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Research Paper

Height Estimation Based on 3-Dimensional CT Scan of 12th Thoracic, 1st and 5th Lumbar Vertebrae

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ABSTRACT

Background: Identification of victims is one of the main challenges of forensic medicine. Height is one of the key measurements of the biological profiles of individuals. This study aimed to evaluate height based on measuring three-dimensional CT scan indices of twelfth thoracic (T12), first lumbar (L1), and fifth lumbar (L5) vertebrae in Iranian adults.

Methods: The present study was a cross-sectional study performed on 100 patients who underwent a spinal CT scan. Vertebral T12, L1, and L5 indices were measured in these individuals. Finally, the evaluated indices were statistically compared and the diagnostic effect of each was evaluated to estimate the height. Independent t-test and linear regression were used using SPSS software v. 21. A P value less than 0.05 was considered significant.

Results: The results showed that the mean difference between T12, L1, and L5 indices in the two groups of male and female patients was statistically significant. With one unit increase in the Transverse process distance T 12 (TDM T12), there is an increase of 0.42 units in height (P=0.02).

Conclusion: According to the results of the present study, the measurements of the T12, L1, and L5 vertebral indices have a significant relationship with gender. Among the measurements of the T12, L1, and L5 vertebral indices, just TDM T12 can be a predictive factor to estimate the height of the Iranian population.

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1. Introduction

Forensic anthropometry plays a role in the determination of the biological profiles of individuals through assessing the human remnants via the metric method [1]. Gender, age, ethnicity, and height are the main parameters to confirm a biological profile [2]. In forensic exploration, height is one of the key measurements [2]. Many skeletal bones are shown that correlated with height, and long bones measurement of limbs were the most reliable bone for height estimation [3]. In most cases, as a result of the severity of the disaster, the intact bone is not available and other human skeletons should be used for estimation of height [4].

The spine is the main bony component that helps in defining the person's height [5]. Therefore, the dimension of the vertebrae column is a portion of the spine that is vastly associated with the height estimation [6]. In the study by Jason et al., stature estimation was done via the length of the cervical, thoracic, lumbar, thoraco-lumbar, and cervico-thoraco-lumbar vertebra of the spine [7]. Pelin et al. in Turkey assessed the living height using the sacral and coccygeal vertebral dimensions [8]. Nagesh et al. estimated the height using various segments of the vertebral column in the South Indian population [6].

Diagnosing and identifying differences in the spinal dimension among adults is very helpful in determining height in forensic medicine. In this regard, any of the components of the spinal cord at any stage, especially in the neck area can be very helpful in identifying height, and especially in cases where it is not possible to assess height, such as severe trauma, will be very useful. Since the alterations in the height of skeletons are affected by ethnic and environmental issues, studying the anthropological features and using them in the identification of cadavers should be done territorially. This study aimed to evaluate height based on measuring three-dimensional CT scan indices of twelfth thoracic (T12), first lumbar (L1), and fifth lumbar (L5) vertebrae in Iranian adults.

2. Materials and Methods

In this cross-sectional study, 100 adults over the age of 18 who were referred to Rasoul Akram and Firoozgar hospitals of Iran University of Medical Sciences for a spinal CT scan and volunteered to participate in the study were included. The exclusion criteria were a history of congenital anomalies of the * low thoracic vertebra * and * lumbar * vertebra spine, a history of trauma of any severity, a history of structural, metabolic, or rheumatic disorders, or a history of any surgical intervention or restorative treatment in the * low thoracic vertebra * and * lumbar * vertebra. A simple sampling method was used in this study.

Sample size determination was done according to the Vasavada study in 2008, in which the Mean±SD height of the seventh cervical vertebra in males and females was 24.6±2.7 mm and 22.6±2.4 mm, respectively [9]. The method of sampling was convenient so that we selected all available patients during the last year.

