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Evaluation of sacral bone parameters in Sex determination by three – dimensional CT images

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Abstract---Introduction: Gender determination in forensic medicine plays an important role in determining the identity which is very important for both the present time and in the future. (Aim)Background: To improve sex determination using skeletal remains, morphometrical study of some bones can be helpful. The aim of this study is to assess the application of five parameters of sacral bone by means of Three – Dimensional (3D) images reconstructed by multi-slice Computed Tomography (CT) in sex determination of Iranian individuals. Materials and Methods: This cross-sectional study was conducted on one hundred of Iranian people with equal number of men and women who have undergone Pelvic CT in radiology department of Hazrat Rasoul-Akram Hospital were included. Five anthropometric indices including S1 Perimeter, S1 Area, Anterior-posterior diameter (APD), Maximum transverse diameter (MTD) and Maximum breadth of sacral alae (MBA) of their sacral bone were

measured using computed tomography (CT) three dimensional images with an accuracy of 0.01° and 0.01 mm and then the association of the measurements with the gender of individuals was studied. Conclusion: No significant difference was observed between two gender groups in terms of age ($P=0.678$). The indexes of sacral bones measured were compared between males and females and the results showed that measures of four parameters, S1 perimeter, S1 area, Maximum anterior-posterior diameter (APD), Maximum transverse diameter (MTD), have significant differences between the genders ($p < 0.001$) except for the Maximum Breadth of sacral alae (MBA) which shows the difference between two genders but not highly significant as the other indexes ($p:0.049$). measurements of the sacral bone parameters, mentioned in this study, can be used as a valid method for sex estimation in Iranian population.

Keywords---*Sacral bone, Morphometric indices, Sex determination, CT scan.*

Introduction

Gender determination in forensic medicine plays an important role in determining the identity which is very important for both the present time and in the future. As mentioned the estimation of sex using morphometric analysis of the skeletal remains is an important part of forensic anthropology [1, 2]. These analyses could help the sex estimation to be considered quantitatively and the relevant error rates could also be determined [3]. Recently, Morphometries carried out with computerized tomography (CT) have been used in Forensic Medicine to obtain precise and accurate results for sex prediction in populations. While being expensive, this method because of its repeatability is reliable [4, 5].

Several bones such as cranium, sternum, and patella have been previously studied for sex determination using CT scans [5, 6]. In addition, there are a few studies that investigate the ability of sacral measurements in the correct sex determination. Several authors have demonstrated that measuring the sacral base can reach to an accuracy of 80–90% in correct sex determination [7-12].

Stradalova, Flander et al. and Benazzi et al. applied caliper for measurement of the maximum transverse diameter, maximum anterior-posterior diameter, and perimeter of sacral vertebra (S1) and found that the maximum transverse diameter of S1 is the most variable factor for sex determination [7, 13, 14]. Furthermore Benazzi et al. carried out an image processing on the studied factors and found the same results [13]. In another study, Zech et al. obtained the metric data of the same factors as Benazzi using CT scans and also caliper on post mortems and found the same results as previous researches [5]. Osteometry indices are diverse in different populations based on their genetics and environmental factors [15]. Therefore it is need to analyze the ability of bone indexes in the sex determination for each population. In the present study, the five factors of sacral vertebra are measured using CT scans in some males and

females of Iranian people and the results can illustrate the potential of these indexes in sex prediction.

Materials and methods

Study design and participants

This cross-sectional study was conducted on one hundred of Iranian people admitted to Hazrat Rasoul-Akram Hospital and undergone pelvic computed tomography (CT) for any reason, during one year (from April 2019 to April 2020).

All the 100 individuals (50 men and 50 women) who had the inclusion criteria and were in the age range of 18 to 80 years old of Iranian people with a reliable identity certificate were enrolled in this study. Sample size was calculated using article studied by Zech, W.D., et al., Sex determination from os sacrum by postmortem CT (5) and by using $\alpha = 0.05$, $\beta = 0.2$, $\mu_1 = 16.58$, $\mu_2 = 12.58$, $SD_1 = 3.22$, $SD_2 = 31.83$, which has estimated to be minimum sample of 19 cases[5].

