Age and Sex Identification Using Multi-slice Computed Tomography of the Last Thoracic Vertebrae of an Egyptian Sample

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Abstract

Introduction: Accurate sex estimation plays a very important role in determining the identity of unknown individuals. Age determination also has become increasingly important in forensic science for both living and remains. Vertebrae are one of the least studied bones for age and sex identification; however, its presence at a death scene is the most common of all. The 12th thoracic vertebra (T12) is easily identifiable in a disarticulated skeleton, due to its unique morphology. Identification depending on radiological techniques is an emerging valuable tool in forensic science field.

Methodology: The study was conducted on 123 Egyptian patients; 61 males and 62 females and the age range was from 10 to 64 years. The subjects used in this study were patients who had a need for Computer Tomography (CT) scan of the abdomen for several medical reasons in the Radiology Departments of Cairo University and the CT was done for them after giving informed consent. None of the vertebrae used possessed any pathological condition and vertebrae with moderate to severe degenerative changes and osteophyte formation were excluded from this study. Fifteen linear measurements were taken for T12 thoracic vertebrae. All the procedures for this study were approved by the ethical committee of faculty of medicine, Cairo University. Microsoft excel 2010 was used for data entry and the statistical package for social science (SPSS version 21) was used for data analysis.

Results: Males were statistically significant larger than females in all measurements of T12, and sex was identified from T12 at accuracy rate 88.6%. In addition, there was significant positive correlation between age and most of measurements, however, this correlation wasn’t strong.

Conclusion: Computed tomography of T12 vertebrae is a useful tool for sex and age Identification of unknown; however, further studies are needed for proper evaluation of its role on age estimation.

Keywords: Computed tomography; Egyptians; 12th thoracic vertebrae; Age; Sex

Introduction

Personal identification is a main task in forensic practice. Determination of sex, age, stature and ancestry, which is known as biological profile, decrease the possible victim matches in the forensic investigation process and therefore provide useful clues in personal identification [1].

Sex identification is an important starting point in developing a biological profile for human skeletal remains as it reduces the number of possible matches by 50% [2]. Age estimation is also important in both anthropology and forensic medicine [3].

When complete skeleton is available, the pelvis and skull are the most reliable indicators of sex estimation [4]. However, in several situations, especially when post-mortem interval increases, the human skeleton became porous, fragmented or destroyed [5]. So it is essential to develop other methods for sex identification using a wide range of skeletal elements [6].

Many previous studies reported sexual dimorphism of different vertebrae from cervical, thoracic, and lumbar regions of the spinal column [7]. In addition, morphological changes of the vertebrae have been shown to be useful in understanding ageing patterns [8].

The 12th thoracic vertebra (T12) is easily identifiable in a disarticulated skeleton, due to its unique morphology. Its place as a transitional vertebra results in the morphological characteristics between both thoracic and lumbar vertebrae [9].

Recently, Postmortem Computed Tomographies (PMCT) becomes a valuable tool in forensic practice; due to its effectiveness in visualization of osseous structures, it can help forensic anthropologists to can collect data for estimation of biological profiles using the skeleton [10].

Only few studies that tested the role MSCT of the 12th thoracic vertebrae (T12) in sex identification, however, this is the first study to use MSCT for evaluation of the role of T12 measurements in age estimation.

The aim of the present study is to develop population specific parameters for sex and age determination based on the 12th thoracic vertebrae measurements among Egyptians, a population that has not been represented so far in the existing forensic anthropology population databases.
Subjects and Methods

Subjects

All the procedures for this study were approved by the ethical committee of faculty of medicine, Cairo University. The study was conducted on 123 Egyptian patients; 61 males (ages ranged from 10 to 64 years) and 62 females (ages ranged from 10 to 60 years). The subjects used in this study were patients who had a need for computer tomography (CT) scan of the abdomen for several medical reasons in the Radiology Departments of Cairo University and the CT was done for them after giving informed consent. None of the vertebrae used possessed any pathological condition and vertebrae with moderate to severe degenerative changes and osteophyte formation were excluded from this study.

Methods

Computer tomographic (CT) scanning was performed using a helical CT scanner imaging machine (SOMATOM emotion 16 slice 78830, Siemens, Germany). The patients lay supine on the scanner. The scanning procedure was performed to acquire 1.5 mm slices width; bone window and sharpness B70 for optimum visualization using the software program analyze (Syngo VB 42). Most of images were maximum intensity projection (MIP) images to minimize errors of measurements. The protocol used was identical for all patients to avoid technical variations in measurements. Measurements were taken using the calibrated ruler of the system and are approximated to the nearest 0.1 mm. Fifteen linear measurements were taken for T12 thoracic vertebrae as described in Table 1 and Figure 1 at the workstation by senior radiologist.

