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The Relationship Between Anatomical Variations and Paranasal Sinus Volumes With Climate and Altitude

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ABSTRACT

This study aimed to evaluate the effect of climate and altitude differences on the volume of paranasal sinuses and on the frequency of anatomic variations by comparing the paranasal sinus computerized tomography (PNSCT) of patients who were born and living in a cold, dry climate at high altitude with those of patients who were born and living on the coast at sea level in a temperate climate. We also aimed to determine differences relating to gender. A total of 914 individuals, 402 (44%) in Adana, and 512 (56%) in Sivas were evaluated and compared prospectively. Axial and coronal CT sections were used for volume measurements in the paranasal sinuses. For measurements, the widest view of the sinuses was used. The findings of this study have shown that age groups and genders compared measurements between the two cities. When the age groups are examined, there is no significant difference between the regions between 0-20 years of age (p> 0.05), whereas 21-40,41-60,61 and above individuals have a significant difference between the frontal and sphenoid sinuses (p <0.05) . Maxillary sinus volume was similar between the two cities, and no significance was found (p> 0.05). Considering the difference between paranasal sinus volumes between males, males were larger than females (p <0.05). Besides, when the diameter of the paranasal sinuses between regions is examined; It was found that individuals in Adana were longer than Sivas (p <0.05). The percentage of aplasia and hypoplasia observed in individuals participating in the study is similar in both cities. In conclusion, there have been many studies of nasal cavity changes due to climatic conditions, but this is one of the first studies to measure the difference in paranasal sinus volumes. The present study demonstrated that the climate has a unique effect on the respiratory system, including paranasal sinuses. One should consider the paranasal sinus anatomy and surgery by taking the region and the climate count into the decision processes.

Keywords: Paranasal Sinuses, Morphometry, Computed Tomography, Climate Adaptation

Anatomik Varyasyonlar ve Paranazal Sinüs Hacimlerinin İklim ve Rakım İle İlişkisi

Süreç

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ÖZ

Bu çalışmada, soğuk ve kuru bir iklimde doğup yüksek rakımda yaşayan hastaların paranazal sinüs bilgisayarlı tomografisi (PNSCT) ile ılıman bir iklimde deniz seviyesinde kıyıda doğup yaşayan hastaların paranazal sinüs bilgisayarlı tomografi (PNSCT) görüntüleri karşılaştırılarak, iklim ve rakım farklılıklarının paranazal sinüslerin hacmi ve anatomik varyasyonların sıklığı üzerindeki etkisinin değerlendirilmesi amaçlanmıştır. Ölçümler için sinüslerin en geniş görünümü kullanıldı. Bu çalışmanın bulguları, yaş gruplarının ve cinsiyetlerin iki şehir arasındaki ölçümleri karşılaştırdığını göstermiştir. Yaş grupları incelendiğinde 0-20 yaş arasında anlamlı fark bulunmazken (p> 0.05), 21-40,41-60,61 ve üzeri bireylerde frontal ve sfenoid sinüsler hacimlerinde bölgeler arasında anlamlı fark vardır(p <0.05). Maksiller sinüs hacmi iki şehir arasında benzerdi ve anlamlı bulunmadı (p> 0.05). Erkekler arasındaki paranazal sinüs hacimleri arasındaki farka bakıldığında, erkeklerin kadınlardan daha büyük olduğu görüldü (p <0.05). Ayrıca paranazal sinüslerin bölgeler arası çapları incelendiğinde; Adana'daki bireylerin Sivas'a göre daha uzun olduğu bulundu (p <0.05). Araştırmaya katılan bireylerde gözlenen aplazi ve hipoplazi yüzdesi her iki ilde de benzerdir. Sonuç olarak, iklim koşullarına bağlı olarak nazal kavite boşluğu değişiklikleri ile ilgili birçok çalışma yapılmıştır, ancak bu, paranazal sinüs hacimlerindeki farkı ölçen ilk çalışmalardan biridir. Mevcut çalışma, iklimin paranazal sinüsler dahil olmak üzere solunum sistemi üzerinde benzersiz bir etkiye sahip olduğunu göstermiştir. Karar sürecinde bölge ve iklim hesaba katılarak paranazal sinüs anatomisi ve cerrahisi göz önünde bulundurulmalıdır.

