

# The effects of gender and age on forensic personal identification from frontal sinus in a Turkish population

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## ABSTRACT

**الأهداف:** تحديد أبعاد الجيب الأمامي في مجموعات موحدة العمر والجنس ومناقشة أسباب وآثار الاختلاف.

**الطريقة:** حصلنا على قياسات الجيوب الجبهية من الأشعة المقطعية الأنفية 180 من الذكور و 180 من الإناث في قسم الأشعة في مركز دورسون أوداباس الطب في جامعة يوزنجو يل، مدينة فان، والذي يقع في شرق تركيا، بين شهري فبراير ومارس 2016. جرى قياس العرض والارتفاع من الجيوب على مستوى اكليبي وجرى قياس الطول الأمامي الخلفي على مستوى محوري. احتسبت الكميات باستخدام إدارة نظم معلومات المستشفى وبرنامج أرشفة الصور وإدارة النظام. واستخدمت الحزمة الإحصائية للعلوم الاجتماعية النسخة 13 للتحليلات الإحصائية.

**النتائج:** حددنا الاختلافات في قياسات الجيوب الأمامية من مختلف الفئات العمرية في السكان الأتراك البالغين. أبعاد الجيوب الأمامية عادة ما تكون أعلى لدى الإناث وتنخفض في الذكور بعد عمر 40-49 سنة مقارنة بنظرائهم الأصغر سناً، ولكن كانت القياسات أقل في الإناث، وأكثر ارتفاعاً في الذكور  $\leq 70$  عام مقارنة 60-69 سنة. كان الجيب الجبهية الأيسر مهماً في الفئات العمرية الشابة لكن الجيب الجبهية الأيمن المهيمن في مجموعات 40-49 سنة أو أكثر.

**الخاتمة:** لاحظنا تجاوز القياسات بين الفئات العمرية المختلفة، والتي لا يمكن أن نجد لها تفسيرات واضحة. قد تؤثر نتائج مثل هذه على دراسات تحديد هوية قياسات الجيوب الأمامية.

**Objectives:** To define the dimensions of the frontal sinus in groups standardized for age and gender and to discuss the reasons and the effects of the variations.

**Methods:** Frontal sinus measurements were obtained from paranasal CT scans of 180 males and 180 females in the Radiology Department of Dursun Odabas Medical Center of Yuzuncu Yil University, Van, which is located in Eastern Turkey, between February and March 2016. The width and height of sinuses were measured on a coronal plane, and

the anteroposterior length was measured on an axial plane. Volumes were calculated using the Hospital Information Management Systems and Image Archiving and Management System program. The Statistical Package of the Social Science version 13 was used for statistical analyses.

**Results:** We determined differences in the frontal sinus measurements of different age groups in a Turkish adult population. Frontal sinus dimensions were usually higher in females and lower in males after 40-49 years of age than their younger counterparts, but the measurements were lower in females and higher in males in  $70 \leq$  years of age group than 60-69 years of age. Left frontal sinus was dominant in young age groups but right frontal sinus was dominant in groups 40-49 years of age or older.

**Conclusion:** We observed crossing of the measurements between the different age groups, which we could not find clear explanations. The results of such studies may affect forensic identification from frontal sinus measurements.

