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Fourth lumbar vertebral parameters in predicting the gender, height and age in Iranian population

Seyed Reza Saadat Mostafavi [a], Azadeh Memarian [b,*], Omid Motamedi [a], Maryam Mohamadi nejad khanamani [c], Mohammadreza Khaleghi [a], Shirin Habibi [a]

[a] Department of Radiology, Iran University of Medical Sciences, Tehran, Iran
[b] Department of Forensic Medicine, Iran University of Medical Sciences, Tehran, Iran
[c] Iran University of Medical Sciences, Tehran, Iran

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ABSTRACT

Introduction: Lumbar vertebral dimensions can be considered as a criterion to diagnose unidentified individuals with severe burning or corpses. The aim of this study was to evaluate gender, age, and height using the parameters of fourth lumbar vertebral (L4).
Methods: This cross-sectional study was carried out on 106 volunteers. Lumbar diameters of L4 were measured in the two sagittal and horizontal sections by three-dimensional CT scan with reconstruction and volume rendering. The measured parameters were Upper end plate depts (EPD); Upper end plate widths (EPW); Anterior height of vertebral body (VBH); Foramen diameter (depts.) (FDS); Foramen diameter (widths) (FDC); Pedicle height (PH); Pedicle widths (PW); Articular process height (APH); Maximum distance between (ADM); Transverse process distance (TDM); Spinal process height (SPH); Spinal process lengths (SPL); and Vertebral lengths (VL). These parameters were compared. The relationship of each parameter was evaluated with age, height and gender.
Results: Totally, the mean parameters of L4 was higher in men compared to women, but this difference was not significant in FDS, APHI, and SPL. In the study of the correlation of diameters with age, only EPD and SPL parameters were significant, but in the linear regression model to predict age, only the FDS index showed a significant relationship. All parameters except APHS, APHI, SPL, and VL showed a significant and positive correlation with height. But in the linear regression model to predict height, only a significant relationship was reported for EPD.
Conclusion: It was shown that the parameters of the fourth lumbar vertebra can be helpful to determine the age, height, and gender.

Introduction

Identification of the skeletal remnants is a challenge for forensic medicine particularly in burning and explosion with severe fragmentation and human remnants. Determination of gender, age, and stature reduces the probable victim matches in forensic exploration and provides useful pieces of evidence in the identification of individual [1].

The gender determination is a significant start point to create a biological profile for human skeletal remnants, since it decreases the number of probable matches by 50 % [2]. Height is a significant component to create the biological profile of an individual [3]. Also, estimation of age and height is essential in anthropology and forensic medicine [4].

There are several approaches to define chronological gender, age, height, and other features that can be useful in detecting the remnants using a metrical study of skeletal remnants. The remnants of long bones like the femur and tibia are the best choices for this aim [5–7]. In most times, long bones are fragmented, and smaller bones are often preserved better [8]. Then, we performed a study on the fourth lumbar vertebra to determine gender, age, and height.

It is obvious that there is sexual dimorphism in vertebral size [9,10]. It is shown that the vertebral cross-sectional area is larger in men about 20 %–30 % representing that vertebral morphology may be valuable in the determination of gender [11]. In a study on different morphological parameters of the lumbar vertebrae (L1-L5), successful rate of gender estimation was between 57.7 % and 88.7 % and the diameters of the vertebral body had high accuracy [12,13]. Some studies have shown a reduction in vertebral heights with increasing age and menopause [14,15]. The spine and the vertebrae, as the main bony components of the spine, is one of the core components of the stature [16]. Therefore, it is reasonable that vertebral dimensions could produce accurate stature estimates. A number of studies have measured the lumbar, cervical,

* Corresponding author.
E-mail address: memarian.a@iums.ac.ir (A. Memarian).

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sacral, and thoracic segments in different populations using regression equations to predict stature in those populations [17–20].

Recently, modern imaging techniques have developed in the forensic medicine. Virtual anthropology achieved by 3D imaging techniques like computer tomography (CT) helps us to visualize every pathological or anatomical structure with high quality and high resolution [21].

Bone diameters are different in various populations, therefore to use these diameters; further studies are needed in a special population. To the best of our knowledge, there is not enough study to evaluate the use of fourth lumbar vertebra in the Iranian population. This study aimed to evaluate parameters for estimating gender, age and height based on the measurements among the Iranian population.

