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The diagnostic value of anthropometric indices of maxillary sinuses for sex determination using CT-scan images in Iranian adults: A cross-sectional study

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ABSTRACT

Background: The identification of human remains is an essential part of forensic science. Studying paranasal sinuses is very useful in identification of mutilated or burnt bodies from accidents such as plane crashes. We aimed to assess the diagnostic value of anthropometric indices of maxillary sinuses for sex determination using CT-scan images in Iranian adults.

Methods: CT-scan slices of 228 maxillary sinuses (from 144 men and 144 women) were studied. The maximum height, maximum anterior-posterior diameter, maximum width, and maximum distance between the sinuses were measured in both sexes. Our participants were divided into three age groups of 20–34, 35–49, and over 50 to compare the recorded measurements in different age groups.

Results: We found a significant difference between men and women regarding the maximum height, maximum width, maximum A-P diameter of sinuses and the maximum distance between the right and left maxillary sinuses in all of our participants. We also found that the highest accuracy for sex determination was related to the maximum distance between the sinuses (65.6%) and the lowest to the maximum width of the right sinus (56.2%). The most accurate identification resulted from assessing the maximum distance between the sinuses in the 20–34 age group (74.3%), the maximum anterior-posterior diameter of the sinuses in the 35–49 age group (62.8%) and the maximum height of the left sinus in the over 50 age group (65.7%).

Conclusion: Regardless of age, according to our study the parameters of height, width, anterior-posterior diameter of sinuses and the maximum distance between the right and left maxillary sinuses are partially valuable for sex determination. The most accurate sex identification was examined in the 20–34 age group from studying the maximum distance between the sinuses. Especially in the over 50 age group, it is not enough to consider the sinus parameter for sex identification.

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Abbreviations

CT-scan	Computerized Tomography scan
PACS	picture archiving communication system
ROC curve	receiver operating characteristic
SPSS	statistical package for the social sciences
AUC	area under the curve
SD	standard deviation
A-P diameter	anterior-posterior diameter

1. Introduction

The identification of human remains is an essential part of Forensic Science. The determination of a person's identity from skeletal remains is a complicated process and a great proportion of forensic textbooks have been dedicated to the identification of human remains. Human identification is also important with respect to natural disasters as well as accidents.[1] The accuracy of sex determination varies depending on age, fragmentary conditions, and biological characteristics.[2] Moreover, different criteria should be used to analyze human bones.[3] Studying paranasal sinuses is very useful in identification of mutilated or burnt bodies from accidents such as plane crashes. Sinuses are highly resistant to trauma and since they are situated in a relatively hard part of the skull, they are reserved better and can resist trauma. Also, the sinuses are unique so that the sinus airway patterns of no two individuals are alike, even in identical twins.[1] Assessing the anthropometric characteristics of the maxillary sinus is one of the important and aiding factors in sex determination.[3] Since ethnicity is an influential factor in the form and shape of the human skeleton, sex determination from skeletons varies in different ethnic groups with respect to the sensitivity and specificity of anthropometric indices.[4]

There are many studies in forensic literature on different ethnic groups regarding the paranasal sinuses[5,6] especially the maxillary sinuses and also various anthropometric parameters that have been assessed for sex determination. Most of these studies have used radiography of the maxillary sinuses and there are limited studies using CT-scan images.[7] Hacer et al. found that using maxillary sinus measurements yielded a specificity of 69.4% in men and 69.2% in women for sex determination in Turkey.[8] Another study found a specificity of 71.6% for sex determination using CT-scan images of paranasal sinuses.[9]

We aimed to assess the diagnostic value of morphometric indices of the maxillary sinus for sex determination in Iranian adults.

