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Determination of Sex Using the First Lumbar Vertebra in the Malaysian Population

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Abstract

Sex determination is one of the main steps in the identification of human skeletal remains. The vertebrae are weight-bearing structures in the human body that may provide variety of information from an individual. The aim of this study is to assess the sexual dimorphism of the first lumbar (L1) vertebrae using three-dimensional (3D) computed tomography (CT) imaging to develop population-specific equations for sex identification in the Malay population. Thirteen linear measurements of the first lumbar (L1) vertebrae were taken from 50 males and 50 females' patients in the Radiology Department of Universiti Kebangsaan Malaysia Medical Centre, using images of the Computed Tomography (CT) scan. Independent T-test and discriminant function analysis (DFA) were performed for analysis. By using independent T-test analysis, there were eight measurements showed statistically significant difference between men and women ($p<0.001$). Using stepwise method of discriminant analysis showed three measurements predicted sex with the accuracy 93.0% : (a) lower end-plate width (EPWI), (b) lower end-plate depth (EPDI), and posterior height of the vertebral body (VBHp). This study provides discriminant equation for forensic identification of sex from the first lumbar vertebrae among Malaysia population with the accuracy 93.0%.

Keywords:
Sex determination; lumbar vertebrae; computed tomography; Malay population

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1. INTRODUCTION

Estimation of sex is an important starting point for identification of the skeletal remains, as it eases to match down the possible object by 50%. Several studies have been utilizing variety of bone for determining sex, however pelvis bone and the skull are the most reliable to use of all bones. But in some conditions, especially in cases of mass disaster, severe fragmentation, commingled and broken bone may occur. Therefore it is essential to develop

alternative method using other skeletal elements for sex identification [1],[2],[9].

Few studies have examined the vertebral bones for sex assessment, such as cranial base, C1 vertebra, 12th thoracic and the first lumbar vertebra [1],[5],[8],[9], [12].

Most of them had reported reliable and significant as indicators of sex. The vertebral column are weight-bearing functioning and relative dense, therefore often utilize in archaeological skeletal assemblages and forensic studies, especially the lower thoracic and the lumbar vertebrae. They are composed of dense cortical bone on the superficial part, and calcellous bone on the central part, which contribute to the weight-bearing function of the human vertebra. [3],[11].

Several studies have reported that the first lumbar (L1) vertebra shown to be sexual dimorphic with variety of accuracy. Zheng (2012) reported the first lumbar were sexual dimorphism with 88.6% accuracy in Chinese population [12]. While Otrofsky doing sexing in the population of South Africa using L1 to L4, reported that the L1 reached the highest accuracy, at 87.1%. In addition, El Dine was found that the first lumbar was sexual dimorphism with 68.0 % accuracy in the Egyptian population [7]. Nevertheless, to the best of our knowledge, there is no published research doing on anthropometric measurements of the L1 vertebra to determine sex among the Malaysian population using CT scan image [1].

Over the last decade, modern imaging techniques such as multi-slice Computerized Tomography (CT) has been strongly utilized for forensic anthropology. It allows researcher to determine almost each anatomical and pathological appearance in high resolution and quality, without doing conventional autopsy [1].

It is widely acknowledged that there is specificity in population of metric human elements. Therefore, for sex estimation, a standard method may not be applied in different other population, since there are variable pattern of sexual dimorphism among population. Thus, it is important to develop specific population standards for first lumbar vertebrae measurements for estimating sex, particularly Malay populations [4],[6]. For this reason, this study was to investigate sex estimation criteria in first lumbar vertebrae by 3-dimensional CT scan, and to generate population-specific equations for identification of sex in the Malay population.

2. MATERIALS AND METHODS

About 100 adult patients (50 males and 50 females) was conducted with age ranged from 18 to 75 years, who presented to the Radiology Department, Universiti Kebangsaan Malaysia (UKM) Medical Centre for multi-slices Computerized Tomography (CT) of the abdomen. Only

intact vertebrae subject by the image CT scan were included, without any pathological condition. The ethics approval was granted by the University Ethics Committee (Ethic no: UKM PPI/111/JEP-2019-742).

2.1. Methods

The Computed Tomography (CT) scanning was performed using Toshiba Aquilion 160 slices CT scanner with 0.5 mm slice thickness and auto-programmed for reconstruction at 1.0 mm for better resolution. The 3D-reconstructed images of the L1 vertebra were formatted by volume rendering technique of the CT images.

2.2. Data collection

Thirteen linear measurements were taken following to the method by Zheng (2012), using three-dimensional morphometry software (RadiAnt Dicom viewer version 2020.1) by the same operator. The measurements name is presented graphically in Fig. 1 by 3D image of the software, and listed in Table 1.