Inclusion and Exclusion Criteria

Patients who have been undergone Pelvic CT scan because of their physician's description were included in this study. People who had deformation in the pelvic bone such as previous pelvic fractures, congenital malformations and non-Iranian populations were excluded from this study.

Ethical Considerations

Present study was performed according to the approval by Ethical Committee of Iran University of Medical Sciences, Tehran, Iran (No.: IR. IUMS. REC.1399.598). Every step of the study was implemented under the supervision of the Research Committee of Iran University of Medical Sciences.

Data collection

The Sacral bone parameters including the S1 Perimeter, S1 Area, Anterior-posterior diameter (APD), Maximum transverse diameter (MTD) and Maximum breadth of sacral alae (MBA) were applied to measure the Three-Dimensional Computed Tomography radiographs of participants' Sacral bone using digital means with an accuracy of 0.01° and 0.01 mm (Table/Fig-1). The measured data with gender information were recorded in a check list. First of all, the Sacral landmarks (S1 Perimeter, S1 Area, Anterior-posterior diameter (APD), Maximum transverse diameter (MTD) and Maximum breadth of sacral alae (MBA)) were determined by Marcopacs software in the division then the above parameters were measured.

Construction of Three-Dimensional graphies from pelvic CT scan

All CT images of 100 individuals were taken by the imaging device located in Hazrat Rasoul-Akram hospital (Aquilion-advance, Toshiba, 120 KV, 100 MA, 16 slices, 5 mm-thick layers) to obtain orthogonal multiplanar reconstruction images and volume-rendered images. All the data of pelvic computed tomography scans

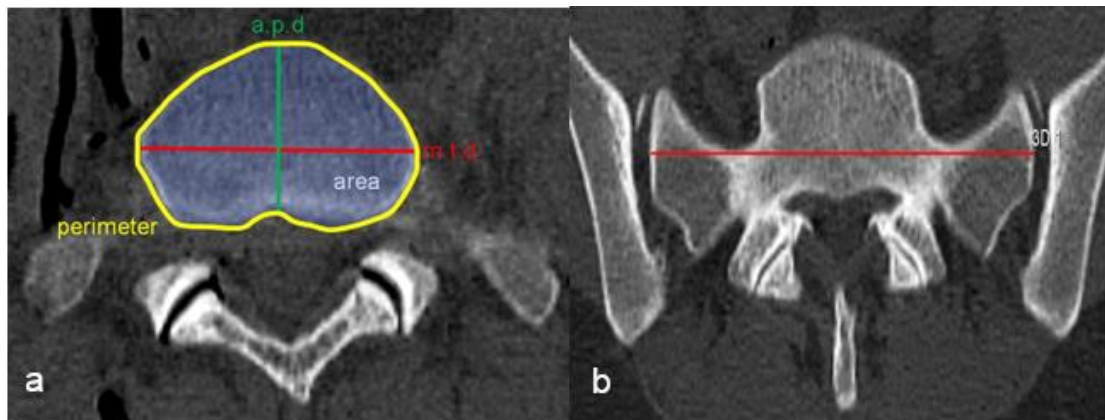
measurements were untitled then CT images were assessed in a 3D mode and converted by a conversion program by using Marcopacs software to obtain appropriate views of the sacrum.

Statistical analysis:

The data analysis was performed using SPSS statistical software version 21.0 (SPSS Inc, Chicago, IL, USA). Means, standard deviations and standard errors were calculated for all measurements. The Shapiro-Wilk test and Levene's test were performed to evaluate normality and equality of variances, respectively. All p-values were > 0.05 , indicating normal distributions with equal variances. Accordingly, Student's-t-test was used to compare mean differences between the sexes. A p-value < 0.05 was considered statistically significant.

[Table 1]: Definitions of the measurements of the sacrum.

Measurement	Definition	Reference
S1 Perimeter	Perimeter of the first sacrum	[13]
S1 Area	area of the first sacrum	[13]
Maximum diameter (APD)	anterior-posterior Linear distance from the two anterior point to the most posterior point on the body of S1	[9]
Maximum transverse diameter (MTD)	Linear distance between the two most laterally projecting points on the body of S1	[9]
Maximum breadth of sacral alae (MBA)	Maximum transverse distance between the two most lateral parts of the sacral alae	[9]



[Table/Figure-1]: CT images showing measurements from axial view with an accuracy of 0.1 mm (see Table 1 for the definitions); (a) S1 perimeter, S1 area, APD and MTD in the axial plane; (b) MBA in the axial plane [5].