2. Materials and methods

In this descriptive cross-sectional study, we enrolled Iranian adults over 20 years of age who had been referred to Sina Hospital, Tehran, in one year from October 2014 to October 2015 to have their paranasal sinuses CT-scanned. The exclusion criteria were fracture of the maxillary sinuses walls or facial bones, maxillary sinuses diseases that caused fading of the bone lines of the maxillary sinus, CT-scan slices of more than 2 mm, anatomic deformities in facial bones, bisexuality disorder, and low quality slices. Our sample size was calculated based on Uthman et al.[9] Standard axial Coronal CT-scanning of the paranasal sinuses or skulls was performed while the patient was lying in the supine position. Then the maximum height, maximum anterior posterior diameter, maximum width, and maximum distance of the sinuses were measured. Table 1 illustrates the definition of maxillary sinus parameters.

Measurements were taken by a radiology technician under the supervision of a researcher using the PACS system. In order to increase the accuracy of our measurements, after determining the largest cross section, all measurements were repeated for one slice above and one slice below the target slice. Then we used the largest measurement in our study. Figs. 1–4 show examples of measured parameters by CT-scan. Also, the participants were divided into three age groups of 20–34, 35–49, and over 50 to compare the recorded measurements in different age groups.

Our data were analyzed using SPSS software version 18 and we also used descriptive statistics such as central tendency and dispersion indices. Pearson's chi-squared test was used to compare quantitative variables and Crosstab was used for assessing sensitivity and specificity. T test was used to compare two sexes.

$P < 0.05$ was considered as statistically significant. We had no missing data.

3. Results

The mean ± SD age of the 288 participants (144 men and 144 women) was 40.27 ± 14 years. The mean ± SD ages of the men and women were 41 ± 14 (range: 20–85) and 39 ± 14 (range: 20–82) years, respectively.

Table 2 shows the anthropometric criteria of the maxillary sinuses in both sexes.

In every studied sinus, we found a significant difference between men and women with respect to the maximum height, maximum width and maximum A-P diameter of sinuses and also the maximum distance between the right and left maxillary sinuses in all of the participants ($P < 0.05$).

In Fig. 5 the ROC curve shows the predictive value of the maximum height, maximum width and the maximum A-P diameter of the left maxillary sinus and also the maximum distance between maxillary sinuses in sex determination.

The ROC curve in Fig. 6 shows the predictive value of the maximum height, maximum width and the maximum A-P diameter of the right maxillary sinus and also the maximum distance between maxillary sinuses in sex determination.

Table 3 shows the area under the ROC curve of the anthropometric criteria for maxillary sinuses.

Based on the ROC curve, specific points were determined for the above-mentioned criteria and then the sensitivity, specificity, positive predictive value, negative predictive value and their accuracy were determined. Table 4 shows sensitivity, specificity, positive and negative predictive values of anthropometric parameters of maxillary sinuses for all of our participants.

In all of our studied population, the highest accuracy for sex determination was related to the maximum distance of maxillary sinuses (65.6%) and the lowest to the maximum width of the right sinus (56.2%).

Age frequency distribution based on gender is shown in Table 5. The above-mentioned anthropometric criteria were examined for all age groups. Comparison of maxillary sinus parameters between two sexes for all age groups is shown in Table 6.

In the 20-34 year-old age group, a significant difference was found between men and women with respect to maximum height, maximum width, anterior-posterior diameter and maximum distance between sinuses ($p < 0.05$). In this age group, the highest and the lowest accuracy were for the maximum distance between two sinuses (74.3%) and the height and width of the right sinus, (62.8%) respectively. In the 35-49 year-old age group, the only significant difference was found in the maximum height and maximum anterior-posterior diameter measurements of the left sinus

Table 1
Definition of maxillary sinus parameters.