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Frontal sinuses are paired lobulated cavities located behind the superciliary arches in the frontal bone. Each frontal sinus opens into the middle meatus on the same side via the infundibulum.<sup>1</sup> Frontal sinuses are not radiographically visible at birth. They begin to develop during the second year of life, and they can be detected radiographically after the age of 5.<sup>2-4</sup> The radiographic pattern of frontal sinuses are unique to every individual, even among monozygotic twins.<sup>3</sup> There is consensus among forensic scientists concerning the usability of antemortem and postmortem radiographs and CT scans of frontal sinuses for forensic personal identification today. Superimposing the antemortem and postmortem radiographs of a person for positive identification is an accepted procedure in forensic medicine.<sup>2,3,5</sup> Authors have typically accepted that the development of the frontal sinus is completed by approximately 20 years of age and remains stable until further enlargement may occur from bone resorption during advanced ages, except in rare events such as fractures, severe infections, or tumors.<sup>2,3</sup> Since the frontal sinuses are unique to every individual, some authors have considered using them as a substitute for fingerprints. Yoshino et al<sup>2</sup> proposed a classifying system for frontal sinuses utilizing area, asymmetry, scalloping, septa, and cells as criteria. Riberio Fde<sup>6</sup> suggested a method of obtaining standard measurements from the radiographs of frontal sinuses and storing the acquired information in a computer databank. In 2007, Tatlisumak et al<sup>7</sup> reported on the presence or absence of frontal sinus, septum, scalloping (FSS) system as a simple and useful method to use in frontal sinus CT scans. Recently, some authors published papers supporting the usability of the FSS system for forensic identification.<sup>8-10</sup> Other systems were also proposed.<sup>11</sup> The use of frontal sinus radiographs for personal identification relies on the stability of frontal sinuses throughout the lifespan or at least for a long period of time. McLaughlin et al<sup>12</sup> proposed that frontal sinuses continue to expand until the age of 40 years due to the mechanical stresses of mastication and growth hormone levels. Tatlisumak et al<sup>13</sup> reported that most of the frontal sinus measurements reached their highest values between 31 and 40 years of age or between 41 and 50 years of age in both genders, and later decreased with increasing age. The aim of this study is to define the dimensions of the frontal sinus in groups standardized for age and gender and to discuss the reasons and the effects of the variations.

**Methods.** This retrospective study was conducted using paranasal CT scans with 5 mm thickness. The CT scans were of the axial and coronal planes of 360

patients over the age of 20 taken by a 16-detector multislice CT device (Somatom Emotion 16-Slice; CT2012E- Siemens AG, Berlin and Munich-Germany) in the Dursun Odabas Medical Center of Yuzuncu Yil University, Van, which is located in Eastern Turkey between February and March 2016. This study used CT scans with no apparent sinonasal pathology. Cases with unilateral or bilateral absence of frontal sinuses were not included in the study.

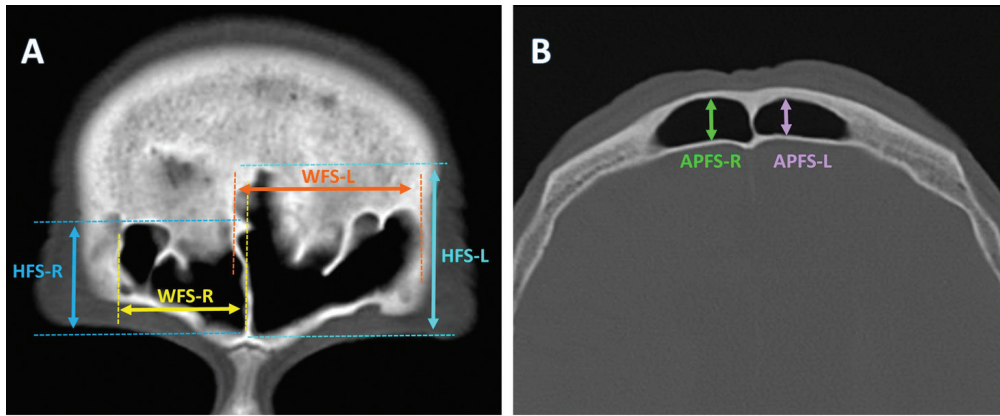
All evaluations and measurements were performed together by 2 scientists in this study with a Digital Imaging Communication in Medicine (DICOM) viewer program. Measurements were expressed in millimeters in the Hospital Information Management Systems and Image Archiving and Management System (HBYS & PACS) program. Volumes were expressed in cubic centimeters. In total, 8 measurements were used in this study: 1) width of the right frontal sinus (WFS-R), 2) width of the left frontal sinus (WFS-L), 3) height of the right frontal sinus (HFS-R), 4) height of the left frontal sinus (HFS-L), 5) anteroposterior length of the right frontal sinus (APFS-R), 6) anteroposterior length of the left frontal sinus (APFS-L), 7) volume of the right frontal sinus (VFS-R), and 8) volume of the left frontal sinus (VFS-L). The width and height of both sinuses were measured on a coronal plane, and the anteroposterior length was measured on an axial plane (Figure 1). Volumes were calculated using the HBYS & PACS program.

This study used CT scans of 180 female and 180 male patients. Cases were divided into 6 age groups according to age for both genders: 20-29, 30-39, 40-49, 50-59, 60-69, and 70-70+. Each group included 30 cases, and the mean age of each group was adjusted for more accurate results, as age was statistically similar to the corresponding group of the other gender except in the 70-70+ group. The mean age could not be adjusted in the 70-70+ age group due to the difficulty of finding cases in this age group.