| Measurement                              | Description                                                                 | Image     |
|------------------------------------------|-----------------------------------------------------------------------------|-----------|
| Upper end plate depth (EPDu)            | Distance from the anterior edge to the posterior edge of the upper endplate  | Sagittal MIP |
| Lower end plate depth (EPDi)            | Distance from the anterior edge to the posterior edge of the lower endplate  | Sagittal MIP |
| Upper end plate width (EPWu)            | Distance between the most lateral edges of the upper endplate                | Coronal MIP |
| Lower end plate width (EPWi)            | Distance between the most lateral edges of the lower endplate                | Coronal MIP |
| Maximum height of anterior vertebral body (XHA) | Distance between the upper and lower most points of the anterior cortex of the vertebral body | Sagittal MIP |
| Maximum height of posterior vertebral body (XHP) | Distance between the upper and lower most points of the posterior cortex of the vertebral body | Sagittal MIP |
| Length of the vertebral foramen (LVF)   | The sagittal internal length of vertebral foramen between the posterior aspect of the vertebral body and the anterior aspect of the spinous process | Sagittal MIP |
| Maximum width of the vertebral foramen (WFV) | The maximum internal side to side width of the vertebral foramen            | Axial     |
| Spinal process length (SPL)             | From inner posterior border of the vertebral foramen to the most posterior edge of the spinous process | Sagittal MIP |
| Spinal process height (SPH)             | Distance from the superior border to the inferior border at junction of the middle and posterior 1/3s of the spinous process | Sagittal MIP |
| Pedicle height (PH)                     | Distance between the superior and inferior borders of the left pedicle      | Sagittal MIP |
| Pedicle width (PW)                      | Distance between the lateral and medial edges of the left pedicle           | Axial     |
| Vertebral length (VL)                   | Distance from the center of a line touching the anterior edge of vertebral body to the posterior edge of spinous process | Sagittal MIP |

Figure 1: Measurements taken from the 12th thoracic vertebrae. A: Sagittal plane, B: Axial plane, C: Sagittal plane at level of pedicle, and D: Coronal plane.

Statistical analysis

Microsoft excel 2010 was used for data entry and the statistical package for social science (SPSS version 21) was used for data analysis. Simple descriptive statistics (arithmetic mean and standard deviation) used for summary of quantitative data and frequencies used for qualitative data. T-independent test was used to compare normally distributed qualitative data. Pearson correlation was used to compare normally distributed quantitative data and Pearson correlation coefficient describes the direction (either positive or negative) and the power of correlation (<0.5 weak correlation) (between 0.5 and 0.7 moderate correlation) (>0.7 strong correlation). Those factors that demonstrated significant association with age in bivariate analysis (P<0.05) were included in linear regression models, and those factors that demonstrated significant association with sex in bivariate analysis (P<0.05) were included in stepwise discriminant function analysis models [11].
**Transverse process diameter (TD)**
The distance from the tip of the right transverse process to the inner border of the lamina

| Measurements | Unstandardized coefficient | Fisher's linear discriminant function | Group centroid | Wilks' Lambda | Correct prediction rate |
|--------------|-----------------------------|--------------------------------------|----------------|--------------|------------------------|
| EPWl         | 0.187                       | 3.457                                | 3.05           | 1.098        | 0.563                  | 85.20%                  |
| XHP          | -0.271                      | -0.212                               | 0.378          | -            | 0.52                   | 88.60%                  |

Stepwise discriminant function analysis showed that sex can be predicted from T12 measurements at accuracy rate 88.6% using the following equation:

\[ S = 0.187 \times \text{EPDl} - 0.271 \times \text{XHP} + 0.279 \times \text{LVF} + 0.229 \times \text{EPWl} - 12.660 \]

If the result of this equation less than the sectioning point (zero), the sex is female. If the result of this equation more than the sectioning point (zero), the sex is male. The Correct prediction rate (accuracy) of this equation is 88.6% (Table 3).

**Table 1**: Nomenclature of the different measurements from the last thoracic vertebrae.

**Results**
The results of descriptive statistics showed that males displayed larger mean values than females for all measured variables of 12th thoracic vertebrae (Table 2). Most of the dimensions differed highly significantly \((P<0.001)\) between sexes.

| Measurements | Males | Females | P. value |
|--------------|-------|---------|----------|
|              | Min.  | Max.    | Mean     | S.D.   | Min.  | Max.    | Mean     | S.D.   |
| EPDu         | 22    | 41      | 31.9     | 3.9    | 22.5  | 32.2    | 28.2     | 2.1    |
| EPDi         | 22.6  | 38.6    | 31.9     | 3.3    | 21.8  | 32.5    | 27.9     | 2.3    |
| XHA          | 15    | 29.2    | 24.2     | 3.1    | 16.2  | 26      | 22.8     | 1.8    |
| XHP          | 16    | 34      | 27.2     | 3.5    | 16    | 28.3    | 24.7     | 1.9    |
| LVF          | 11    | 18.4    | 14.4     | 1.6    | 10    | 17      | 13.4     | 1.6    |
| SPL          | 16    | 37.6    | 28.8     | 4.6    | 15    | 36      | 26.3     | 3.9    |
| SPH          | 10    | 29      | 17.8     | 4.2    | 10    | 21.7    | 16.3     | 2.9    |
| VL           | 54    | 83.5    | 74.3     | 6.6    | 54.5  | 74      | 67       | 4.1    |
| PH           | 10    | 21.5    | 17.2     | 2.2    | 11    | 17      | 14.9     | 1.3    |
| EPWu         | 28.5  | 50      | 42.4     | 4.6    | 30    | 45      | 36.6     | 2.9    |
| EPWl         | 31    | 57      | 45.2     | 4.9    | 31    | 43      | 38.5     | 2.7    |
| WVF          | 19    | 28      | 23.9     | 2.3    | 17.6  | 28      | 22.2     | 2.1    |
| TD           | 11.7  | 26.2    | 18.2     | 2.8    | 11.2  | 20      | 15.9     | 1.9    |
| TDM          | 32.6  | 59      | 46.3     | 6.6    | 30    | 50      | 41.1     | 4.1    |
| PW           | 6.6   | 14      | 10.2     | 1.7    | 5     | 11      | 8.6      | 1.4    |