Definition	View	Parameter
Maximum distance between the upper and lower sinus wall borders on the largest section	coronal	Max Height
Maximum distance between the innermost and the outermost borders of the sinus wall on the largest section	axial	Max Width
Maximum distance between the outermost borders of the right and left sinus walls on the largest section	axial	Max total width
Maximum distance between the anterior and posterior sinus walls on the largest section	Axial	Max AP diameter

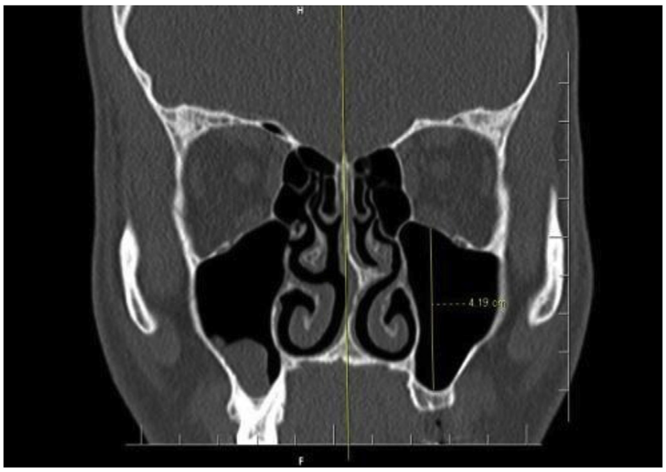

Fig. 1.. Maximum height of the maxillary sinus, coronal section.

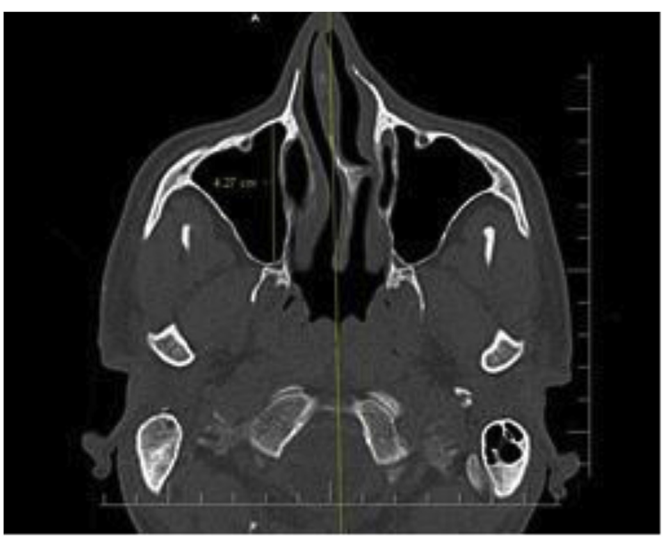

Fig. 2.. Maximum anterior posterior diameter of the maxillary sinus, axial section.

($p < 0.05$). The highest and the lowest accuracy in this age group were observed in the maximum anterior-posterior diameter (62.8%) and height of the left sinus, (61.9%). In the over 50 year-old age group, the only difference between the two sexes was found in the maximum height of the left maxillary sinus ($P < 0.05$) which had an accuracy of 65.7%.

Table 7 shows sensitivity, specificity, positive and negative predictive values for anthropometric parameters of the maxillary sinus in different age groups.

In the male participants, the maximum height, width and anterior-posterior diameter of the left sinus, the maximum width and anterior-posterior diameter of the right sinus and the maximum distance between two maxillary sinuses of 20–34 year-old age group were significantly higher than those of 35–49 and over 50 year-old age groups ($P < 0.05$). We did not find any significant difference between age groups considering anthropometric criteria in the female participants ($P > 0.05$).

Table 8 shows statistical analysis of the mean values for maxillary sinus indices between different age groups and genders.

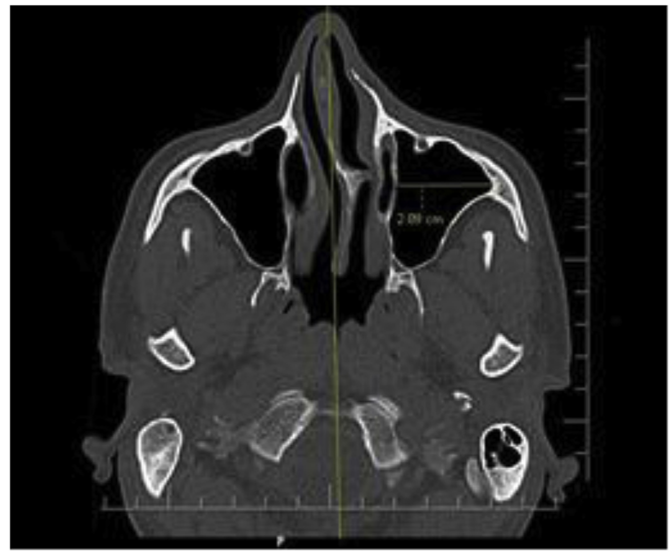

Fig. 3.. Maximum width of the maxillary sinus, axial section.