Descriptive statistics for studied variables were presented as the mean, standard deviation, minimum and maximum values. One-way analysis of variance (ANOVA) (including post hoc tests) were used to compare the age groups and genders.

Statistical significance was considered as  $p < 0.05$ . The Statistical Package of the Social Science version 13 (SPSS Inc., Chicago, IL, USA) was used for all statistical computations.

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Yuzuncu Yil University, Van, Turkey on February 2016.



**Figure 1** - A) Measurements of the widths and heights of both sinuses (WFS-R - width of the right frontal sinus, WFS-L - width of the left frontal sinus, HFS-R - height of the right frontal sinus, HFS-L - height of the left frontal sinus) on a coronal plane, and B) the anteroposterior length (APFS-R - anteroposterior length of the right frontal sinus, APFS-L - anteroposterior length of the left frontal sinus) on an axial plane.

**Table 1** - Comparison of measurements of frontal sinus in females and males.

Measurements	N	Mean	Median	SD	Min	Max	P-value
<b>WFS-R</b>							0.073
Female	180	26.85	26.88	8.24	10.09	50.88	
Male	180	27.65	28.09	8.26	6.20	46.28	
Total	360	27.25	27.52	8.25	6.20	50.88	
<b>WFS-L</b>							0.000
Female	180	27.37	27.08	8.10	7.89	49.94	
Male	180	28.11	28.30	8.35	7.86	59.66	
Total	360	27.74	27.55	8.23	7.89	59.66	
<b>HFS-R</b>							0.082
Female	180	22.95	22.45	8.16	7.34	48.13	
Male	180	23.82	23.00	7.76	7.34	50.02	
Total	360	23.38	22.83	7.97	7.34	50.02	
<b>HFS-L</b>							0.047
Female	180	23.83	22.97	7.48	9.63	44.98	
Male	180	24.09	23.46	7.70	7.80	55.09	
Total	360	23.96	23.37	7.58	7.80	55.09	
<b>APFS-R</b>							0.000
Female	180	14.84	12.85	7.33	5.13	59.21	
Male	180	17.17	13.92	9.04	5.50	49.57	
Total	360	16.00	13.31	8.30	5.13	59.21	
<b>APFS-L</b>							0.000
Female	180	16.01	14.26	7.86	5.41	60.12	
Male	180	17.87	14.92	8.90	1.44	51.47	
Total	360	16.94	14.69	8.44	1.44	60.12	
<b>VFS-R</b>							0.000
Female	180	5.29	3.64	4.93	0.32	35.01	
Male	180	6.57	4.92	5.99	0.23	35.05	
Total	360	5.93	4.20	5.52	0.23	35.05	
<b>VFS-L</b>							0.001
Female	180	5.95	4.24	4.99	0.46	27.15	
Male	180	7.15	5.02	6.86	0.45	43.10	
Total	360	6.55	4.74	6.02	0.45	43.10	

SD - Standard deviation, comparison of frontal sinus measurements in females and males (WFS-R - width of the right frontal sinus, WFS-L - width of the left frontal sinus, HFS-R - height of the right frontal sinus, HFS-L - height of the left frontal sinus, APFS-R - anteroposterior length of the right frontal sinus, APFS-L - anteroposterior length of the left frontal sinus, VFS-R - volume of the right frontal sinus, VFS-L - volume of the left frontal sinus). Values are in millimeters (mm) for widths, heights and AP lengths, and in cubic centimeters (cc) for volumes.  
Min - Minimum, Max - Maximum

**Results.** Paranasal CT scans of 180 females (mean age: 50.14, standard deviation [SD]: 18.68; median age: 49.50; minimum age: 20, maximum age: 101) and 180 males (mean age: 49.66, SD: 17.53; median ages: 49.50, minimum age: 20, maximum age: 88) ( $p=0.800$ ) were evaluated in this study.

All of the measurements of the frontal sinus were higher among males than among females. These differences were statistically significant in the WFS-L, HFS-L, APFS-R, APFS-L, VFS-R, and VFS-L ( $p<0.05$ ), but the differences were not statistically significant in WFS-R and HFS-R ( $p>0.05$ ) (Table 1).

