Sex estimation from measurements of the 12th thoracic vertebra using Multidetector Computed Tomography in Egyptian population

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Abstract: Objective: The purpose of this study is to determine the presence/degree of sexual dimorphism of the 12th thoracic vertebra through a quantitative analysis and to further examine its potential and reliability in the sex estimation of human skeletal remains. Method: In order to assess this, the 12th thoracic vertebrae, 100 persons 51 males (age range 23-70 years) and 49 females (age range 17-62 years) from Egypt. These persons were patients who needed to undergo CT of the abdomen for several reasons in the Radiology Departments of Minia University hospital. CT studies were performed using a 16-detector Multi-Detector Computed Tomography (MDCT) scanner .The morphology of the 12th thoracic vertebra was examined by nine measurements. Descriptive statistics, including means, standard deviation and test of significance were performed for each of the measurements. To assess the level of significance in the mean values between the sexes, t-test was applied and a value of $P < 0.05$ was considered significant. Univariate and stepwise discriminant function analysis were carried out respectively. Results: The coronal diameter of vertebral body (BDc) and vertebral length (VL) are found to be highly significant sexually dimorphic. The sagittal diameter of vertebral body (BDs) and length of spinous process (SL) showed high significant sexual dimorphism. While the height of pedicle on right and left side (PHr & PHl) are significantly sexually dimorphic. The highest accuracy was obtained with the BDc (87%). Conclusion: The result of the present work showed that the lih thoracic vertebra exhibits anatomic variability between genders. 12th thoracic vertebra dimensions measurements, especially the coronal diameter of vertebral body, are valuable in studying sexual dimorphism.

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Key words: MDCT, sex estimation, lih thoracic vertebra, discriminant function analysis.

1. Introduction

Identification of skeletal and decomposing human remains is one of the most difficult skills in forensic medicine. Sex determination is also an important problem in the identification. Skeletal remains have been used for sexing the individual as bones of the body are last to perish after death, next to enamel of teeth(1), Radiography is used in forensic pathology for the identification of humans especially in cases where the body is decomposed, fragmented, or burned(2).

When the skeleton exists completely, sex can be determined with 100% accuracy. This estimation rate is 98% in existence of pelvis and cranium, 95% with only pelvis cranium, 95% with only pelvis and long bones, and 80-90% with only long bones. However, in explosions, warfare, and other mass disasters like aircraft crashes, identification and sex determination are not easy tasks(3).

But the presence of the pelvis and the skull can never be guaranteed in a forensic case. When a skeletonised body is recovered, usually several parts are missing or are broken due to the effect of carnivores and environmental conditions. Furthermore, in mass disasters bones are usually commingled and broken in which situation identification of sex will be based on few components of the skeleton(4). So it is necessary to develop metric methods on various kinds of bones, especially those without directly observable anatomical measurements of sex.

The lower thoracic and lumbar vertebrae are often preserved well in archaeological skeletal assemblages and forensic contexts, because of their weight-bearing function and relative density. Even when bone preservation is problematic for the axial skeleton, the 12th thoracic vertebra can be readily distinguished because of its unique widely acknowledged(5).

Accounting for biological and statistical variation in the methods applied across populations and the ways in which such evidence is used in varying judicial systems is important because of the increasing amount of international forensic casework being done globally. Population variation or the perceived effect of such variation on the accuracy and reliability of methods is important as it may alter trial outcomes, and debates about the scientific basis for human variation are now making their way into international courtrooms[6]. There are some studies on the Egyptian population to determine the sex from skeletal elements such as the hand bones[7,8], talus measurements[9], maxillary sinus[10], foot and patella [11], however, no Egyptian studies had been done on 12th thoracic vertebra.

The aim of the present study is to develop population-specific standards for sex determination based on the 12th thoracic vertebra in Egypt, a population that has not been represented so far in the existing forensic anthropology population databases.