Fig. 4.. Maximum distance of both maxillary sinuses, axial section.

Table 2
The means and the standard deviation of means for the anthropometric parameters of the maxillary sinus in both sexes for the participants.

Sex		Female		Male		p-value
Parameter		mean	SD	Mean	SD	
Height**	right	34.4	5	37.5	6	0.000*
	left	35.1	5	38.4	6	0.000*
Max width**	right	24.4	5	26.1	7	0.027*
	left	24.5	4	26.3	5	0.001*
Max A-P diameter**	right	37	4	38.6	4	0.005*
	left	37	4	39	3	0.006*
distance between right and left sinus**		79.3	7	83.38	8	0.000*

*p < 0.0.05 was considered statistically significant.
** The measurements are in millimeter.

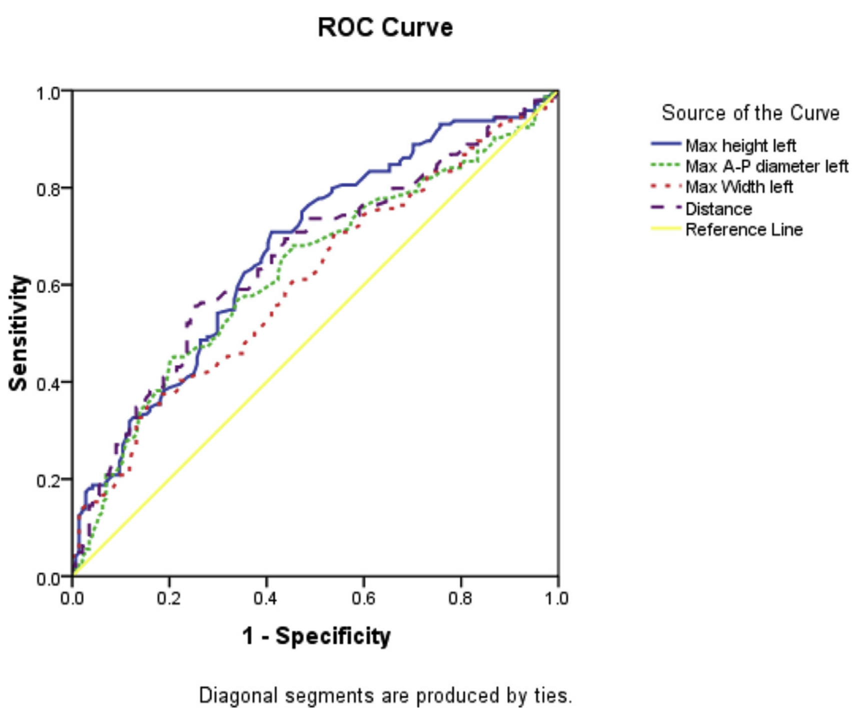

Fig. 5. The ROC diagram for predictive value of maximum height, maximum width, maximum A-P diameter of the left maxillary sinuses and maximum distance of both maxillary sinuses in sex determination.