Methods

This cross-sectional study was carried out on 106 volunteers referred to the Rasoul-e-Akram and Firoozgar hospitals, Tehran, Iran. The volunteers over the age of 18 years (after finishing 18 years) for whom a physician requested a lumbar spine CT scan were included in the study. Participants with a history of congenital anomalies in the lumbar spine, a history of lumbar spine trauma of any severity, a history of structural, metabolic, or rheumatic disorders in the lumbar spine, and a history of any surgical or reconstructive interventions in this area were excluded from the study. This study was approved by the ethical committee of the Iran University of Medical Sciences (#IR.IUMS.FMD.REC.1399.060). All participants signed written consent. The sample size was calculated according to the study by El Dine et al. [22] and using the following formula:

$$n = \frac{Z^2_{(1-\alpha/2)} P(1-P)}{d^2}$$

P = 93%

D = 5%

106 people participated in this study voluntarily in which five people were excluded from the study process due to the lack of additional information. Diameters of fourth lumbar vertebra were measured in the two sagittal and horizontal sections using a three-dimensional CT scan (16 slice, Toshiba, Japan) with reconstruction (MPR) and volume rendering. Height of participants was measured using standard machine (stadiometer).

The parameters measured in this study were as follow:

EPD: Upper end plate depts.
EPW: Upper end plate widths
VBH: Anterior height of the vertebral body
FDS: Foramen diameter (depts.)
FDC: Foramen diameter (widths)
PH: Pedicle height
PW: Pedicle widths
APH: Articular process height
ADM: Maximum distance between
TDM: Transverse process distance
SPH: Spinal process height
SPL: Spinal process lengths
VL: Vertebral lengths

Then, the evaluated parameters were compared statistically and the relationship of each with age, height, and gender were investigated.

Statistical analysis

SPSS version 22 was used to analyze the data. The normality of distribution was assessed using the Shapiro-Wilk test or histogram. To have access to research purposes, descriptive statistics (frequency and percentage for qualitative variables, and mean and standard deviation for quantitative variables) as well as statistical analysis methods including parametric tests such as independent *t*-test, Pearson correlation test, linear and multiple regressions were applied to predict the outcome. P-value less than 0.05 was considered as significant.

Results

Five participants were excluded and 101 participants remained in the study in which 53 subjects (52.47 %) were male and 48 subjects (47.53 %) were female. The mean age of the male participants was 32.96 ± 9.86 years and the mean age of the female participants was 34.28 ± 10.72 years. The mean height of the male participants was 176.37 ± 8.907 cm and the mean height of the female participants was 163.63 ± 5.627 cm.

The mean diameters of the fourth lumbar vertebra calculated by CT scan are shown in Table 1. Independent *t*-test was used to evaluate the mean differences between the measured parameters in the two study groups. These statistical analyzes showed that there was a significant difference between the two gender in all parameters except VBH, APHI, and SPL. There was a higher mean in males than females in all parameters (Table 1).

Pearson correlation test was used to examine the correlation between the measured parameters and height (Table 2). All parameters except APHS, APHI, SPL, and VL showed a significant correlation with height. Pearson correlation test was used to examine the correlation between the measured parameters and age (Table 2). Only FDC and EPD parameters showed a significant correlation with participants' age.

A linear regression model was used to understand the relationship between the measured parameters and height. Only the EPD index showed a significant relationship with height.

A linear regression model was used to investigate the relationship between the measured parameters and age. Only the FDS index showed a significant relationship with age.

The logistic regression model was used to investigate the relationship between the measured parameters and gender. According to the logistic regression, among the parameters and gender, Cox & Snell R square were 0.506 and Nagelkerke R square was 0.675. Only VBH, FDC, PW, and TDM parameters showed a significant relationship with gender.

Estimating the age and height of the subjects in all parameters was done using linear regression in which FDS (P = 0.042, Beta: -1.183) was a significant predictor for age and EPD (P = 0.047, Beta: 0.746) was significant predictor for height (Tables 3 and 4).

To estimate the gender of the subjects, according to the logistic regression analysis, VBH (OR: 0.859), FDC (OR: 0.740) and TDM (OR:

Table 1
The mean values of fourth lumbar vertebral parameters measured in CT scan.

Parameters	Male (mean ± SD)	Female (mean ± SD)	P value	Total (mean ± SD)
EPD	33.44 ± 2.04	30.55 ± 3.33	0.001	32.11 ± 3.19
EPW	47.08 ± 4.71	42.34 ± 3.29	0.001	44.90 ± 4.74
FDS	15.33 ± 2.37	14.87 ± 1.90	0.001	15.15 ± 2.16
VBH	31.54 ± 7.38	27.43 ± 4.41	0.431	29.60 ± 6.39
FDC	28.48 ± 4.24	25.15 ± 3.25	0.001	26.95 ± 4.13
PH	12.92 ± 2.96	11.51 ± 2.20	0.012	12.29 ± 2.71
PW	10.29 ± 1.94	8.43 ± 1.42	0.001	9.43 ± 1.94
APHS	9.69 ± 1.99	8.68 ± 1.67	0.020	9.20 ± 1.90
APHI	22.54 ± 5.60	21.96 ± 3.28	0.352	22.26 ± 4.59
ADM	40.31 ± 6.36	37.34 ± 4.97	0.019	39.05 ± 5.96
TDM	90.06 ± 17.10	78.70 ± 7.32	0.001	84.66 ± 14.35
SPH	21.12 ± 4.87	18.30 ± 2.90	0.001	19.75 ± 4.24
SPL	29.50 ± 15.46	24.68 ± 8.55	0.102	27.33 ± 12.73
VL	70.77 ± 13.57	68.60 ± 10.13	0.049	69.99 ± 1206

