found that EPWu was the most accurate measurement with a sex correction rate of 88.6%, and that males were significantly larger in all measurements.

Although **Ramadan *et al.*** [(4)] EPWu was found to have the highest accuracy (87.1%) when compared to other methods, including POE of the vertebra.

Based on a South African study that employed physical osteological examination (POE) of lumbar vertebrae, **Ostrofsky and Churchill** [(13)] concluded that EPWu was the most reliable measurement with accuracy of 87.1%.

CONCLUSION

When skeletal remains are incomplete, sex can be reasonably determined from the first to the fifth in lumbar vertebrae for legal and humanitarian circumstances.

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