4. Discussion

In general, we found that in Iranian population included in the study, the height of the right maxillary sinus was significantly less than that of the left. The mean maximum height of the right and left sinuses in our population was less than that reported in Turkish population (Hacer et al.),[8] more than that in Swedish population (P-Johnson et al.)[10] but similar to measurements of Egyptians (Amin et al.).[11]This could denote the effect of ethnicity on the morphometry of the sinuses or it could be due to different methodologies applied in those studies.[12] In our study, the height of maxillary sinuses was significantly higher in men compared to women, which was similar to measurements reported by Raoof et al.,[5] Sabrina et al.[7] and Teke et al.[8] studying Iraqi, Californian and Turkish populations,respectively. Based on our study, the mean maximum width of both sinuses was similar to Teke et al. studying Turkish population,[8] Uthman et al. studying Baghdad population[9] but the findings of Lee et al. on South African population showed lower measurements.[12] In our study as well as studies from Turkey, Iraq and Egypt,[8,9,12] the width of maxillary sinuses have a significant difference between the two sexes. A considerable difference was observed between our study and studies from Sweden[10] and Egyptians[11] with respect to the width of sinuses, which could be attributed to the environmental differences as well as different study designs. In the same time and based on our findings, the mean anterior-posterior diameter of both maxillary sinuses in men and women was similar to the finding from Iraq[9] South Africa[12] but different from studies in Turkey[8] and Egypt.[11] Also, the mean anterior-posterior diameter of both maxillary sinuses was significantly higher in men compared to women, which were consistent with studies from Turkey,[8] Iraq,[9] Egypt,[11] and South Africa.[12]

In our study, the mean maximum distance between the two sinuses varied in men and women, which is similar to the findings of Uthman et al.[9] in Baghdad population.

Based on our findings, the highest accuracy for sex determination was related to the maximum distance between the two sinuses (65.6%) and the height of the left maxillary sinus (65.2%), whereas, the lowest accuracy was for the maximum width of the right sinus (56.2%). In a study by Uthman et al.,[9] the best variables for sex determination were the height and anterior-posterior diameter of the left maxillary sinus. Hacer et al.[8] reported a little higher accuracy (67.7%) for the height, width and anterior-posterior diameter

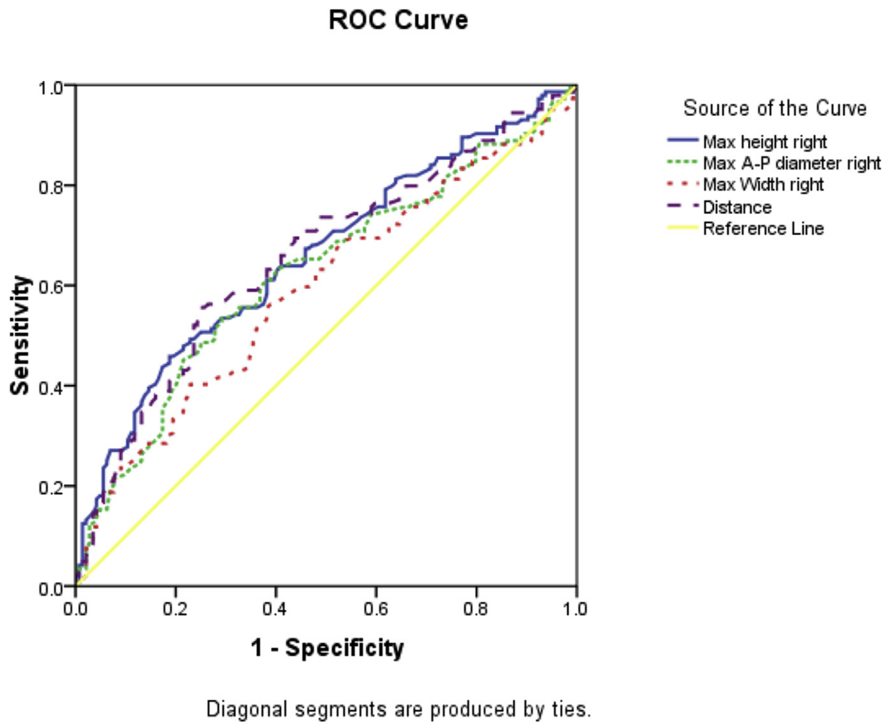

Fig. 6.. The ROC diagram for predictive value of maximum height, maximum width, maximum A-P diameter of the right maxillary sinus and maximum distance of both maxillary sinuses in sex determination.