Results

In the current study, 50 males and 50 females have been participated. The average age was 42.32 ± 11.21 years in the male's group and 40.88 ± 10.03 years in the female's group. Equality of the means were evaluated by the help of using the Student's t- test and after that the p-value was calculated. No significant difference was observed between the two groups in term of age ($P=0.5$). The description of the age of the cases in relation with the gender have been shown in [Table/Fig-2].

[Table/Fig-2]: Comparison of the age between sexes.

Characterization	Sex	Mean	SD	Minimum	Maximum	P-value
Age (year)	Male	42.32	11.21	25	64	0.678
	Female	40.88	10.03	25	61	

The indexes measured in this study were compared between males and females. The means showed the significant difference ($p<0.001$) between male and female cases in four out of the five indices (S1 Area, S1 Perimeter, Maximum Transverse Diameter, Anterior – Posterior Diameter) except for one of the parameters (Maximum Breadth of Sacral Alae) which have showed difference between two genders but not as significant as the other indices. And this study has showed that the mean of each parameter in males and females was enough far from together. The results have been illustrated in [Table/Fig-3].

The correlation between the Sacral parameter and the age were analyzed by the means of Pearson's correlation coefficient test. It has shown that all of the parameters had no correlation with age($p>0.05$) [Table/Fig-4].

Table 3. Characteristics of measured parameters of sacrum specified by sex

Variable	Female				Male				p-value
	Min	Max	Mean	SD	Min	Max	Mean	SD	
S1 perimeter	125.9	140.6	131.64	3.39	143.3	157.9	150.33	3.52	<0.001
S1 area	12.6	14.6	13.08	0.39	14.5	16.9	15.79	0.69	<0.001
MBA	98.2	106.0	102.68	1.97	99.5	108.8	104.59	2.63	0.049
MTD	38.6	46.4	41.81	1.83	46.6	55.8	51.16	1.79	<0.001
APD	27.3	31.6	30.16	0.83	36.6	42.3	38.81	1.54	<0.001

[Table/Fig-4]: The correlation of Sacral parameters and age**Discussion**

Determining gender in skeletal remains is a fundamental issue in anthropological and forensic research [17]. There are different characteristics in the size and

Parameters	Male		Female	
	Pearson correlation	P- value	Pearson correlation	P-value
S1 Area	-0.185	0.092	-0.258	0.569
S1 Perimeter	-0.108	0.250	-0.047	0.606
Anterior – Posterior Diameter	-0.007	0.938	--0.059	0.520
Maximum Breadth of Sacral Alae	-0.165	0.071	-0.078	0.401
Maximum Transverse Diameter	-0.038	0.687	-0.153	0.095

proportion of different populations that can affect the gender evaluation [18]. In this study, five sacral factors have been considered in 100 people of Iranian population to assess their ability in sex determination. The results have shown that four of these polymorphic indices of Sacrum, including S1 Perimeter, S1

Area, MTD and APD, have high significant p-value for determining sex ($p < 0.001$). Also, the Maximum Breadth of Sacral Alae (MBA) also can be used for sex determination but with lower p-value ($p: 0.049$) and not as high significant as the other ones. The measured mean value of all the five indices in men was higher than women. This finding is in agreement with several studies. Bennazi et al. utilized an image processing technique and investigated that three variables of the sacral base (S1 area, S1 perimeter, and MTD) represent high sex discrimination potential in 117 adults of Italian population. Contrary to our study, the results of this study showed that the amount of these indicators does not differ significantly between different groups ($p \text{ value} > 0.05$) [13]. In this present study, which is derived from the data obtained from the three-dimensional CT scan of sacrum bones in MarcoPacs software, patients admitted to Hazrat Rasoul-Akram Hospital from April 2019 to April 2020, for the A.P.D (anterior posterior length) Parameter of the sacrum bone with p-value: < 0.001 , it indicates that this parameter is helpful in determining gender, while in the study of Zech et al., this parameter with p-value: 0.096 did not have a significant difference in determining gender [5]. But it should be noted that in other studies such as Yadav et al., this parameter had a p-value: < 0.0001 [19] and in the study of Yan-Mei Wang and colleagues, p-value: 0.002 [20] and in the study D. Talsaniya., p-value obtained for this parameter is equal to 0.001, which indicates the significant effectiveness of this parameter in determining gender by the sacrum bone in CT scan[21].