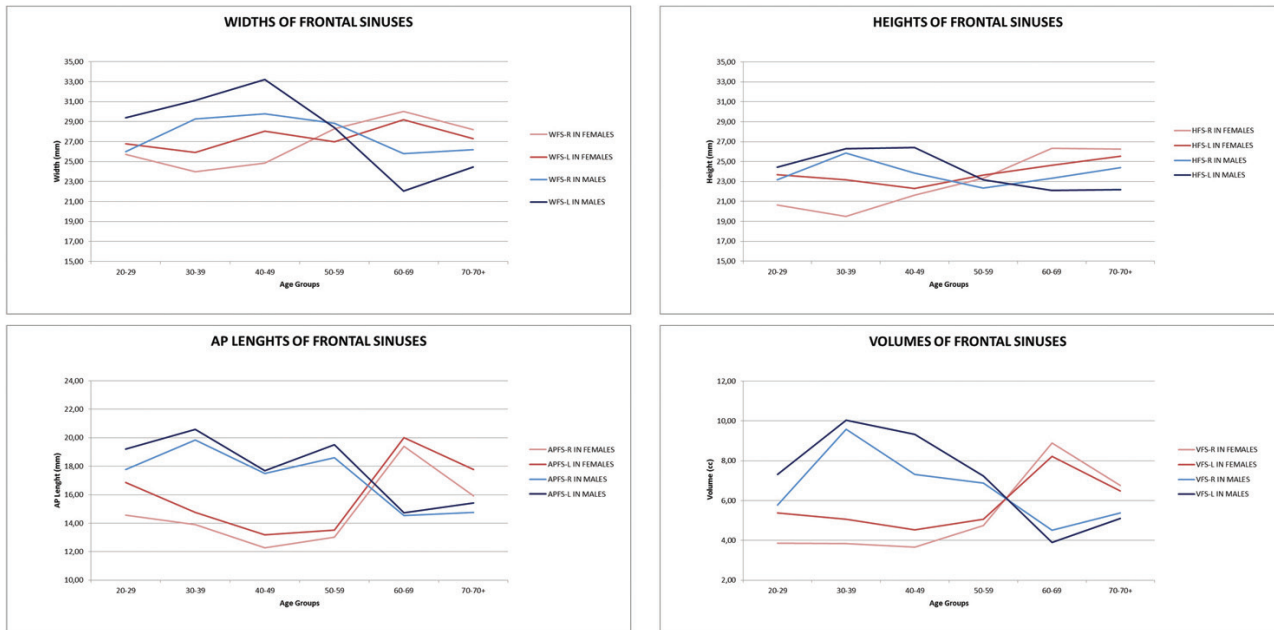
All the measurements of the frontal sinus were higher at the left side for females, males and the total population. Anteroposterior (AP) length and volume of frontal sinuses were significantly larger on the left side among females and in the total population ( $p<0.05$ ), whereas other measurements of frontal sinuses were slightly larger on the left side, but the differences were not statistically significant ( $p>0.05$ ) (Table 2). Of all included cases, 55.6% ( $n=200$ ) had left sinus dominance, and 44.4% ( $n=160$ ) had right sinus dominance based on volumetric measurements ( $p<0.05$ ).

Up to age 50-59 (and up to age 40-49 for widths), the widths, heights, and volumes of the left frontal sinuses were slightly greater than those of the right side. After age 50-59 (after age 40-49 for widths), a crossing occurred, and the widths, heights, and volumes of the right frontal sinuses were found to be slightly greater than the left side. Anteroposterior length was slightly higher in the left frontal sinus than in the right frontal sinus among all age groups for both genders (Figure 2).

