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ORIGINAL ARTICLE

Investigation of sexing accuracy of second and seventh cervical vertebras in adult Iranian population by using CT scan images

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Abstract

Sexing accuracy of several metric dimensions of second and seventh cervical vertebras from CT scan images of a series of Iranian adult people were investigated. In this cross-sectional study, sexual dimorphism of 15 indexes of second cervical vertebra and 10 indexes of the seventh cervical vertebra were investigated. Indexes were obtained from CT scan images of 70 patients (35 males and 35 females) who underwent imaging for indications other than present study. Among measured dimension of second vertebra, 9 were associated with sex. Of these indexes, Maximum width of the superior Facet and Maximum height of axis were independent predictors of sex with correct sex classification of 81.4% when used in combination. Of 10 investigated indexes of the seventh vertebra, 4 were associated with sex: Length of superior facets, Length of the inferior surface of the vertebral body, Width of the inferior surface of the vertebral body and Length of spinous process. Length of the inferior surface of the vertebral body and Length of spinous process were independent sex predictors and together provided sex classification accuracy of 78.6%. We found considerable accuracy in sex classification by using metric dimensions of cervical vertebras in adult Iranian population.

Keywords

Cervical vertebrae; Computer tomography; Dimension; Metric; Sex

Introduction

Reliable estimation of sex from human skeletal remains is one of the most important factors in biological profiling and forensic anthropology casework especially in cases of mass disaster and high intensity explosions.[1,7] Therefore, finding novel trustworthy methods for skeletal identification is considered as an essential component of medico-legal surveys.[4] Forensic anthropology is applied with the goal to identify unknown human skeletal remains through the standard scientific techniques and to make a biological profile, an osteological biography.[4] The biological profile indices including age at death, stature, and ancestry are sex dependent which are affected by sex estimation as a primary significance.[1,4,8] Some traditionally morphological and anthropometric methods have been employed by forensic scientists and physical anthropologists for the sex estimation of bone samples.[9-11] Several sex determination studies have been conducted by metric analysis of talus, femur, patella, humerus, calcaneus, metatarsals, tarsals, metacarpals, phalanges, scapula, clavicle and sternum.[12-20] Different studies had applied the first and the second cervical vertebrae to determine sex correctly with nearly the same level of accuracy compared to the other traditionally used bones.[3,21] Other studies applied CT imaging and real bone subjects with different sample size and level of accuracy for sex discrimination from the vertebra.[3,21-26] Wescott et al. showed that sex determination accuracy between 76-86% in the sagittal length.[22] They showed that accuracy levels for estimating sex from the axis varied correctly between 77-90% correct.[22] Voisin et al. showed that the useful sexually dimorphic bones for forensic sex estimation are the seven cervical vertebrae (C1-C7).[27] Forensic medicine has been revolutionized using modern cross-sectional imaging techniques including 3D imaging techniques such as computer tomography (CT) and magnetic resonance imaging (MRI) over the past decade.[7] These methods could be useful in visualizing almost every anatomical and pathological structure with high resolution and quality.[28]

In a review of methods involved in sex estimation from human skeletal remains in South Africa within the forensic context showed that sex considered as one of the key factors in biological profiling of the individuals.[29] The examined methods of sex determination included morphological, metrical, geometric morphometries and molecular approaches.[29] The aim of current study was focus on the level of sexual accuracy in the second and seventh cervical vertebrae to establish an accurate sex estimation method using measurements data obtained from the CT scan imaging of Iranian skeletal populations.