EPD: Upper- end plate depts.; EPW: Upper end plate widths; VBH: Anterior height of vertebral body; FDS: Foramen diameter (depts.); FDC: Foramen diameter (widths); PH: Pedicle height; PW: Pedicle widths; APHI/APHS: Articular process height inferior/superior; ADM: Maximum distance between; TDM: Transverse process distance; SPH: Spinal process height; SPL: Spinal process lengths; VL: Vertebral lengths.

Table 2
Correlation of fourth vertebrae parameters with height and age.

Parameters	Height		Age	
	r	P-value	r	P-value
EPD	0.464	0.000	0.256	0.006
EPW	0.437	0.000	0.152	0.068
FDS	0.307	0.001	−0.062	0.271
VBH	0.178	0.040	−0.141	0.084
FDC	0.356	0.000	0.170	0.047
PH	0.303	0.001	0.131	0.099
PW	0.357	0.000	−0.012	0.452
APHS	0.097	0.170	0.147	0.074
APHI	0.022	0.415	0.013	0.449
ADM	0.246	0.007	0.105	0.152
TDM	0.402	0.000	0.017	0.434
SPH	0.206	0.021	−0.147	0.074
SPL	0.121	0.117	0.229	0.012
VL	0.144	0.079	−0.041	0.343

EPD: Upper- end plate depts.; EPW: Upper end plate widths; VBH: Anterior height of vertebral body; FDS: Foramen diameter (depts.); FDC: Foramen diameter (widths); PH: Pedicle height; PW: Pedicle widths; APHI/APHS: Articular process height inferior/superior; ADM: Maximum distance between; TDM: Transverse process distance; SPH: Spinal process height; SPL: Spinal process lengths; VL: Vertebral lengths.

0.897) can be considered as effective parameter, so that the likelihood of being male, increased with increase in the VBH, FDC and TDM amount ($P < 0.05$) (Table 5).

Discussion

Estimation of gender, age and height is important in the patients with unknown remnants or whose bodies are unrecognizable [20]. This importance is doubled in serious events such as earthquakes, burning, flood, etc. Computer measurement of bone diameters is a low-cost and fast method that can be used in this regard [21,22]. Bone diameters vary in different races. In this study, we investigated the relationship between different diameters of the fourth lumbar vertebra with age, gender, and height in the Iranian population. For this study, 14 parameters of the L4 vertebra were measured using software from participants' lumbar CT scans, and the relationship between these parameters and age, gender, and height was evaluated.

In this study, all parameters in men had a higher mean than women, but these differences were not significant regarding VBH, APHI, and SPL parameters. In a study by Dine et al. on the first lumbar vertebra, parameters including EPD, VBH, FDS, ADM, TDM, VL, and VBH were significantly different between male and female and all of them are higher in male [23]. In contrast to this study, FDS was different in the two genders but similar to the present study, APHI, VBH and SPL showed no difference in the two genders. A study by Ramadan et al. demonstrated a significant difference between males and females, in such a way that males were larger than females, for all parameters of the L1 vertebra except VL and the result was close to this study [24]. Zheng et al. revealed differences between males and females in almost all parameters of L1 vertebra except EPW and EPD [25]. Although in the current study, these parameters were different in the two genders. The observed differences can parameters differences in bone diameters between different populations. Oura et al. evaluated the dimensions of the fourth lumbar vertebra to estimate gender and found that the measurements of width, depth, and height of the L4 vertebra can be used in gender estimation with an accuracy of more than 80 % [5].