Table 3
The area under the ROC curve for predictive value of the maximum height, maximum width, the maximum A-P diameter and the maximum distance of the maxillary sinuses for all of our participants.

parameter		Area	P-value	95% Confidence	
				min	max
Max	R	0.657	0.000*	0.595	0.720
Height**	L	0.672	0.000*	0.611	0.734
Max	R	0.592	0.007*	0.526	0.658
Width**	L	0.606	0.002*	0.541	0.671
Max	R	0.624	0.000*	0.559	0.689
Diameter**	L	0.629	0.000*	0.564	0.693
Max Distance**		0.656	0.000*	0.592	0.719

*p < 0.0.05 was considered statistically significant.
** The measurements are in millimeter.
R = Right Sinus.
L = Left Sinus.

Table 4
Sensitivity, specificity, positive and negative predictive values of anthropometric parameters of the maxillary sinus for all of our participants.

Sex determination			Sensitivity%	Specificity%	PPV%[b]	NPV%[c]	Accuracy%
Parameter D-point[a]							
Max	R	36.3	61.1	61.8	61.5	61.4	61.4
Height	L	36	71.5	59	63.6	67.5	65.2
Max	R	24.6	60.4	52.1	55.8	56.8	56.2
Width	L	24.7	61.1	54.2	57.1	58.2	57.6
Max	R	38.3	61.1	61.1	61.1	61.1	61.1
Diameter	L	38.5	68.1	54.9	60.1	63.2	61.4
Distance		83.5	56.3	75	69.2	63.2	65.6

R = Right Sinus.
L = Left Sinus.
[a] D-point = demarking point (mm).
[b] Positive predictive value.
[c] Negative predictive value.

Table 5
Age frequency distribution based on gender.

Age group (year)	Female		Male		Total	
	N	%	N	%	N	%
20–34	63	43.8	50	34.7	113	39.2
35–49	50	34.7	55	38.2	105	36.5
50 ≤	31	21.5	39	27.1	70	24.3

Table 6
Comparison of mean, standard deviation of anthropometric parameters of maxillary sinus between the two sexes in different age groups.

Sex			Female		Male		P Value
Age group	parameter		mean	SD	mean	SD	
20-34 years	max	right	34.6	5	39.3	6	0.000*
	Height	left	35.8	5	40.7	6	0.000*
	max width	right	25.6	6	28.6	5	0.012*
		left	25.1	4	29.1	5	0.000*
	Max AP- diameter	right	37.3	4	40.2	3	0.001*
		left	38.1	3	40.4	3	0.000*
	Distance		78.6	8	86.8	7	0.000*
49-35 years	max	right	34.3	6	36.7	6	0.056
	Height	left	34.9	5	37.6	6.4	0.033*
	max width	right	23.4	5	25.3	8	0.056
		left	24.1	4	25.5	5	0.152
	Max AP- diameter	right	36.7	5	37.7	5	0.298
		left	36.6	5	38.5	4	0.045*
	Distance		79	7	82.1	10	0.168
≥50 years	Max	right	33.9	5	36.4	5	0.052
	height	left	33.6	5	36.6	4.1	0.012*
	Max	right	23.4	4	23.8	5	0.052
	width	left	23.9	4	24.1	4	0.823
	Max A-	right	37	3	37.6	3	0.509
	P diameter	left	38.1	4.2	37.6	3.2	0.584
	Distance		81.3	8	80.7	7	0.750

*p < 0.05 was considered statistically significant.

Table 7
Sensitivity, specificity, positive and negative predictive values and accuracy of anthropometric parameters of the maxillary sinus for sex determination in different age groups.