Material and Methods

This cross-sectional study was carried out on sexuality accuracy of several metric dimensions of second and seventh cervical

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vertebras from CT scan imaging of a series of Iranian adult population. The 70 cases (35 females and 35 males) more than 18-year old age who had undergone imaging for indications other than present study in Hazrat-Rasool Hospital during April-September 2018. Informed consent was obtained from all patients. All cases were selected via multi-level cluster random sampling. Patients who were ≥ 18-year old age and underwent CT imaging according to their physician's advice were included in this study. Cases who were under 18-year old age and who had history of the mentioned disorders were excluded from the study:

- History of trauma to the neck with any severity
- Having structural or anatomical abnormalities in the neck area
- History of rheumatologic disorders with neck involvement
- History of any type of surgery, regenerative or therapeutic intervention in the neck area

The collected data were analyzed using the SPSS statistical software package version 21.0 (SPSS Inc, Chicago, IL, USA). To test the relationship between qualitative variables, Chi-squared test was used. Quantitative variables were compared between the two groups by T-test and Pearson correlation test was used to examine the relationship between quantitative variables such as age and dimensions of vertebrae. Logistic Regression Model was applied to determine the independent predictor variables of gender and was selected as the reference in female gender regression. Statistically significant level was < 0.05. The several metric dimensions of second and seventh cervical vertebras were applied to measure sexual dimorphism using CT scan imaging of cases the following indices were measured.

The 15 indices of second cervical vertebra

1. Max height of the axis (AMA): measured as sagittal view
2. Max length of the axis (CMA): measured as sagittal view
3. Odontoid process sagittal diameter (DSD): measured as axial view
4. Odontoid process transverse diameter (DTD): measured as axial view
5. Max distance between the superior facets (DMFS): measured as coronal view
6. Max length of the sup. Facet (CMFS): measured as sagittal view
7. Max width of sup. Facet (LMFS): measured as coronal view
8. Length of the vertebral foramen (CMFV): measured as axial view
9. Sagittal max body diameter (DSMC): measured as sagittal view
10. Max width of the vertebral foramen (LMFV): measured as axial view
11. Max height of the odontoid process (AMD): measured as coronal view
12. Max transvers diameter of the body (DTMC): measured as coronal view
13. Max width of the axis (LMA): measured as coronal view
14. Max length of the inf. Facet (CMFI): measured as sagittal view
15. Max width of the inf. Facet (LMFI): measured as coronal view

The 10 indices of the seventh cervical vertebra

1. Length of the sup. Facet (LSF): measured as sagittal view
2. Width of the sup. Facets (WSF): measured as coronal view
3. Length of the inf. Facets (LIF): measured as sagittal view
4. Width of the inf. Facets (WIF): measured as coronal view
5. Length of the vertebral foramen (LVF): measured as axial view
6. Width of the vertebral foramen (WVF): measured as axial view
7. Length of the inf. surface of the vertebral body (LVB): measured as sagittal view
8. Width of the inf. surface of the vertebral body (WVB): measured as coronal view
9. Length of spinous process (LSP): measured as axial view
10. Height of spinous process (HSP): measured as sagittal view

Results

A total of 70 cases (35 females and 35 males) with the mean age of 40.91±14.85 years (18-82) participated in this study. Data showed that there is no significant difference between male and female groups in this study (p-value = 0.8). The characteristics of the 10 and 15 indices of each cervical vertebra in the whole population are described in Tables 1 and 2. A total of 9 out of 15 indices measured in the second cervical vertebra were statistically significant (p-value<0.05). The AMA, LMA, DSD, DMFS, CMSF, LMFS, AMD, DSMC and LMFI indices were significantly higher in males than in females Table 3. Four out of 10 indices measured in the seventh cervical vertebra were statistically significant (p-value<0.05). The LSF, LIVB, WIVB and LSP indices were significantly higher in men than in women Table 4.

Regarding the relationship between a number of dimensions belong to each vertebra and gender, logistic regression was used to determine the independent predictive dimensions of gender in each vertebrate. The cases that were statistically significant

Table 1: The characteristics of the 15 indices of second cervical vertebra in the whole population

Indices	AMA	CMA	LMA	DSD	DTD	DMFS	CMFS	LMFS	CMFV	LMFV	AMD	DSMC	DTMC	CMFI	LMFI
Mean	37.93	48.5	53.47	10.79	9.50	44.29	13.26	13.84	17.69	23.76	16.19	15.34	18.70	10.04	10.53
Standard deviation	3.68	3.76	4.98	1.03	.90	3.07	1.62	1.47	1.40	1.93	1.86	1.62	1.77	1.23	1.24
Minimum	52	58	70	14	12	54	17	17	21	28	20	20	25	12	13
Maximum	30	39	43	9	7	36	9	10	15	20	12	11	15	7	8