**Table 2**: Difference between males and females in measurements of 12th thoracic vertebrae.

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Table 3: Unstandardized discriminate function equations and demarking points for predicting the sex of the 12th thoracic vertebra when using one measurement.

Correlation studies were done and revealed the presence of significant positive correlation between age and all measurements of T12 (p<0.05) except for LVF, PW, TD and TDm for which the correlation were not significant (Table 4).

In addition, Linear regression analysis of the significant measurements showed that age can be predicted from T12 using the following model: Age=-10.685+1.752* XHA (the adjusted R² is 0.348 with the R²=0.471).

Table 4: Correlation between age and measurements of T12.

Discussion
In the current study, males displayed larger mean values than females for all measured variables of 12th thoracic vertebrae and sex was predicted at accuracy rate 88.6%. These results were in great accordance with previous studies [2,12,13].

Badr and El Shafei [2] study on Egyptians concluded that most of T12 measurements were sexually dimorphic using multi-slice computed tomography (MSCT), with accuracy of 93.1%. Hou et al. [13] also reported sexual dimorphism of all measurements of T12 of Chinese except LVF with accuracy rate of 94.2% using MSCT. In addition, Yu et al. [12] reported that there was statistical significant difference between males and females in most of measurements taken from T12 multi-slice computed tomography of Korean sample with accuracy rate 90%.

Moreover, different studies as [7,14-16], approved the role of T12 measurements in sex determination, however, they took measurements from T12 real bone (Table 5).

There are many advantages for taking measurements from MSCT:
- It is an effective technique for depiction of osseous structures [17].
- The use of CT images increases accuracy and reproducibility over traditional metric analyses in a biological profile identification [18].
- Data treatment using appropriate software reduces errors associated with the location of the landmarks and the performance of the measurements [19].
- CT scans offer an easy way for data collection and storage to create databases for forensic anthropology studies [10].
Zech et al. [20] concluded that metric measurements based on CT images were very accurate and comparable to caliper measurements on real bones.

| Author | Year | Population | Measurements | Most accurate | Method | Accuracy |
|--------|------|------------|--------------|---------------|--------|----------|
| Current study | 2017 | Egyptians | 15 | EPDI, LVF, XHP, EPW | MSCT | 88.60% |
| Badr and El Shafei | 2015 | Egyptians | 24+ ratios (including ours) | EPDI, EPWu | MSCT | 93.10% |
| Amores et al. | 2014 | Spanish | 8 (4 in our study) | EPDI | Real bone | 80.20% |
| Gambaro | 2013 | Greek | 16 (12 in our study) | VLI, EPDI | Real bone | 79% |
| Hou et al. | 2012 | Chinese | 30+ ratios (including ours) | EPDI | MSCT | 94.20% |
| Yu et al. | 2008 | Korean | 33+ ratios (including ours) | EPWu, EPW | MSCT | 90% |
| Pastor | 2005 | Americans | 14 (9 in our study) | EPD, EPW | Real bone | 86.60% |
| Jankauskas | 1994 | Lithuanian | XHA, XHP, TBD | Real bone | | 88.90% |

Table 5: Studies approved the role of measurements of last thoracic vertebrae in sex identification.

Although few studies used MSCT in sex identification from T12, no previous study, to my extent of knowledge, tried to evaluate the role of MSCT in age estimation from measurements of T12. Even for other vertebrae, Only few studies [21,22] that tested the role of aging on vertebral body height (anterior, posterior and middle) on lateral radiography of cervical vertebrae or vertebral volume on CT of cervical vertebrae, however, these studies were conducted on young ages <18 years to identify cervical vertebral maturation as a method of age estimation in juveniles which was different from this study.

In contrast, Taitz [38] found that no relationship between aging and the size of the vertebral foramen diameters (LVF and WVF) in males or females, while Ishikawa et al. [39] found that the WVF diameter decreased with age in males and females, and these studies were on real bone not imaging.

Finally, MSCT of the last thoracic vertebrae is a useful tool for sex identification especially in cases of mass disasters where other bones may be destroyed, with further studies needed to evaluate its role in age determination.

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