Age Group (years)	Sex determination parameter		d-point[a]	Sensitivity %	Specificit y%	PPV%[b]	NPV%[c]	Accuracy %
20–34	Max height	right	35.9	70	57	56	70	62.8
		left	37.2	70	62	59	72	65.4
	Max Width	right	25.9	70	57	56	70	62.8
		left	26.8	74	58	58	74	66.3
	Max A-P diameter	right	30.3	68	66	62	72	67.2
		left	39.2	68	65	60	72	66.3
	Distance		82.8	76	73	69	79	74.3
35–49	Max height	left	36.7	63	60	63	60	61.9
	Max A-P diameter	left	38	65	60	64	61	62.8
≥50	Max height	left	34.4	80	50	63	69	65.7

[a] d-point = demarking point (mm).
[b] Positive predictive value.
[c] Negative predictive value.

Table 8
Statistical analysis of the mean values for maxillary sinus indices between different age groups and genders.

Parameter	Age 20-34 ≥ 50		35-49 20-34		≥50 35-49	
Max left sinus height	M	0.004*	M	0.022*	M	1.000
	F	0.209	F	1.000	F	0.901
Max left sinus width	M	0.000*	M	0.001*	M	0.588
	F	0.614	F	0.644	F	1.000
Max left sinus A-P diameter	M	0.002*	M	0.029*	M	0.733
	F	1.000	F	0.198	F	0.398
Max right sinus height	M	0.108	M	0.108	M	1.000
	F	1.000	F	1.000	F	1.000
Max right sinus A-P diameter	M	0.021*	M	0.016*	M	1.000
	F	1.000	F	1.000	F	1.000
Max right sinus width	M	0.004*	M	0.042*	M	0.884
	F	0.240	F	0.132	F	1.000
Max distance	M	0.003*	M	0.017*	M	1.000
	F	0.396	F	1.000	F	0.646

*p < 0.0.05 was considered statistically significant.
** The measurements are in millimeter.
M = male.
F = female.

of left maxillary sinus and the distance between sinuses.

The highest accuracy for sex determination by using anthropometric indices of the maxillary sinus was observed in the 20-34 year-old age group (74.3%) on examining the maximum distance between two sinuses, but with the increase of age, the accuracy decreased, so that the accuracy for the over 50 year-old age group was 65.7% using maximum height parameters.

These results are similar to the findings of Knight et al.[1] who reported that the age reduces the difference between two sexes in terms of anthropometric indices of the maxillary sinuses. We did not find a comprehensive study about the accuracy of sex determination by using anthropometric indices of the maxillary sinuses in different age groups.

Our study shows that in the male participants, the maximum height, width and anterior-posterior diameter of the left sinus, the maximum width and anterior-posterior diameter of the right sinus and the maximum distance between two maxillary sinuses of the 20-34 year-old age group were significantly higher than those of 35–49 and over 50 age groups ($P < 0.05$) but we did not find any significant difference considering anthropometric criteria in the female age groups ($P > 0.05$). Although the best way to examine anthropometric criteria of the skull such as maxillary sinus parameters with age changes, is to compare CT scan images of skull and paranasals of an individual during different ages, however in practice, these studies have limitations such as using similar CT scan machinery, the anatomical site, using standard procedures of CT scan imaging, the accessibility of an individual's images and time interval between CT scans during different ages of an individual.

In this study, we did not find any significant difference related to maxillary sinus parameters in the females and one of the reasons could be lack of sufficient samples. On the other hand, the significant difference in maxillary sinus parameters of the male participants from the 20–34 age group in comparison with the other age groups might result from the process of aging which affects some anthropometric criteria and subsequently the accuracy of sex determination. Knight et al.[1] reported that the sex determination of Caucasians and most Asians under 20 and over 50 by using skull measurements should be dealt with caution.

5. Conclusion

The height of the left maxillary sinus might have a constant discrimination value for the sex determination in all age groups of Iranian adults. In young adults, the maxillary sinus parameters had a considerable value in sex determination, especially the distance between the two sinuses, whereas in the over 50 year-old age group, the accuracy of the sinus parameter was lower and not sufficient alone to determine the gender. More research on other maxillary sinus parameters as the volume of the sinuses, in different human races and different age groups should be carried out to make more benefit from skull remains in forensic identification.

Conflict of interest

None declared.

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