The data were analyzed using SPSS version 23.0. Independent t-test was applied to test differences in means of the measurements between sexes and a value $p<0.05$ was considered significant. Univariate and stepwise discriminant function analysis (DFA) were performed to create a discriminant function equation, and a leave-one out classification technique was used to evaluate the validity of the functions. To evaluate the significance of the discriminant functions sex group, Wilk's lambda was performed. The scale ranged from 0 to 1, in which 0 indicated total discrimination and 1 indicated no discrimination.

Table 1. Nomenclature of the measurements used in this study

Vertebral Part	Symbol	Measurement
Vertebral body	EPDu	Upper end-plate depth
	EPDl	Lower end-plate depth
	VBHa	Anterior height of vertebral body
	VBHp	Posterior height of vertebral body
	EPWu	Upper end-plate width
	EPWl	Lower end-plate width
Vertebral foramen pedicle	PHl	Pedicle height left
	PHr	Pedicle height right
Articular process	AHSl	Superior articular process left
	AHSr	Superior articular process right
	ADm	Maximum distance between articular process

Transverse process	TDm	Transverse process distance
Spinous process	SPH	Spinous process height

3. RESULTS AND DISCUCCION

The results of descriptive statistics of the first lumbar vertebrae in two groups and sexual differences were presented in table 2. There were significantly differences between sex in eight measurements ($p< 0.01$) by independent t-test, mostly coming from measurements part of the vertebral body which are: EPWu , EPWl, EPDu, EPDl, VBHp ; the right pedicle height (PHr) ; spinous process height (SPH); and process transverse distance (TDm). This indicate that the sexual dimorphism was obvious in first lumbar vertebrae based on those parameters. While measurements from the articular process had no differences in sex.

Using DFA, eight parameters were significantly different in sex among 13 measurements, with the accuracies ranged from 84.1 % to 10.7% to estimate sex classification. The highest accuracy was obtained with the EPWl (84.1%) and the least was obtained with ADm (10.7%). Wilks lambda was done to show how strength the contributions of each independent parameter to the equation model. The values range from 0 to 1, if Wilks lambda closer to 0, indicating that the parameter highly contributes to the model discriminant functions.

Discriminant equation was performed using stepwise method approach. By stepwise analysis, the combinations of parameters that had the highest sex differences were selected according to its discriminatory power to differentiate males and females. By this method, the best discriminatory parameters were automatically selected and those which are not highly discriminate were removed. From the thirteen parameters that entered the analysis, only three parameters were selected (EPWl, EPDu and VBHp) and included in the equation. Using these parameters, the discriminant equation for estimating sex was as follows with accuracy 93.0 %.

Discriminant score = (1.977 x EPWl) + (1.984 x EPDu) + (1.328 x VBHp) – 18.243.

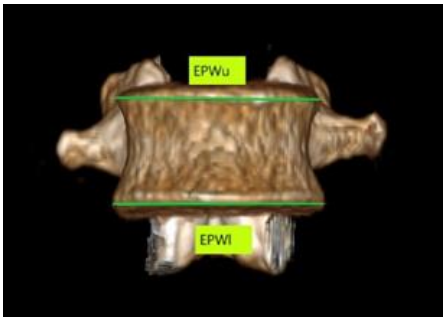
Using the discriminant equation, if the values is greater than or equal to 0 it is classified as male, and if the values less than 0 it is classified as female.

This study was to determine whether in the first lumbar vertebrae were sexual dimorphism and able to be utilized as an effective method for sex estimation. The discriminant functions classification rates agree that the L1 vertebrae are sex reliable indicators.

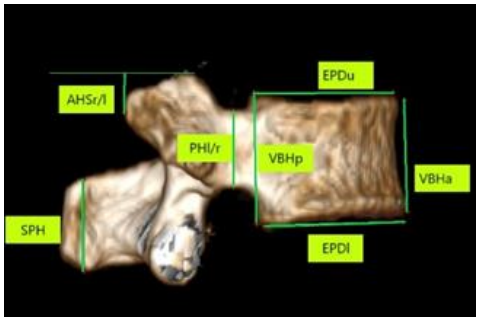
In this study, eight of thirteen measurements were sexually dimorphism, with three of them had a predictive accuracy about 75%. The discriminant equation was provided by stepwise approach involving those three measurements (EPWl, EPDl and VBHp) with accuracy 93.0 %. This high accuracy equation is probable to be utilized in conditions of fragmentary remains, since there were only three parameters used.

Table 2. Discriptive analysis of the first lumbar in males and females.