2. Subjects and methods:

Subjects: The research was conducted on100 persons 51 males (age range 23-70 years) and 49 females (age range 17-62 years) from Egypt. These persons were patients who needed to undergo CT of the abdomen for several reasons in the Radiology Departments of Minia University hospital. These persons constituting the sampling were selected randomly from a variety of socio-economic and occupational groups on a voluntary basis. None of the vertebrae used possessed any pathological condition.

Methods:

CT studies were performed using a16-detector Multi-Detector Computed Tomography (MDCT) scanner (Bright Speed 16; GE Medical Systems). The acquisition parameters were summarized in table (1). 3D reconstruction created followed by clipping of thoracic vertebra from other vertebrae. Measurements were made by a senior radiologist.

There were nine measurements of 12th thoracic vertebra which are shown in table (2), figure (1) by 3D MDCT image of 1ih thoracic vertebra. These measurements include three measure- ments of the vertebral body (the coronal diameter of endplate, the sagittal diameter of endplate and height of vertebral body from anterior side), two measurements of the pedicle (the height of both the right and left pedicles), two measurements of the vertebral foramen (coronal and sagittal diameters of vertebral foramen on median plane), spinous process length and finally the length of the whole vertebra.

Statistical analysis:

The data was analyzed using the SPSS version13.0 (SPSS, Chicago, IL, USA). Descriptive statistics, including means, standard deviation and test of significance were performed for each of the measurements. To assess the level of significance in the mean values between the sexes, t-test was applied and a value of $P < 0.05$ was considered significant. Univariate and stepwise discriminant function analysis were carried out respectively. A leave-one out classification procedure was used to assess the validity of these functions.

The discriminant function is constructed by assigning a discriminant score to each case. Depending on the variable and combination of variables for a function, the score changes from case to case. The discriminant score was obtained by multiplying each measurement by its unstandardized discriminant coefficient, then adding the constant. A Sectioning point (SP) was created by using the mean male and female discriminant scores, which are also known as the group centroids.

To assign the case to either male or female sex the discriminant function score was compared to the sectioning point. If it was smaller than the sectioning point or when the value was negative, then it was considered to be of female while a value greater than or being positive considered to be a male.

3. Results:

The results of descriptive statistics showed that males display larger mean values than females for all measured variables of 12th thoracic vertebrae as shown in table (3). Statistically, the dimensions of the vertebrae showed significant difference ($p < 0.05$) between sexes except for the height of vertebral body (BHa) and the diameters of vertebral foramen (FDs & FDc).

The coronal diameter of vertebral body (BDc) and vertebral length (VL) are found to be highly significant sexually dimorphic (p=0.0001). The sagittal diameter of vertebral body (BDs) and length of spinous process (SL) showed high significant sexual dimorphism (p=0.001). While the height of pedicle on right and left side (PHr & PHl) are significantly sexually dimorphic (P=0.01 for both PHr & PHl).

In table (4) direct discriminate analysis was employed to obtain the correct prediction accuracies for all single variables for 30 MDCT measurements. On the basis of single variables, the accuracy of sex classification reached from 87% to 62%. The highest accuracy was obtained with the BDc (87%) and the least was obtained with VL (62%).

Discriminant score of any measurement = (measurement of unknown bone x coefficient) + constant.

Then compare the product of the equation with the sectioning point:

- If the result of this equation less than the sectioning point, the sex is female.
- If the result of this equation more than the sectioning point, the sex is male.