AMA: maximum height of the axis; CMA = maximum length of the axis; LMA = maximum width of the axis; DSD = odontoid process sagittal diameter; DTD = odontoid process transverse diameter; DMFS = maximum distance between the superior facets; CMFS = maximum length of the superior facet; LMFS = maximum width of the superior facet; CMFV = length of the vertebral foramen; LMFV = maximum width of the vertebral foramen; AMD = maximum height of the odontoid process; DSMC = sagittal maximum body diameter; DTMC = maximum transverse diameter of the body; CMFI = maximum length of the inferior facet; LMFI = maximum width of the inferior facet.

Table 2: The characteristics of the 10 indices of seventh cervical vertebra in the whole population

Indices	LSF	WSF	LIF	WIF	LVF	WVF	LIVB	WIVB	LSP	HSP
Mean	91	12.1286	9.57	12.17	15.27	24.79	16.33	25.79	23.99	7.80
Standard deviation	1.18	1.21490	1.20	1.50	1.96	1.85	1.88	2.59	3.98	14.10
Minimum	12	15.00	13	15	24	30	21	33	33	11
Maximum	7	9.00	7	8	13	22	12	21	14	5

LSF = length of the superior facet; WSF = width of the superior facet; LIF = length of the inferior facet; WIF = width of the inferior facet; LVF = length of the vertebral foramen; WVF = width of the vertebral foramen; LIVB = length of the inferior surface of the vertebral body; WIVB = width of the inferior surface of the vertebral body; LSP = length of the spinous process; HSP = height of spinous process

Table 4: Comparison of 10 indices related to seventh cervical vertebra between genders

Indices	Gender	Mean	Standard deviation	Minimum	Maximum	*p-value*
LSF	**Male**	9.49	1.09	12	7	0.005
	Female	8.71	1.15	12	7	
WSF	**Male**	12.40	1.17	15	9	0.06
	Female	11.86	1.22	14	9	
LIF	**Male**	9.77	1.21	12	8	0.16
	Female	9.37	1.17	13	7	
WIF	**Male**	12.46	1.24	15	10	0.11
	Female	11.89	1.69	15	8	
LVF	**Male**	15.66	2.21	24	13	0.10
	Female	14.89	1.62	19	13	
WVF	**Male**	24.94	1.71	30	22	0.48
	Female	24.63	1.99	29	22	
LIVB	**Male**	17.17	1.76	21	13	<0.001
	Female	15.49	1.62	21	12	
WIVB	**Male**	26.63	3.06	33	21	0.006
	Female	24.94	1.66	27	21	
LSP	**Male**	26.03	3.51	33	20	<0.001
	Female	24.94	1.66	28	14	
HSP	**Male**	8.11	1.47	11	5	0.06
	Female	7.49	1.29	10	5	

LSF = length of the superior facet; WSF = width of the superior facet; LIF = length of the inferior facet; WIF = width of the inferior facet; LVF = length of the vertebral foramen; WVF = width of the vertebral foramen; LIVB = length of the inferior surface of the vertebral body; WIVB = width of the inferior surface of the vertebral body; LSP = length of the spinous process; HSP = height of spinous process

Table 3: Comparison of 15 indices related to second cervical vertebra between genders