The indices of T12, L1, and L5 vertebra were measured in the subjects. The measured indices in this study were as follows: Upper Endplate Depth (EPDu), Lower Endplate Depth (EPDl), Upper Endplate Width (EPWu), Lower Endplate Width (EPWl), Anterior Height of the Vertebral Body (VBHa), Posterior Height of the Vertebral Body (VBHp), Foramen Diameter (depth) (FDs), Foramen Diameter (width) (FDc), Pedicle Height (PH), Pedicle Width (PW), Maximum Distance between Articular processes (ADm), Transverse process Distance (TDm), Spinal Process Height (SPH), Spinal Process Length (SPL), and Vertebral Length (VL).

Diameters of the 12th thoracic and first and fifth 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. The height of participants was measured using the standard machine (stadiometer). The measurement was taken by several readers, and the readers were purposefully blinded to the sex of the subjects. Finally, the evaluated indices in different sex groups were statistically compared and the diagnostic accuracy of each was evaluated for height estimation.

Statistical analysis

SPSS software v. 21 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 coefficient, and linear and multiple regression, were applied to predict the outcome. A P-value of less than 0.05 was considered significant.

3. Results

The mean age and height of patients by sex are demonstrated in Table 1. In this study, 100 patients were studied. Of these, 49% were female and 51% were male.

Table 1. Comparison of the mean age and height of the subjects by gender

Variables		N	Mean±SD	Min	Max	P
Age (Y)	Male	49	32.41±9.22	17	51	0.489
	Female	51	33.73±9.71	17	61	
Height (cm)	Male	49	176.84±9.28	150	194	<0.001
	Female	51	163.83±5.15	150	173	

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The results of the independent t-test showed that the mean age difference between the two groups of male and female patients was not statistically significant (P>0.05). However, the difference between the mean height of patients in the two groups of men and women was statistically significant (P<0.05).

The comparison of T12, T1, and T5 indices in the two groups of male and female patients are shown in Table 2. The results showed that the mean difference of all T12 indices except articular process height inferior (APHi), articular process height superior (APHs), and SPH in the two groups of male and female patients was statistically significant.

The mean difference of all L1 indices except APHi and SPH in the two groups of male and female patients was statistically significant. Besides, in all significant indices, it was more in males than females.

The mean difference of all L5 indices except APHi and SPL in the two groups of male and female patients was statistically significant. Also, in all significant indices, it was more in males than females. Descriptive statistics of T12, L1, and L5 indices were shown in Table 3.

To check estimation bias, in the univariate analysis of linear regression, among all studied variables some factors were not significant, including FDsT12 (P=0.396), APHsT12 (P=0.687), APHiT12 (P=0.989), APHiL1 (P=0.932), APHsL5 (P=0.180) and APHiL5 (P=0.826) but others were significant, including EPDuT12, EPWuT12, VBHaT12, FDcT12, PHT12, PWT12, AdmT12, TDmT12, SPHT12, SPLT12, VLT12, EPDuL1, EPWuL1, VBHaL1, FDsL1, FDcL1, PHL1, PWL1, APHsL1, AdmL1, TDmL1, SPHL1, SPLL1, VLL1, EPDuL5, EPWuL5, VBHaL5, FDsL5, FDcL5, PHL5, PWL5, AdmL5, TDmL5, SPHL5, SPLL5 and VLL5 (P<0.1). Therefore, just significant variables were selected to be analyzed in the final model of multivariate analysis. With one unit increase in the TDm T12, there was an increase of 0.42 units in height (P=0.02). TDM T12 can be an effective factor to predict height. In the univariate analysis, the observed significant results were not valid and it was shown without modifying the effect of confounding but in the multivariate analysis, confounders were adjusted then the results can be reliable, which is shown in Table 4.