The findings indicate that the M.T.D (maximum transverse diameter) parameter of the sacrum bone, in the study conducted by us, did have a p-value of < 0.001 , which indicates the significant difference of this parameter in determining the gender by the sacrum bone. Comparison the data obtained from this parameter with similar studies such as the study by Yadav et al. showed the same result [19] but there was no significant difference in using this parameter in the study by Zech et al. (p-value: 0.68) [5] and the same in the study by D. Talsaniya., (p-value: 0.12) [21].

Another parameter studied in this study is called MBA (Maximum Breadth of Sacral Alae). The p-value for this parameter is estimated to be 0.049, which indicates the difference but not highly significant of this parameter in determining gender from the sacrum bone. while in other studies this parameter was not helpful in determining gender, for example in the study of Zech et al. the p-value obtained from this parameter was 1 [5] and in the study of Yadav et al. the p-value estimated < 0.056 [19] and in Yan-Mei Wang et al.'s study it is estimated as 0.636 [20].

Another investigated parameter in this study includes Perimeter of S1, with the p-value of < 0.001 , which as well as the other parameters (APD, S1 Area, MTD) studied by us means a significant difference in this parameter to determine gender with the help of the sacrum bone. which in the study of Yadav et al. and colleagues have also achieved a similar result with a highly significant difference for this parameter (p-value: < 0.0001) [19], while in the study of Zech et al. this parameter p-value estimated as 0.010, which shows that there was no significant difference between two genders using this parameter [5].

Another parameter that were studied was S1 area with p-value of <0.001 , which confirms previous studies, including the study of Zech et al. with p-value: <0.005 [5] and the study of Yadav et al. with p-value: <0.0001 [19].

In another study, Flander et al. also analyzed six measurements of the sacrum in black and white American populations. One of those variables was MTD that showed significant discriminant power with for both blacks and whites. Results of the univariate analysis show that significant sex differences in the sacrum involve primarily the top portion of the bone for both whites and blacks. However, measurements of curvature are important sex differences in the sample of blacks [14]. In another study Zech et al. applied postmortem CT images for obtaining metric data of S1 perimeter, MBA, MTD and APD of the sacrum. By comparing the results of CT images and caliper measurements on real bones, they concluded that there is no significant difference between two measurement methods [5]. In the present study, because the sample cases were alive, it was not possible to obtain caliper measurements on the bones for comparison with the CT Scans results. The results of present study investigated the CT Scans can be performed as a precise and powerful quantitative method for sex determination especially in the cases of dismembered or charred corpses.

Limitation

Because the data were measured by one person, there could be a possibility of making a mistake in measurement.

Conclusion

Sacral bone can be used as one of the determinants of gender in forensic medicine. In the present study, the high accuracy of sex assessment in the pooled sample suggests that discriminant analysis of these sacral base traits is a valid method to estimate the sex of Iranian population and it probably can be used for the sex determination of skeletal remains from this population. In the future, examination of other factors of the sacral bone can be useful for more accurate sex diagnosis. Using Three-Dimensional CT in this study helped us to view and measure Sacral bone parameters better and because of that we suggest that Three dimensional CT can be considered as a significant tool in forensic Osteology for measuring parameters and there for determining gender.

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Author's contributions

The authors contributions are as follows: Niloofar Laderian carried out Sample taking and contributed in writing the paper and performing the statistical analysis. Siamak Soltani and Kamran Aghakhani carried out sample taking and also participated in the design of the study. Omid Motamedi participated in the design of the study and contributed in writing the paper. All authors read and approved the final manuscript.

Conflict of interest

The authors declared no conflict of interest.

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