**Table 2 -** Comparison of frontal sinus measurements in right and left sides.

Groups	WFS-R	WFS-L	HFS-R	HFS-L	APFS-R	APFS-L	VFS-R	VFS-L
<i>Females</i>								
N	180	180	180	180	180	180	180	180
Mean	26.85	27.37	22.95	23.83	14.84	16.01	5.29	5.95
Median	26.88	27.08	22.45	22.97	12.85	14.26	3.64	4.24
SD	8.24	8.10	8.16	7.48	7.33	7.86	4.93	4.99
Minimum	10.09	7.89	7.34	9.63	5.13	5.41	0.32	0.46
Maximum	50.88	49.94	48.13	44.98	59.21	60.12	35.01	27.15
P-values	0.435		0.099		0.000		0.010	
<i>Males</i>								
N	180	180	180	180	180	180	180	180
Mean	27.65	28.11	23.82	24.09	17.17	17.87	6.57	7.15
Median	28.09	28.30	23.00	23.46	13.92	14.92	4.92	5.02
SD	8.26	8.35	7.76	7.70	9.04	8.90	5.99	6.86
Minimum	6.20	8.86	7.34	7.80	5.50	1.44	0.23	0.45
Maximum	46.28	59.66	50.02	55.09	49.57	51.47	35.05	43.10
P-values	0.455		0.531		0.095		0.076	
<i>Total</i>								
N	360	360	360	360	360	360	360	360
Mean	27.25	27.74	23.38	23.96	16.00	16.94	5.93	6.55
Median	27.52	27.55	22.83	23.37	13.31	14.69	4.20	4.74
SD	8.25	8.23	7.97	7.58	8.30	8.44	5.52	6.02
Minimum	6.20	7.89	7.34	7.80	5.13	1.44	0.23	0.45
Maximum	50.88	59.66	50.02	55.09	59.21	60.12	35.05	43.10
P-values	0.279		0.093		0.000		0.003	

SD - Standard Deviation, comparison of frontal sinus measurements on the right and left sides (WFS-R - width of the right frontal sinus, WFS-L - width of the left frontal sinus, HFS-R - height of the right frontal sinus, HFS-L - height of the left frontal sinus, APFS-R - anteroposterior length of the right frontal sinus, APFS-L - anteroposterior length of the left frontal sinus, VFS-R - volume of the right frontal sinus, VFS-L - volume of the left frontal sinus). Values are in millimeters (mm) for widths, heights and AP lengths, and in cubic centimeters (cc) for volumes.



**Figure 2 -** Changes of the frontal sinus sizes with age and gender in right and left sides

**Table 3** - Comparison of frontal sinus measurements in right and left sides.

Measurements	Age groups	Female			Male			Total		
		Mean	SE	SD	Mean	SE	SD	Mean	SE	SD
WFS-R	20-29	25.72	ab	6.15	26.01	a	7.68	25.87	a	6.92
	30-39	23.98	b#	8.98	29.26	a#	10.24	26.62	a	9.61
	40-49	24.87	b#	7.93	29.79	a#	8.91	27.33	a	8.42
	50-59	28.30	ab	8.41	28.82	a	6.79	28.56	a	7.60
	60-69	30.03	a#	7.71	25.79	a#	8.45	27.91	a	8.08
	70-70+	28.22	ab	8.92	26.21	a	6.54	27.22	a	7.73
WFS-L	20-29	26.78	a	8.10	29.40	ab	6.39	28.09	ab	7.25
	30-39	25.90	a#	9.56	31.14	ab#	7.86	28.52	ab	8.71
	40-49	28.06	a#	7.33	33.22	a#	8.73	30.64	a	8.03
	50-59	26.97	a	9.09	28.40	b	7.50	27.69	ab	8.30
	60-69	29.20	a#	6.37	22.06	c#	6.55	25.63	b	6.46
	70-70+	27.28	a	8.04	24.44	c	7.91	25.86	b	7.98
HFS-R	20-29	20.63	b	7.47	23.17	a	7.34	21.90	a	7.41
	30-39	19.51	b#	6.18	25.87	a#	10.44	22.69	a	8.31
	40-49	21.62	b#	8.80	23.83	a#	7.30	22.73	a	8.05
	50-59	23.33	ab	7.62	22.32	a	7.00	22.83	a	7.31
	60-69	26.34	a	7.52	23.34	a	7.11	24.84	a	7.32
	70-70+	26.25	a	9.06	24.38	a	6.96	25.32	a	8.01
HFS-L	20-29	23.68	a	7.39	24.42	a	8.37	24.05	a	7.88
	30-39	23.18	a	8.64	26.30	a	8.42	24.74	a	8.53
	40-49	22.29	a	6.91	26.39	a	8.91	24.34	a	7.91
	50-59	23.64	a	7.83	23.15	a	6.30	23.40	a	7.07
	60-69	24.63	a	6.35	22.12	a	6.10	23.38	a	6.23
	70-70+	25.54	a	7.77	22.18	a	7.01	23.86	a	7.39
APFS-R	20-29	14.58	b	6.79	17.76	ab	9.54	16.17	a	8.17
	30-39	13.90	b#	5.10	19.85	a#	11.06	16.88	a	8.08
	40-49	12.26	b#	4.54	17.49	ab#	9.33	14.88	a	6.94
	50-59	13.01	b#	5.36	18.59	ab#	10.06	15.80	a	7.71
	60-69	19.39	a	11.75	14.54	b	6.70	16.97	a	9.23
	70-70+	15.91	ab	6.18	14.77	ab	5.91	15.34	a	6.05
APFS-L	20-29	16.85	abc	7.03	19.22	ab	8.23	18.04	a	7.63
	30-39	14.75	bc	5.41	20.60	a	10.44	17.68	a	7.93
	40-49	13.17	c#	5.51	17.69	ab#	8.66	15.43	a	7.09
	50-59	13.52	c#	7.17	19.52	ab#	11.41	16.52	a	9.29
	60-69	20.00	a#	11.78	14.73	b#	6.96	17.37	a	9.37
	70-70+	17.77	ab	6.76	15.42	b	5.45	16.60	a	6.11
VFS-R	20-29	3.86	a#	2.26	5.78	a#	4.26	4.82	a	3.52
	30-39	3.83	a#	2.93	9.59	b#	9.01	6.71	ab	7.25
	40-49	3.65	a#	2.85	7.31	ab#	6.97	5.48	a	5.59
	50-59	4.74	a#	3.15	6.87	ab#	5.86	5.81	a	4.79
	60-69	8.90	b#	7.75	4.51	ac#	2.26	6.71	ab	6.08
	70-70+	6.76	c	5.94	5.38	abc	4.16	6.07	a	5.13
VFS-L	20-29	5.38	a	2.92	7.31	a	5.45	6.34	a	4.44
	30-39	5.06	a#	4.02	10.03	a#	9.52	7.54	a	7.67
	40-49	4.52	a#	3.53	9.33	a#	8.91	6.92	a	7.15
	50-59	5.06	a#	4.23	7.23	a#	6.48	6.15	a	5.53
	60-69	8.21	b#	6.68	3.90	b#	2.38	5.53	a	5.43
	70-70+	6.49	ab#	6.51	5.11	ab#	3.80	5.42	a	5.42