Indices	Gender	Mean	Standard deviation	Minimum	Maximum	*p-value*
AMA	Male	39.57	3.93	31	52	<0.001
	Female	36.29	2.53	30	40	
CMA	Male	49.97	3.53	42	58	0.30
	Female	47.06	3.43	39	56	
LMA	Male	55.14	3.90	46	63	0.004
	Female	51.80	5.42	43	70	
DSD	Male	11.17	1.07	9	14	0.001
	Female	10.40	0.85	9	12	
DTD	Male	9.63	0.91	7	11	0.23
	Female	9.37	0.88	8	12	
DMFS	Male	45.11	2.27	40	50	0.02
	Female	43.46	3.54	36	54	
CMFS	Male	13.66	1.53	10	16	0.04
	Female	12.86	1.63	9	17	
LMFS	Male	14.51	1.29	11	17	<0.001
	Female	13.17	1.34	10	16	
CMFV	Male	17.97	1.50	15	20	0.09
	Female	17.40	1.24	15	21	
LMFV	Male	24.17	2.06	20	28	0.07
	Female	23.34	1.71	20	27	
AMD	Male	16.69	2.04	13	20	0.02
	Female	15.69	1.51	12	19	
DSMC	Male	16.14	1.37	14	20	<0.001
	Female	14.54	1.46	11	19	
DTMC	Male	19.11	1.73	17	25	0.05
	Female	18.29	1.74	15	22	
CMFI	Male	10.20	1.02	8	12	0.29
	Female	9.89	1.41	7	12	
LMFI	Male	10.94	1.26	9	13	0.004
	Female	10.11	1.08	8	13	

AMA = maximum height of the axis; CMA = maximum length of the axis; LMA = maximum width of the axis; DSD = odontoid process sagittal diameter; DTD = odontoid process transverse diameter; DMFS = maximum distance between the superior facets; CMFS = maximum length of the superior facet; LMFS = maximum width of the superior facet; CMFV = length of the vertebral foramen; LMFV = maximum width of the vertebral foramen; AMD = maximum height of the odontoid process; DSMC = sagittal maximum body diameter; DTMC = maximum transverse diameter of the body; CMFI = maximum length of the inferior facet; LMFI = maximum width of the inferior facet.

Table 5: The Logistic regression model to determine the predictive indices of gender in the second cervical vertebra

Dimensions of second cervical vertebra	95% confidence interval		Odds ratio	B
	Upper limit	Lower limit		
AMA	2.046	1.051	1.466	0.383
LMA	1.178	0.838	0.994	-.006
DSD	3.235	0.598	1.391	0.330
DMFS	1.304	0.776	1.006	.006
CMFS	1.376	0.519	0.845	-0.169
LMFS	3.454	1.153	1.996	0.691
AMD	1.435	0.500	0.847	-0.166
DSMC	2.549	0.786	1.415	0.347
LMFI	2.725	0.723	1.404	0.339

Table 7: Correlation between age and indices related to seventh cervical vertebra in whole population

Indices	LSF	WSF	LIF	WIF	LVF	WVF	LIVB	WIVB	LSP	HSP
Correlation Coefficient	0.27	0.09	0.19	-0.14	0.07	-0.17	0.29	0.06	0.19	0.21
p-value	0.02	0.45	0.11	0.26	0.58	0.17	0.02	0.62	0.12	0.09

LSF = length of the superior facet; WSF = width of the superior facet; LIF = length of the inferior facet; WIF = width of the inferior facet; LVF = length of the vertebral foramen; WVF = width of the vertebral foramen; LIVB = length of the inferior surface of the vertebral body; WIVB = width of the inferior surface of the vertebral body; LSP = length of the spinous process; HSP = height of spinous process

Table 6: Correlation between age and indices related to second cervical vertebra in whole population

Indices	AMA	CMA	LMA	DSD	DTD	DMFS	CMFS	LMFS	CMFV	LMFV	AMD	DSMC	DTMC	CMFI	LMFI
Correlation Coefficient	0.51	-0.06	0.19	0.02	0.23	0.26	0.18	0.15	-0.08	0.05	0.08	0.26	0.05	0.27	0.13
p-value	0.68	0.62	0.11	0.84	0.06	0.02	0.13	0.22	0.49	0.66	0.50	0.03	0.70	0.02	0.28

AMA = maximum height of the axis; CMA = maximum length of the axis; LMA = maximum width of the axis; DSD = odontoid process sagittal diameter; DTD = odontoid process transverse diameter; DMFS = maximum distance between the superior facets; CMFS = maximum length of the superior facet; LMFS = maximum width of the superior facet; CMFV = length of the vertebral foramen; LMFV = maximum width of the vertebral foramen; AMD = maximum height of the odontoid process; DSMC = sagittal maximum body diameter; DTMC = maximum transverse diameter of the body; CMFI = maximum length of the inferior facet; LMFI = maximum width of the inferior facet.

with gender in the tables 3 and 4 were included in the logistic regression model. In order to predict the dependent variable of gender based on the dimensions of each vertebrate, results of the Logistic regression are summarized in Tables 5 and 6. The reference point for logistic regression is female gender.