4. Discussion

The relationship between height and morphology of the spine is one of the effective factors in identifying a person in forensic medicine. Therefore, in cases where only part of the spine of the body is available, the morphology of the vertebrae of the spine can be used to understand various skeletal features of the person, including his standing height. In this study, the estimation of height was done based on three-dimensional CT scan indices of T12, L1, and L5 vertebrae in Iranian adults.

The results showed that the mean difference of all T12 indices except APHi, APHs, and SPH in the two groups of male and female patients was statistically significant, and in all significant indices, it was more in males than females. The results showed that the mean difference of all L1 indices except APHi and SPH in the two groups of male and female patients was statistically significant, and in all significant indices, it was more in males than females. The study results showed that the mean difference of all L5 indices except APHi and SPL in the two groups of male and female patients was statistically significant at a 95% confidence level, and in all significant indices, it was more in males than females.

FDsT12 (P=0.396), APHsT12 (P=0.687), APHiT12 (P=0.989), APHiL1 (P=0.932), APHsL5 (P=0.180) and APHiL5 (P=0.826) were not significant factors to predict height even in univariate analysis. In multivariate analysis of regression, with one unit increase in the TDm T12, there was an increase of 0.42 units in height (P=0.02). TDM T12 can be a predictive factor to estimate height.

Table 2. Comparison of T12, L1, and L5 indices in two groups of male and female patients

Variables		Mean±SD/Median (First Quarter, Third Quarter)		
		T12	L1	L5
EPDu	Male	29.82±3.32	31.41±3.06	34.47±3.13
	Female	26.98±2.56	28.29±3.10	31.14±2.75
	P	<0.001	<0.001	<0.001
EPWu	Male	41.14±4.26	44 (41, 47)	50.06±5.03
	Female	35.73±3.70	38 (35, 40)	45.98±3.56
	P	<0.001	<0.001	<0.001
VBHa	Male	26 (24, 28)	28 (26, 30)	31 (29, 34)
	Female	24 (22, 25)	26 (24, 28)	28 (26, 30)
	P	<0.001	0.004	0.001
FDs	Male	17.37±2.03	17.24±1.95	17.49±3.05
	Female	16.18±2.19	16.37±1.63	15.49±2.21
	P	0.006	0.017	<0.001
FDc	Male	23.96±1.92	24 (23, 25)	32.16±4.56
	Female	22.10±2.60	23 (21, 23)	28.82±3.73
	P	<0.001	<0.001	<0.001
PH	Male	14.82±2.77	14 (12, 15)	12.59±2.58
	Female	13.53±2.73	13 (11, 14)	11.43±1.96
	P	0.021	0.005	0.013
PW	Male	7.67±1.80	7.31±1.59	11.98±2.68
	Female	6.94±1.71	5.92±1.26	10.96±2.36
	P	0.040	< 0.001	0.046
APHs	Male	8.69±1.48	9.27±1.85	9.98±2.25
	Female	8.80±2.17	8.37±2.09	8.86±1.90
	P	0.103	0.027	0.009
APHi	Male	20.37±5.17	22.76±6.29	18.67±4.53
	Female	20.20±3.87	23.12±4.13	19.57±4.31
	P	0.856	0.733	0.314
Adm	Male	27.69±3.16	28 (26, 30)	47.0±7.31
	Female	25.78±2.61	25 (24, 28)	41.65±5.98
	P	0.001	<0.001	<0.001

Variables		Mean±SD/Median (First Quarter, Third Quarter)		
		T12	L1	L5
TDm	Male	49 (44, 52)	72.92±8.42	92.08±7.22
	Female	42 (40, 48)	66.55±5.44	84.94±7.0
	P	<0.001	<0.001	<0.001
SPH	Male	18.04±3.88	21.37±4.60	18 (15, 20)
	Female	16.59±4.69	19.55±4.60	17 (14, 18)
	P	0.096	0.051	0.020
SPL	Male	20.94±4.59	24.78±4.72	23.10±5.21
	Female	18.22±3.71	21.29±4.10	22.22±4.96
	P	0.002	<0.001	0.386
VL	Male	68.96±8.11	73.65±7.01	76.02±8.25
	Female	62.31±6.44	65.82±5.98	69.16±6.28
	P	<0.001	<0.001	<0.001