SE - statistical evaluation, SD - standard deviation, distribution of frontal sinus measurements according to age groups (WFS-R - width of the right frontal sinus, WFS-L - width of the left frontal sinus, HFS-R - height of the right frontal sinus, HFS-L - height of the left frontal sinus, APFS-R - anteroposterior length of the right frontal sinus, APFS-L - anteroposterior length of the left frontal sinus, VFS-R - volume of the right frontal sinus, VFS-L - volume of the left frontal sinus). a,b,c - In the same column, the difference between means of the age groups shown by different letters is statistically significant ( $p<0.05$ ), # - In every age group, the difference between means of genders is statistically significant ( $p<0.05$ ). Values are in millimeters (mm) for widths, heights and AP lengths, and in cubic centimeters (cc) for volumes.



All measurements of the frontal sinus exhibited different features by age group for both females and males. In females, WFS-R, WFS-L, HFS-R, APFS-R, APFS-L, VFS-R, and VFS-L reached maximum values between the ages of 60 and 69 years old, whereas HFS-L reached a maximum value at over 70 years of age. In males, WFS-R, WFS-L and HFS-L reached maximum value between the ages of 40 to 49 years old; HFS-R, APFS-R, APFS-L, VFS-R, and VFS-L reached maximum value between the ages of 30 and 39 years old (Table 3). When we examined these changes in the right and left frontal sinus for both genders in Figure 2, a second crossing event was observed between frontal sinus sizes of females and males between 60 and 69 years of age in WFS-R, WFS-L, APFS-R, and APFS-L and between 50 and 59 years of age in the HFS-R and HFS-L. The sizes of the frontal sinuses in females increased with age, and the sizes of frontal sinuses in males decreased with age after 50.

In the overall population, APFS-L reached a maximum value between 20 and 29 years of age; HFS-L, VFS-R and VFS-L reached a maximum value between 30 and 39 years of age; WFS-L reached a maximum value between 40 and 49 years of age; WFR-R reached a maximum value between 50 and 59 years of age; APFS-R reached a maximum value between 60 and 69 years of age; and HFS-R reached a maximum value at over 70 years of age (Table 3).