Discriminant function equation, including multiple variables with highest accuracy, was created using the "stepwise method" approach. The BDc, PHr and SL diameters predicted sex with 89% accuracy in the following equation:

Discriminate score= (0.413x BDc) + (0.121x PHr) + (0.109x SL) - 21.360 (Sectioning point -0.025)

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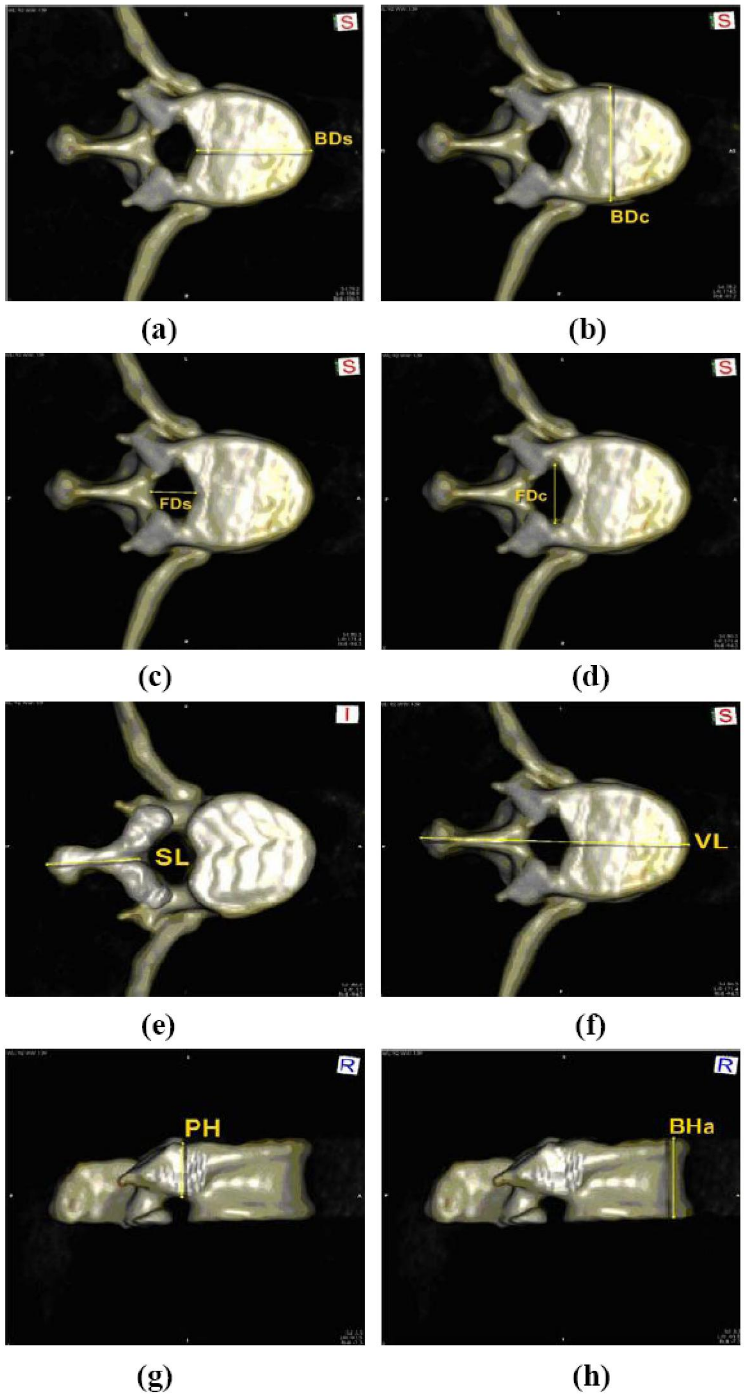

Figure1: 3DCT of the 12th thoracic vertebra. The various measurements determined in the present study are indicated and further explained in the nomenclature in Table 2. (a), (b), (c), (d), (h) and (f) show the measurements of the vertebral body and foramen, and (g) show the measurement of the pedicle and (e) demonstrates the spinous process.[(a),(b), (c), (d) and (f) are superior views; (i) is inferior view; (g) and (h) are right lateral views].