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Upper Endplate Depth (EPDu); Upper Endplate Width (EPWu); Anterior Height of theVertebral Body (VBHa), Foramen Diameter (depth) (FDs); Pedicle Height (PH); Pedicle Width (PW); Maximum Distance between Articular processes (ADm); Transverse process Distance (TDm); Spinal Process Height (SPH); Spinal Process Length (SPL); Vertebral Length (VL); Articular process height inferior (APHi); Articular process height superior (APHs).

Table 3. Descriptive statistics of T12 indices

Indices	Mean±SD/Median (First Quarter, Third Quarter)		
	T12	L1	L5
EPDu	28.37±3.27	30 (27, 32)	32 (30, 35)
EPWu	38.38±4.81	40.46±5.04	48 (45, 51)
VBHa	24 (23, 27)	27 (25, 30)	30 (27, 32.75)
FDs	17 (15.2, 18)	17 (16, 18)	16 (15, 18)
FDc	23 (22, 25)	23 (22, 25)	30.46±4.48
PH	14 (13, 16)	13 (12, 15)	12 (11, 13)
PW	7 (6, 9)	7 (5, 8)	11 (9.25, 13)
APHs	8 (7, 10)	9 (8, 10)	9 (8, 11)
APHi	21 (18, 23)	23 (20, 25)	19.13±4.42
Adm	27 (25, 28)	27 (25, 29)	44.27±7.16
TDm	45.50 (41, 50)	69.67±7.72	88.44±7.93
SPH	17.30±4.35	20.44±4.67	17.22±4.38
SPL	19.55±4.36	23.0±4.73	23 (19, 27)
VL	65.57±8.0	69.66±7.57	72.48±8.04

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Table 4. Multivariate analysis of the studied variables to predict height using linear regression

Variables	Unstandardized Coefficients		Standardized Coefficients	t	P
	B	Std. Error	Beta		
EPDu T12	0.661	0.689	0.217	0.960	0.341
EPWu T12	-0.071	0.437	-0.035	-0.162	0.872
VBHa T12	0.258	0.505	0.121	0.510	0.612
FDc T12	-0.143	0.623	-0.036	-0.230	0.819
PH T12	0.085	0.489	0.024	0.174	0.863
PW T12	-0.828	0.809	-0.147	-1.024	0.310
Adm T12	-0.089	0.437	-0.028	-0.204	0.839
TDm T12	0.426	0.178	0.278	2.393	0.020
SPH T12	0.025	0.355	0.011	0.070	0.945
SPL T12	-0.070	0.660	-0.031	-0.106	0.916
VL T12	-0.290	0.456	-0.234	-0.635	0.528
EPDu L1	-0.220	0.673	-0.077	-0.327	0.745
EPWu L1	0.229	0.428	0.118	0.535	0.595
VBHa L1	-0.117	0.421	-0.067	-0.278	0.782
FDs L1	0.159	0.803	0.029	0.198	0.843
FDc L1	0.494	0.614	0.133	0.804	0.425
PH L1	-0.036	0.466	-0.011	-0.078	0.938
PW L1	1.204	1.011	0.197	1.191	0.239
APHs L1	-0.373	0.561	-0.078	-0.664	0.509
Adm L1	-0.221	.303	-0.089	-0.729	0.469
TDm L1	0.107	0.176	0.085	0.606	0.547
SPH L1	0.104	0.358	0.050	0.291	0.772
SPL L1	-0.359	0.628	-0.169	-0.571	0.570
VL L1	0.281	0.524	0.215	0.536	0.594
EPDu L5	0.237	0.528	0.081	0.449	0.655
EPWu L5	-0.032	0.402	-0.016	-0.080	0.936
VBHa L5	-0.033	0.193	-0.025	-0.169	0.866
FDs L5	0.071	0.557	0.020	0.128	0.899
FDc L5	-0.092	0.283	-0.041	-0.326	0.746
PH L5	0.151	0.508	0.037	0.297	0.768
PW L5	-0.109	0.538	-0.029	-0.202	0.840
Adm L5	-0.030	0.202	-0.022	-0.147	0.884
TDm L5	0.141	0.172	0.114	0.825	0.413
SPH L5	-0.112	0.380	-0.050	-0.294	0.770
SPL L5	-0.206	0.430	-0.105	-0.480	0.633
VL L5	0.495	.392	0.402	1.264	0.211