**Discussion.** Most previous studies have reported that the frontal sinus was larger in males than in females.<sup>8,11,13-16</sup> Only a few authors have reported that the frontal sinus measurements for females and males were not significantly different.<sup>3,17,18</sup> In our study, the WFS-L, HFS-L, APFS-R, APFS-L, VFS-R, and VFS-L were significantly larger in males ( $p < 0.05$ ). Other measurements were also slightly larger in males, but the differences were not statistically significant ( $p > 0.05$ ).

In most previous studies, the left frontal sinus was found to be larger than the right frontal sinus, although the cause was not explained.<sup>13,15,19</sup> Tatlisumak et al<sup>13</sup> stated that the size of the left frontal sinus is more pronounced in both genders. Nevertheless, some authors have reported that there were no statistically significant differences between the right and left frontal sinuses.<sup>20</sup> Kanat et al<sup>21</sup> reported that the left sinuses were dominant in 50.1% of the cases, the right sinuses were dominant in 35.6% of the cases, and both sinuses were equal in 14.3% of their series.

In the present study, anteroposterior (AP) length and volume of frontal sinuses were significantly larger on the left side in females and in total population ( $p < 0.05$ ),

whereas other sizes of frontal sinus were slightly larger on the left side. However, these differences were not statistically significant ( $p > 0.05$ ).

When cases were stratified by age group and gender, interesting results were obtained. Sizes and volumes of left frontal sinuses, except AP lengths, were slightly greater compared to the right side up to 50-59 (40-49 for widths) years of age. However, a crossing occurred after 50-59 (40-49 for widths) years of age, and as a result, the widths, heights and volumes of the right frontal sinuses were found to be larger than those on the left side. Kanat et al<sup>21</sup> suggested that lateralization might be one of the causes of human frontal sinus asymmetry. Because we identified a change in the dominant side with age in this study, we cannot agree with this opinion.

We determined that each measurement exhibited different characteristics with aging among both genders. In the total population, we observed a crossing event in frontal sinus sizes between 50 and 59 years of age in WFS-R, WFS-L, APFS-R, APFS-L, VFS-R and VFS-L and between 40 and 49 years of age in HFS-R and HFS-L. In the literature, we did not encounter such findings in any previously conducted studies. In only one article, Tatlisumak et al<sup>13</sup> described that most of the measurements of the frontal sinus reached their highest values between 31 and 40 or between 41 and 50 years of age in both genders; a reduction occurred with aging.

All measurements of the frontal sinus after 40-49 years of age tended to increase and continued until 70-70+ years of age in females, at which point a decrease occurred, except in HFS-L. Contrarily, all measurements of frontal sinus tended to decrease after 40-49 years of age in males, until 70-70+ years of age, when the values of the measurements increased again. The changes occurring after 40-49 years of age fit the sex steroid decline that occurs in both genders during this period. McLaughlin et al<sup>12</sup> had proposed that growth hormone levels might affect the sizes of frontal sinuses. Further research is required to elucidate whether the levels of sex steroids have effects on diameters of the frontal sinus.

Fatu et al<sup>22</sup> reported that frontal sinuses were dynamic structures and that changes in both size and shape continue to occur during adult life. Tatlisumak et al<sup>13</sup> determined alterations in the diameters of the frontal sinus in an adult Turkish population. We also defined changes in the sizes of frontal sinuses in a Turkish population from a different region of Turkey. However, all these studies were on local populations with a limited number of subjects.

In conclusion, from past to present, frontal sinuses have been accepted as unique for every person, an indispensable element of forensic identification, and a valuable identification tool that can be successful, even in monozygotic twins. We observed differences of dimensions of frontal sinus in different age groups in a Turkish adult population. We suggest that further studies are required to determine whether frontal sinus dimensions change during adulthood. The results of such studies may affect the opinions of researchers working on forensic personal identification using frontal sinus measurements.