Anahtar sözcükler: Paranazal Sinüsler, Morfometri, Bilgisayarlı Tomografi, İklim Adaptasyonu

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Introduction

Factors affecting the development of the paranasal sinuses and variations in the paranasal region are not fully clarified. [1] The size of the sinuses can vary according to age and may vary from person to person. In the same person, as well as left and right sinus shape asymmetries, sinus hypoplasias can occur. [2] Fatua et al. Suggested that the size of the sinuses varies depending on the amount of aeration.[3] Noback et al. Argued that the nasal cavity was higher and narrower in populations living in cold and dry climates, and nasal cavity morphometry was affected by both temperature and pressure changes. Another study showed that human face shape is associated with a climatic effect rather than a genetic effect, especially in polar populations. [4,5] Beals stated that the cephalic index in societies living in cold climates is higher than in hot climates. [6]

Anatomical variations occurring during the development of the paranasal region can play a role in the pathogenesis of chronic sinus infections, as well as cause various types of headaches and cause complications during maxillo-facial surgery. [7,8] In addition to the normal anatomy of the paranasal region, CT is the best imaging method used to evaluate variations and pathologies that cannot be detected in direct radiographs, sometimes even in nasal endoscopy. [9,10] Therefore, in our study, The aim of this study is to investigate the effect of climate and altitude differences on paranasal sinus volumes and the incidence of anatomical variations using CT images. Therefore, the aim of this study is to investigate the effect of climate and altitude differences on paranasal sinus volumes and the incidence of anatomical variations using CT images.

Materials and Method

Nine hundred fourteen images obtained by scanning the paranasal CT images belonging to December 2018 - December 2019 period in the archive of Sivas Cumhuriyet University Radiology Department and Adana State Hospital Radiology Clinic were included in the study. Sivas is in the middle region of Turkey at an altitude of 1285 m. The climate of Sivas is hot-dry in summers and cold-snowy in winters, with a mean annual temperature of 8.9 °C (maximum 40.0 °C, minimum -34.4 °C). Adana is in the southern region of Turkey at an altitude of 23 m and is located at the Mediterranean sea. The climate of this city is hot-humid in summers and mild-rainy in winters, with a mean annual temperature of 19.1 °C (maximum 45.6 °C, minimum -8.1 °C) according to between 1930 and 2019 data. On each image, sinus frontalis, sinus sphenoidal, and sinus maxillaris dimensions were measured, and their volumes were calculated. Also, anatomical variations such as agger nasi cell, Haller cell, Onodi cell, concha bullosa, and septum deviation were investigated.

Image analysis

Axial and coronal CT sections were used for volume measurements in the paranasal sinuses. For measurements, the widest view of the sinuses was used.

For frontal (Figure 1), sphenoid (Figure 2), and maxillar sinus (Figure 3) volumes, anterior-posterior diameter (a) from axial sections, transverse (b), and height (c) from coronal sections were measured. The volume was calculated by multiplying these measurements by the number [a×b×c× 0.523(=π/6)].[11]

Statistical analysis

The data obtained from the study were evaluated with the SPSS 23.0 program. Results were expressed as mean ± standard deviation. Data were used independent sample t-test for two independent groups. More than two groups were analyzed using the F test (ANOVA) and a post-hoc Tukey test was used to identify differences between experimental groups. The level of significance was taken as 0.05.

Results

Demographic Information

A total of 914 individuals, 402 (44%) in Adana and 512 (56%) in Sivas, with an average age of 9 to 81 years, were included in the study. 191 (47.5%) of the individuals in Adana are women, 211 (52.5%) are men, and the average age is 34.64 ± 14.74, 278 (54.3%) of the people in Sivas are women. 234 (45.7%) were male, and the average age was 37.47 ± 16.49 (Table 1).

Age groups and genders were compared measurements between the two cities. When the age groups are examined, there is no significant difference between the regions between 0-20 years of age ($p > 0.05$), whereas 21-40,41-60.61 and above individuals have a significant difference between the frontal and sphenoid sinuses ($p < 0.05$) (Table 2,3,4 and 5). Maxillary sinus volume was similar between the two cities, and no significance was found ($p > 0.05$).

Considering the difference between paranasal sinus volumes between males, males were larger than females ($p < 0.05$) (Tables 2,3,4 and 5).