Table 1: Acquisition parameters of 16-detector MDCT scanner (Bright Speed 16; GE Medical Systems)

Region	Thick speed				Interval mm	FOV	KV	mA	Rotation time	Scan type	Rows configuration
	Helical thickness	Row	Pitch	Speed (mm/rot)							
DV12	1.25	16	0.5625:1	5.625	0.75	Small	80	270	0.5	Helical	16x0.625

Table 2: Nomenclature for the measurements used in this study:

Vertebral part	Measurement	Symbol
Vertebral body	Coronal diameter of endplate. Distance from the most left edge of the endplate to the most right edge of the endplate. (endplate is the part of the vertebra that comes in direct contact with the intervertebral disc.	BDc
	Sagittal diameter of endplate distance from the most anterior edge of the endplate to the most concave point of the posterior edge of the endplate.	BDs
	Anterior height of body	BHa
Pedicle	Height of pedicle on right side	PHr
	Height of pedicle on left side	PHl
Vertebral foramen	Coronal diameter of vertebral foramen on median plane.	FDc
	Sagittal diameter of vertebral foramen on median plane.	FDs
Spinous process	Length of spinous process. Length of spinous process on median plane, from posterior border of the vertebral foramen to the most posterior edge of the spinous process.	SL
Whole vertebra	Sagittal length of the vertebra on superior plane, distance from the anterior edge of vertebral body to the posterior edge of vertebral spinous process at superior plane.	VL

Prefixes used s saggital, c cronal, a anterior, r right, l left.

Table (3): Descriptive statistics for the measured variables of the 12th thoracic vertebrae by 3D MDCT

Measurements of the vertebrae	Males (n=51)		Females (n=49)		T	P
	Range	Mean±SD	Range	Mean±SD		
BDc	40-48.5	44.50±2.7	35-45.1	39.25±1.9	11.2	0.0001***
BDs	23.6-36.9	30.12±3.02	23-38	27.96±3.7	3.17	0.001**
BHa	14.8-28.8	23.34±2.9	16.2-26.5	22.39±2.1	1.85	0.06
PHr	10.7-19	15.44±2.1	10.6-17.9	14.40±2.1	2.43	0.01*
PHI	10.7-19	15.41±2.1	10.7-18	14.34±2.1	2.52	0.01*
FDs	10.8-19	15.56±2.1	12-21.3	15.54±2.3	0.02	0.9
FDc	13.5-23.2	18.97±2.9	15-23.2	18.88±2.1	0.15	0.8
SL	15-25.5	21.45±2.5	12.6-26	19.51±3.3	3.26	0.001**
VL	58.6-73.9	67.12±4.08	52.4-71.2	63.02±5.3	4.35	0.0001***

The measurements are in mm. n=numbers, SD= standard deviation
$P < 0.05$ significant, * Significant , ** High significant , *** Highly significant
BDc= coronal diameter of the endplate. BDs=sagittal diameter of the endplate.
BHa= anterior height of vertebral body. PHr = height of right pedicle.
PHl = height of left pedicle. FDs=sagittal diameter of vertebral foramen on median plane.
FDc=coronal diameter of vertebral foramen on median plane. SL = length of spinous process.
VL = Sagittal length of the vertebra on superior plane.

Table (4): Unstandardized discriminant function equations for predicting the sex of the 12th thoracic vertebra when using one measurement by 3D MDCT.

Measurement	Constant	Unstandardized Coefficient	Sectioning point	Accuracy
BDc	-17.9	0.428	-0.02	87%
BDs	-8.586	0.295	-0.012	75%
PHr	-7.009	0.469	-0.005	68%
PHl	-7.015	0.471	-0.005	68%
SL	-6.905	0.337	-0.006	64%
VL	-13.832	0.212	-0.008	62%

BDc= coronal diameter of the endplate. BDs= sagittal diameter of the endplate.
PHr = height of right pedicle. PHl = height of left pedicle. SL = length of spinous process.
VL = Sagittal length of the vertebra on superior plane.