## References

- Hopkins C. Nose, nasal cavity and paranasal sinuses. In: Standring S, editor. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Elsevier; 2016. p. 565-567.
- Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography: Its application to identification of unknown skeletal remains. *Forensic Sci Int* 1987; 34: 289-299.
- Kirk NJ, Wood RE, Goldstein M. Skeletal identification using the frontal sinus region: a retrospective study of 39 cases. *J Forensic Sci* 2002; 47: 318-323.
- Park IH, Song JS, Choi H, Kim TH, Hoon S, Lee SH, et al. Volumetric study in the development of paranasal sinuses by CT imaging in Asian: a pilot study. *Int J Pediatr Otorhinolaryngol* 2010; 74: 1347-1350.
- Tatlisumak E, Asirdizer M, Yavuz MS. Usability of CT images of frontal sinus in forensic personal identification. In: Homma N, editor. *Theory and applications of CT imaging and analysis*. Rijeca (HR): InTech Open; 2011. p. 257-268.
- Ribeiro Fde A. Standardized measurements of radiographic films of the frontal sinuses: an aid to identifying unknown persons. *Ear Nose Throat J* 2000; 79: 26-33.
- Tatlisumak E, Yilmaz Ovali G, Aslan A, Asirdizer M, Zeyfeoglu Y, Tarhan S. Identification of unknown bodies by using CT images of frontal sinus. *Forensic Sci Int* 2007; 166: 42-48.
- Uthman AT, Al-Rawi NH, Al-Naaimi AS, Tawfeeq AS, Suhail EH. Evaluation of frontal sinus and skull measurements using spiral CT scanning: an aid in unknown person identification. *Forensic Sci Int* 2010; 197: 124.
- Soares CB, Almeida MS, Lopes Pde M, Beltrão RV, Pontual Ados A, Ramos-Peres FM, et al. Human identification study by means of frontal sinus imaginological aspects. *Forensic Sci Int* 2016; 262: 183-189.
- Rabelo KA, Dos Anjos Pontual ML, de Queiroz Jordão N, de Paiva KM, de Moraes Ramon-Perez FM, Dos Santos MS, et al. Human identification by FSS system adapted to cephalometric radiographs. *Forensic Sci Int* 2016; 262: 227-232.
- Kim DI, Lee UY, Park SO, Kwak DS, Han SH. Identification using frontal sinus by three-dimensional reconstruction from computed tomography. *J Forensic Sci* 2013; 58: 5-12.
- McLaughlin RB Jr, Rehl RM, Lanza DC. Clinically relevant frontal sinus anatomy and physiology. *Otolaryngol Clin North Am* 2001; 34: 1-22.
- Tatlisumak E, Ovali GY, Asirdizer M, Aslan A, Ozyurt B, Bayindir P, et al. CT study on morphometry of frontal sinus. *Clin Anat* 2008; 21: 287-293.
- Akhlaghi M, Bakhtavar K, Moarefdoost J, Kamali A, Rafeifar S. Frontal sinus parameters in computed tomography and sex determination. *Leg Med (Tokyo)* 2016; 19: 22-27.
- Belaldavar C, Kotrashetti VS, Hallikerimath SR, Kale AD. Assessment of frontal sinus dimensions to determine sexual dimorphism among Indian adults. *J Forensic Dent Sci* 2014; 6: 25-30.
- Pirner S, Tingelhoff K, Wagner I, Westphal R, Rilk M, Wahl FM et al. CT-based manual segmentation and evaluation of paranasal sinuses. *Eur Arch Otorhinolaryngol* 2009; 266: 507-518.
- Navdeep K, Sunira C, Parvathi D, Srinivasa RM, Neeraj T, Ruhi S. The forensic importance of frontal sinus in gender discrimination: a morphometric study. *J Oral Sign* 2013; 5: 2-5.
- Verma S, Mahima VG, Patil K. Radiomorphometric analysis of frontal sinus for sex determination. *J Forensic Dent Sci* 2014; 6: 177-182.
- Yüksel Aslier NG, Karabay N, Zeybek G, Keskinoglu P, Kiray A, Sütay S, et al. The classification of frontal sinus pneumatization patterns by CT-based volumetry. *Surg Radiol Anat* 2016; 38: 923-930.
- Yun IS, Kim YO, Lee SK, Rah DK. Three-dimensional computed tomographic analysis of frontal sinus in Asians. *J Craniofac Surg* 2011; 22: 462-467.
- Kanat A, Yazar U, Ozdemir B, Coskun ZO, Erdivanli O. Frontal sinus asymmetry: Is it an effect of cranial asymmetry? X-ray analysis of 469 normal adult human frontal sinus. *J Neurosci Rural Pract* 2015; 6: 511-514.
- Fatu C, Puisoru M, Rotaru M, Truta AM. Morphometric evaluation of the frontal sinus in relation to age. *Ann Anat* 2006; 188: 275-280.