The AMA and LMFS variables determined as the independent predictors of gender in second cervical vertebra. The mentioned two variables, along with each other, had a diagnostic accuracy of 81.4% (82.9% for women and 80% for men) Table 5. The LIVB and LSP variables considered as the independent predictors of gender in second cervical vertebra. The mentioned two variables, along with each other, had a diagnostic accuracy of 78.6% (80% for women and 77.1% for men) Table 6. In order to evaluate the relationship between age and indices and due to the normal distribution of data, Pearson correlation test was used in the whole population and in each gender Table 6 and 7.

Only DMFS, DSMC, and CMFI indices of second vertebra showed weak correlation coefficient and positive significant correlation with age. There was no significant correlation between age and second vertebra indices in males. There was also a significant positive and moderate correlation between age in females and CMA, LMA, DTD, DMFS, CMFS indices. Only the LSF and LIVB indices of seventh cervical vertebra had a significant weak and positive correlation with age. Evaluation of correlation between age and the seventh vertebra indices showed that WIF had a reverse and moderate correlation with age and HSP had a moderate and positive correlation with age. In the correlation analysis between the seventh indices with age in females, LIVB and WIVB showed a significant positive and moderate correlation.

Discussion

The most important factor in biological profiling of unidentified human remains is assessment of sexually dimorphic topographies of the skeleton.[7,30,31] The burned and broken parts of bones are the most important components which has been encountered in forensic caseworks.[32] Different parts of bones including different regions of the vertebral column, skull, pelvic, fingers and the upper and lower limbs has been applied in formulation of sex determination.[33-36] To the best of our knowledge, there is no published literature on sexing accuracy from anthropometric measurements of second and seventh cervical vertebras among Iranian adult people using CT scan imaging. In the present study, for the first time, the role of the metric dimensions of second and seventh vertebra in sex determination of some adult population of Iran was investigated according to their cervical CT scan. Findings of the second cervical vertebra indices in males and females showed that in all cases, the dimensions of collected indices from the vertebrae of males are greater than that of females, but in 9 out of 15 indices, this difference was statistically significant. These 9 indices were including AMA, LMA, DSD, DMFS, CMFS, LMFS, AMD, DSMC, and LMFI. Among the 9 variables which had significant correlation with sex, 2 variables of LMSF and AMA considered as the independent predictive of sex with odds ratio of 2 and 1.47, respectively and they had diagnostic accuracy of 81.4%. This indicates the presence of sexual dimorphism in the measurements of Iranian vertebrae. The most significant mean difference was found in the linear dimensions of the second vertebra of LMA (3.34 mm) and AMA (3.28 mm) between the two sexes. A review of various studies on sex determination based on the dimensions of the second cervical vertebra and the comparison of their results with each other showed that there were some limitations among the studies including firstly, there were few studies, and, secondly, the dimensions examined were not the same between the studies.