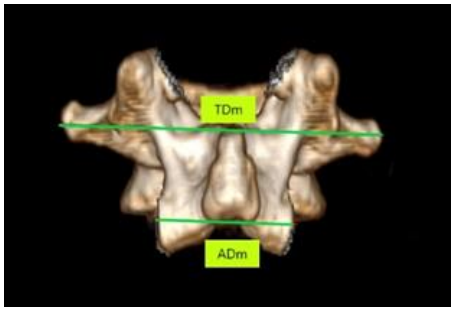
Parameters	Male		Female		*p*	Wilks Lambda	Accuracies (%)
	Mean	SD	Mean	SD			
EPWu	4.36	0.27	3.84	0.25	0.000	0.506	73.2
EPWl	4.68	0.31	4.08	0.25	0.000	0.469	80.9
VBHa	2.33	0.25	2.22	0.23	0.027	0.951	16.7
EPDu	3.25	0.27	2.75	0.18	0.000	0.449	84.1
EPDl	3.42	0.27	2.91	0.19	0.000	0.451	79.7
VBHp	2.87	0.27	2.57	0.17	0.000	0.678	52.2
PHI	1.65	0.14	1.56	0.22	0.017	0.943	28.2
AHSl	0.65	0.18	0.82	0.78	0.136	0.977	13.0
AHSr	0.69	0.18	0.70	0.20	0.837	1.000	14.9
PHr	1.69	0.14	1.55	0.13	0.000	0.783	36.2
SPH	2.51	0.43	2.19	0.33	0.000	0.853	44.9
TDm	6.95	0.68	6.28	0.74	0.000	0.814	24.2
Adm	2.85	0.35	2.70	0.38	0.052	0.962	10.7



(a)



(b)



(c)

Figure 1. Reconstructed 3D models of the first lumbar vertebrae showing the measurements: (a) Anterior view, (b) Lateral view, (c) Posterior view

The parameters which have sexual dimorphism are mostly part of the vertebral body, including the lower end-plate wight (EPWl), lower end-plate depth (EPDl) and the posterior height of the vertebral body (VBHp) which form the discriminant equation. This current study is mostly similar with Zheng et al (2012) who studied in the first lumbar vertebrae in China population, utilized 29 linier measurements of the first lumbar vertebra, which is mostly similar methods and measurements with the current study. They reported 57.1% to 86.6% accuracy from 25 traits, and discovered three variables performing discriminant equation with the accuracy of 88.6% predicting sex, they are: upper end-plate width (EPWu), middle end-plate depth (EPDm), and left pedicle height (PHl). (Zheng et al., 2012) Both El Dine (2014) and Ramadan et al (2017) studied in Egypt population using the first lumbar vertebrae for sex estimation [1],[9]. El Dine reported the upper end-plate depth (EPDu) exhibited the highest sexual dimorphism in first lumbar vertebrae with the accuracy of 75.0%, while Ramadan et al (2017) performed discriminant function equation involving the upper end-plate weight (EPWu) with the accuracy of 84.6% [9].

The previous studies mention above provide lumbar vertebra sexually dimorphic patterns, involving the vertebral body parameters. This may be due to differences in how males and females bear weight from the spine [1],[9],[12]. The lumbar region in females are more likely anterior convex, compare with males. As the convexity is caused by a wedged shape of the vertebral bodies and intervertebral disks [7].

The present study did not used the true bone measurements, but 3D CT scan image was used at 0.6 mm axis slice. Many researchers have estimated sex and used the CT scan as the 3D model measurements, thus reported sexual dimorphism in variety of human bones. Several clinical researches have also provided CT as an accurate and reliable measurements of human regions interest, especially when the samples are often difficult to obtain.

Nevertheless, the measurements were performed by changing the 3D model to a 2D model, whereby the measurements of the actual bone photograph are identical. Therefore, all measurements used in this study could be applicable, since they were selected as part of the actual bone study report [10],[12].

Table 3. Studies of sex estimation using L1 vertebra measurement

Authors	Population	Number of samples	Discriminant score equation	Accuracy
Zhengetal (2012)	Chinese	210	EPWu x 1.703 + PHl x 3.033 + EPDm x 2.384 – 20.207	88.6 %
El Dine (2014)	Egyption	120	4.50-(0.043x VL superior) – (0.023 x EPDl) + (0.040 x VBHa)	68.0 %
Ramadan (2017)	Egyption	123	0.261 x EPWu – 10.789	84.6 %
Ostrofsky (2015)	South Africa	98		87.1 %
Present study	Malaysian	100	(1.977 x EPWl) + (1.984 x EPDu) + (1.328 x VBHp) – 18.243.	93.0%

4. CONCLUSSION

In this study, eight of the thirteen measurements in the L1 vertebra showed significant sexually dimorphic, and predicting sex with an accuracy of 84.1 % to 10.7%. By discriminant function analysis stepwise method, three parameters estimated sex with 93.0 % accuracy. This study demonstrated that the first lumbar vertebrae are reliable for sex assessment, therefore the equation derived from the data may be able to help forensic investigation when dealing with sex identification within the Malaysian population.

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