For example: if an unknown 12th thoracic vertebra with the following diameters:

BDc =43.8mm, PHr = 15.2mm, SL = 20.9. By using the above mentioned equation:

Discriminant score = (0.431 x 43.8) + (0.121 x 15.2) + (0.1 09x20.9) - 21.360=1.6351

The sectioning point is -0.025, therefore it most likely to be male vertebra with accuracy 89%.

4. Discussion

There were statistically significant differences between males and females in all dimensions of 12th thoracic vertebra except for the height of vertebral body (BHa) and the diameters of vertebral foramen (FDs & FDc). The coronal diameter of vertebral body (BDc) and vertebral length (VL) are found to be highly significant sexually dimorphic. The sagittal diameter of vertebral body (BDs) and length of spinous Process (SL) showed high significant sexual dimorphism. While the height of pedicle on right and left side (PHr & PHl) are significantly sexually dimorphic.

Direct discriminant analysis was employed to obtain the correct prediction accuracies for all single variables for 3D MDCT measurements. On the basis of single variables, the accuracy of sex classification reached from 87% to 62%. The highest accuracy was obtained with the BDc (87%) and the least was obtained with VL (62%). The accuracy to predict sex correctly may reach as high as 89% when the bone is complete using three measurements: coronal diameter of vertebral body, height of right pedicle and spinous process length (BDc, PHr and SL) using previous mentioned equation.

These results of the current study are in accordance with the study of Yu et al.[5] who studied 3D reconstructed vertebral body of 12th thoracic vertebra in Korea. The study found that sex can be predicted with 62.7-85.3% accuracy. Using stepwise method of discriminate function analysis, three variables predicted sex with 90.0%. Coronal dimensions of the vertebral body represented the major sex difference.

These results also go with those of Hou et al.[12] who studied the sexual dimorphism in 12th thoracic vertebra using 3D MDCT. They found that univariate discriminate function equations predicted sex with 56.4- 90.1 % accuracies and by using stepwise method of discriminate function analysis, four variables predicted sex with 94.2% accuracy.

As regard coronal diameter of vertebral body (BDc) in this study in Egyptian population sample for males was (44.5 mm) which was higher than that of Korean (44.37 mm)[5] and lower than that of Chinese (44.76 mm)[12]. The same diameter for females in Egyptian was (39.25 mm) which was higher than that of Korean (38.81 mm[5] and lower than that of Chinese (39.65 mm)[12].

The sagittal diameter of vertebral body in this study for males was (30.12 mm) which was lower than that of Korean (31.48 mm)[5] and Chinese (33.06 mm[12] The same diameter for females was (27.96 mm) which was higher than that of Korean (27.65 mm)[5] and lower than Chinese (28.88 mm[12].

The pedicle height on right and left sides (PHr & PHl) in Egyptian male was (15.44 & 15.41 mm respectively) which is lower than that of Korean (19.86 & 19.32 mm)[5] and Chinese (17.64 & 17.62 mm[12]. For Egyptian females were (14.40 & 14.34 mm) which is lower than that of Korean (18.36 & 18.04 mm)[5] and Chinese (15.79 & 16.08 mm[12].

As regard the spinous process length in this study for Egyptian male was (21.45 mm) which is lower than that of Korean (27.82 mm)[5] and Chinese (28.68 mm)[12]. For Egyptian females was (19.51 mm) which is lower than that of Korean (26.16 mm)[5] and Chinese (25.48 mm)[12]. The vertebral length (VL) in this study for Egyptian male was (67.12 mm) which is lower than that of Chinese (79.54 mm)[12]. The same diameter for

Egyptian females was (63.02 mm) which is lower than that Chinese (71.58mm)(12).

Conclusion

The result of the present work showed that the 1ih thoracic vertebra exhibits anatomic variability between genders. 12th thoracic vertebra dimensions measurements, especially the coronal diameter of the vertebral body, are valuable in studying sexual dimorphism and the CT images could provide adequate measurements for 12th thoracic vertebra.

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Ethical approval

No ethical approval is required.

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