In a study on cervical vertebra of skeletal specimens, the 15 linear indices of cervical vertebra were examined, which were largely in accordance with the metric dimensions measured in our study.[1] The size of the examined dimensions was slightly different from the dimensions of our study.[1] In all cases, dimensions were higher in males, but the LMA and DSMC indices had the most difference between the two sexes.[1] In their study, four indices (CMA, LMA, LMFSD, and DSMC) were independent predictors of gender with predictive accuracy of 87% between sexes.[1] The highest risk ratio was related to DSMC (2.66) and LMA (1.97), respectively.[1] In other study conducted by Marlow et al., 9 indices of cervical vertebra dimensions were measured, some of these dimensions are similar to those measured in our study. All of these dimensions in males were significantly larger than females.[3] Of these dimensions, XSL, SFS, SFT, LVF, and XDH were gender-independent predictors that provided a total of 77% gender diagnostic accuracy.[3] Independent gender variables in our study are somewhat similar to those of the four independent variables.[3] In the analysis of the 5 dimensions of the second cervical vertebra between different populations, the diagnostic accuracy was obtained over 80%.[22,26] These five dimensions were including the greatest length of the sagittal (from the anterior part of the vertebra to the posterior part of the genital area), the sagittal of the upper fast diameter, the cross-sectional diameter of the upper fast (the largest diameter of the upper surface of the fast that is perpendicular to the sagittal surface), The length of the vertebral hole (the length of the inner hole measured at its lower end on the median plate), the largest length of the vertebra (the distance between the lower to the upper part of the vertebra in the anterior plane).[22,26]

In comparison of our study with the above-mentioned studies on second cervical vertebral indices, a few points were noted: First, in all of the mentioned cases, as well as our study, the upper fast was considered as an independent predictor of gender; Second, the diagnostic accuracy of sex determination in different dimensions was significant in all cases; Third, although all dimensions were larger in males than females, but the mean difference was low even in significant indices suggesting it is essential to be more focused on practical points of these low rates of mean difference.

In terms of seventh cervical vertebra of current study, the 10 linear indices were investigated. All dimensions in this vertebra were higher in males than in females, and statistically significant correlations with gender was observed in 4 indices including the LSF, LIVB, WIVB and LSP. Of these four indices, only two variables LIVB (with odds ratio of 1.55) and LSP (odds ratio of 1.31) were independent gender predictors. The two variables had a diagnostic accuracy of 78.6%. Studies on the role of the role of seventh cervical vertebra dimensions in the sex determination were scarce and there are differences in measured metric dimensions and study methods among them. In confirmation of the findings of current study, assessment of the seventh cervical vertebra dimensions amongst the three groups of whites, blacks and South Africa tribes showed that the anterior posterior's length, width and height of the vertebra were greater in males than females.[37] In a study in Spain, the length of the lower part of vertebra and the length and width of the intervertebral hole were recognized as strong sex determinants of the seventh cervical vertebra with a diagnostic accuracy of 81% for men and 79% for women.[38] Another study on the European white population showed that the maximum height of the seventh cervical vertebra and the transverse diameter of the intervertebral hole in this group were independent gender predictors with a diagnostic accuracy of over 80%.[4] Results of the mentioned studies showed the accuracy of different dimensions of seventh cervical vertebra in sex determination.

Studies have shown that the dimensions of the cervical vertebrae are correlated with skeletal dimensions and the larger dimensions of the skeletal vertebrae in males are attributed to the larger body size of them.[27, 39] However, in this study, both the dimensions of the vertebral bodies and their posterior pectorals were statistically significant with gender. However, more studies are needed to analyze the cause of gender differences in the vertebra. In the present study, relationships between age and dimensions of the vertebrae were observed. Correlation between age and cervical vertebral dimensions was mostly positive and weak. Considering the age range of population was under the 69 year, the possibility of degenerative changes in the vertebra should be considered, which affects the dimensions of the vertebra. Other studies have shown the relationship between age and dimensions of cervical vertebra.[4,40] Even cervical vertebrae are known as a precise standard for bone age determination.[41] Further studies are required to evaluate the effects of age on cervical vertebra dimensions.

Conclusion

In conclusion, all dimensions measured for the second and seventh cervical vertebra were higher in men than women in this study. The height of the second vertebra and the transverse diameter of the upper fast were independent gender predictors, with an accuracy of 81.4%. In the seventh vertebra, the anterior posterior of the vertebral body and the posterior length of the vertebra were independent predictors of gender, which had an accuracy of 78.6% in sex determination. The results of this study showed a high accuracy of cervical vertebral dimensions in sex determination of skeletal remains in Iranian population.

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