In the present study, the correlation of diameters with age, only EPD, FDC and SPL parameters were significant, but in the linear regression model, only the FDS index showed a significant relationship. Ramadan et al. demonstrated a significant correlation for age and all parameters of L1 vertebra except for TD, LVF, TDM, and PW [24]. It means that similar to this study EPD, SPL, and FDS have a correlation with age. In the study by Güleç et al., it was stated that the pedicle diameters of L4 vertebrae increase with age [18]. In the present study, SPL, EPD, and FDS parameters showed a significant increase with age. Also, in the study by Güleç et al., pedicle diameters increase with age up to 40 years [26]. In a study by Amonoo-Kuofi, it was stated that the vertical and horizontal diameters of the L4 pedicle increase with age [6]. But the equivalent parameters in our study, which were pH and PW, did not show a significant relationship with age. In a study by Amonoo-Kuofi, 540 participants between the ages of 10 and 65 were examined, but in this study, 101 participants between the ages of 18 and 64 were examined. Due to the sufficient sample size in the present study, this difference

Table 3
Estimating the age of the subjects using all parameters.

Predictors for age	Beta	Std. Error	t	P value
EPD	0.803	0.426	1.885	0.063
EPW	0.234	0.290	0.806	0.423
VBH	−0.140	0.173	−0.812	0.419
FDS	−1.183	0.572	−2.069	0.042
FDC	0.290	0.283	1.027	0.307
PH	0.376	0.451	0.833	0.407
PW	−1.411	0.720	−1.960	0.053
APHS	0.458	0.596	0.768	0.444
APHI	0.118	0.218	0.543	0.588
ADM	0.148	0.216	0.682	0.497
TDM	−0.011	0.077	−0.139	0.890
SPH	−0.520	0.279	−1.866	0.066
SPL	0.192	0.114	1.688	0.095
VL	0.059	0.121	0.488	0.627

Table 4
Estimating the height of the subjects using all parameters.

Predictors for height	Beta	Std. Error	t	P value
EPD	0.746	0.370	2.018	0.047
EPW	0.192	0.251	0.765	0.446
VBH	0.244	0.150	1.625	0.108
FDS	0.501	0.496	1.011	0.315
FDC	0.421	0.245	1.718	0.090
PH	0.450	0.392	1.148	0.254
PW	0.571	0.624	0.914	0.363
APHS	−0.785	0.517	−1.520	0.132
APHI	−0.101	0.189	−0.532	0.596
ADM	−0.028	0.187	−0.151	0.880
TDM	0.124	0.067	1.864	0.066
SPH	−0.062	0.242	−0.255	0.799
SPL	0.019	0.099	0.193	0.847
VL	−0.067	0.105	−0.642	0.523

Table 5
Estimating the gender of the subjects using all parameters.

Predictors for gender	Beta	Std. Error	Wald	P value	Odds ratio
EPD	0.076	0.128	0.357	0.550	1.079
EPW	−0.155	0.104	2.229	0.135	0.856
VBH	−0.152	0.062	6.098	0.014	0.859
FDS	0.025	0.218	0.014	0.907	1.026
FDC	−0.302	0.119	6.393	0.011	0.740
PH	0.088	0.171	0.262	0.609	1.092
PW	−0.785	0.274	8.216	0.004	0.456
APHS	0.072	0.201	0.127	0.721	1.074
APHI	0.105	0.113	0.872	0.350	1.111
ADM	−0.007	0.072	0.010	0.920	0.993
TDM	−0.109	0.048	5.105	0.024	0.897
SPH	−0.102	0.097	1.106	0.293	0.903
SPL	−0.028	0.042	0.470	0.493	0.972
VL	0.002	0.039	0.002	0.966	1.002

cannot be attributed to the difference between the sample size and it could be as a result of the difference in ethnicity. Factors affecting bone diameters other than race include nutrition, genetic diseases, physical activity, and socioeconomic status [27,28].

All parameters except APHS, APHI, SPL, and VL showed a significant and positive correlation with height. But in the linear regression model, only a significant relationship was reported for EPD. In a study by Oura et al., it was found that the multiple linear regression models of the mean width, depth, and height of L4 had high accuracy [29].

In conclusion, in this study, it was shown that the parameters of the fourth lumbar vertebra can be helpful in determining the age, height, and gender. It was also shown that the trend of these parameters differs between the Iranian population and other close races. One of the limitations of this study was the lack of study in different age group of the children. It is suggested that in future studies, the trend of changes according to the age group of children be examined.

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Ethical statement

The study was approved by the ethics committee of Iran University of Medical Sciences (IR.IUMS.FMD.REC.1399.060).

Declaration of Competing Interest

There are no conflicts of interest to declare.

CRediT authorship contribution statement

Seyed Reza Saadat Mostafavi: Supervision, Software, Validation. **Azadeh Memarian:** Visualization, Investigation, Supervision, Writing - review & editing. **Omid Motamedi:** Conceptualization, Methodology, Software. **Maryam Mohamadi nejad khanamani:** . **Mohammadreza Khaleghi:** Conceptualization, Methodology, Software. **Shirin Habibi:** Conceptualization, Methodology, Software.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fsir.2021.100175.

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