Earlier studies have shown the precision of assessing height by the use of intact long bones, but since this hardly occurs, we should consider the probability of using other smaller and more resistant bones, such as vertebrae. Since these smaller bones are more frequent and more possible to be available intact and because long bones are often fragmented, it is recommended to use the smaller bones [10]. The results of the current study are similar to those reported in previous works.

In a study by Torimitsu et al. on the estimation of height by measurement of the second cervical vertebra (C2) using multidetector computed tomography, it was demonstrated that there is a positive correlation between all measurements of the C2 with height regardless of gender. The highest correlation was seen for the DA (The length from the top of the dens to the anteroinferior point of the vertebral body) in all cases. They concluded that the size of the C2 may be useful for height estimation [11]. In another study on height estimation using C2 measured using 3D-computed tomographic scanning in Iranian adults, the accuracy of linear dimensions of C2 vertebrae in the estimation of the body height of the Iranian adult was shown [12].

Oura et al. assessed the height estimation from dimensions of the fourth lumbar vertebra using magnetic resonance imaging scans and found that the depth and height of L4 showed the highest prediction accuracies with the lowest prediction errors and can be used for accurate height estimation [13]. In a study by Cui et al. on the evaluation of height estimation for Sichuan Han women via the total vertebral column length measurement in the frontal and lateral X-ray films of whole-spine, it was demonstrated that the total vertebral column length has a good correlation with height; therefore, the height estimation via the measurement of total vertebral column length has great accuracy [14].

Zhang et al. evaluated the correlation between the radiologic anthropometry of the dimensions of the lumbar vertebral and stature in the Chinese population, and when each vertebral body was used, the heights of the central vertebral body of L1 showed the maximum accurate results for the female group, the heights of the posterior vertebral body of L3 gave the most accurate results for the male group, and the heights of the anterior vertebral body of L5 gave the less accurate results. The study results suggest that the lumbar vertebral dimensions can be useful in height estimation [15]. Another study on the south Indian population showed that measurement of the lengths of different segments of the vertebral column along the anterior surface was useful in stature estimation in cases who are extremely decomposed and when long bones are not available [15]. In the study by Rodríguez et al., smaller bones, such as the cervical vertebrae (first and second vertebrae) were used to assess height. In that study, which was performed on 203 people in the Spanish population, the results were meaningfully significant and showed a good relationship between vertebrae size and height [16]. Abdul Waduud et al. assessed the validation of vertebral body parameters, including the vertebral body area, anteroposterior vertebral body diameter, and lateral vertebral body diameter in stature estimation in elderly patients. They demonstrated a significant relationship between the patient's height and the vertebral body measurements [17].

5. Conclusion

According to the result of the present study, the measurements of the T12, L1, and L5 vertebral indices have a significant relationship with gender. Among the measurements of the T12, L1, and L5 vertebral indices, just TDM T12 can be a predictive factor to estimate the height of the Iranian population.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the ethics committee of the Iran University of Medical Sciences (IR.IUMS.FMD.REC.1399.400). The study was performed according to Helsinki's principles of ethics. All participants were aware of the study and signed written consent.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

There is no conflict of interest for the present study.

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