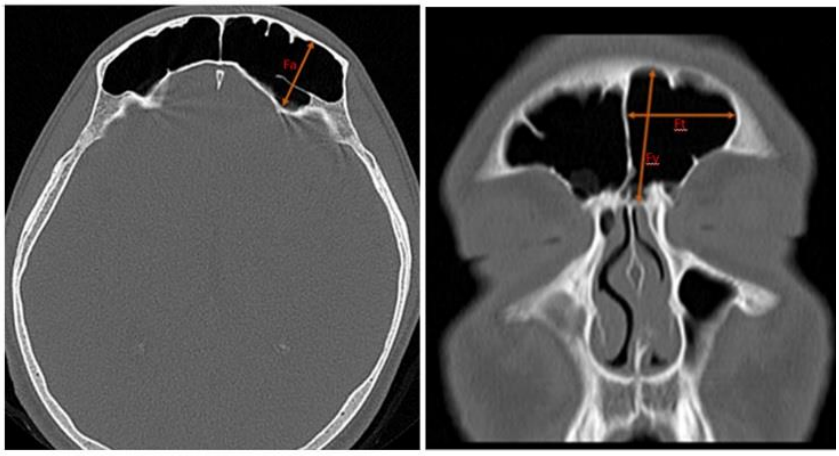
Besides, when the diameter of the paranasal sinuses between regions is examined; It was found that individuals in Adana were longer than Sivas ($p < 0.05$) (Table 6).

The percentage of aplasia and hypoplasia observed in individuals participating in the study is similar in both cities (Table 7).

When looking at anatomical variations, it was determined that climate and altitude do not differ among individuals. However, in general, the rate of anatomical variation in women is higher than in men (Figure 4; Table 8).

Table 1. Comparison of demographic information of the regions

Parameters	Adana (N = 402)	Sivas (N = 512)
Gender (KE)	191-211 (47.5-2.5%)	278-234 (54.3-45.7%)
Age (years)	34.64 ± 14.74	37.47 ± 16.49



Fa: Front-back diameter length

Ft: Transverse diameter length

Fv: Height

Figure 1. Measurements in the frontal sinus in coronal and axial sections.

Table 2. Comparison of paranasal sinus volumes (cm^3) in individuals between the ages of 0-20 by region and gender.

	Adana	Sivas	p-Value[a]
Sphenoid sinus volume			
Women (n = 45)	8.66 ± 2.73	8.13 ± 2.74	.346
Male (n = 51)	9.69 ± 3.27	9.03 ± 3.30	.368
p Value [b]	0,127	.159	
Left maxillary sinus volume			
Women (n = 44)	17.76 ± 4.46	16.79 ± 5.51	.348
Men (n = 50)	19.92 ± 4.79	18.54 ± 5.94	.256
p Value [b]	0,039 *	.149	
Right maxillary sinus volume			
Women (n = 45)	17.39 ± 3.53	18.38 ± 5.09	.266
Male (n = 51)	20.56 ± 4.69	19.72 ± 5.61	.467
p Value [b]	0.001 *	0,229	
Left frontal sinus volume			
Women (n = 39)	2.87 ± 1.84	2.68 ± 1.65	.617
Male (n = 49)	3.73 ± 2.47	3.54 ± 1.80	.716
p-Value [b]	.101	0,022 *	
Right frontal sinus volume			
Women (n = 43)	2.67 ± 1.70	2.55 ± 1.48	.737
Men (n = 50)	4.66 ± 2.95	4.23 ± 2.48	.488
p Value [b]	0.001 *	0,000 *	

p-Value [a]; It shows the paranasal sinus comparison of Adana and Sivas regions according to gender groups. The significance level was taken as p <0.05.

p-Value [b]; It shows gender comparison between Adana and Sivas regions.

Table 3. Comparison of paranasal sinus volumes (cm^3) in individuals aged 21-40 by region and gender

	Adana	Sivas	p-Value [a]
Sphenoid sinus volume			
Women (n = 85-114)	9.65 ± 3.23	8.69 ± 2.78	.026
Male (n = 101-93)	10.31 ± 2.73	9.65 ± 2.56	0.084 *
p Value [b]	0,131	0,137	
Left maxillary sinus volume			
Women (n = 80-111)	18.07 ± 4.16	17.81 ± 5.46	.716
Male (n = 98-93)	20.29 ± 4.33	21.17 ± 5.99	.247
p Value [b]	0.001 *	0.001 *	
Right maxillary sinus volume			
Women (n = 80-112)	17.90 ± 4.71	17.43 ± 5.24	.530
Male (n = 100-90)	20.46 ± 4.62	21.49 ± 6.04	.193
p Value [b]	0,000 *	0,000 *	
Left frontal sinus volume			
Women (n = 69-96)	4.02 ± 1.90	3.04 ± 1.41	0,000 *
Male (n = 90-84)	6.99 ± 3.87	5.33 ± 3.23	0,002 *
p Value [b]	0,000 *	0,000 *	
Right frontal sinus volume			
Women (n = 79-97)	4.15 ± 2.13	3.12 ± 1.50	0,000 *
Male (n = 93-84)	6.83 ± 4.29	5.23 ± 2.64	0,003 *
p Value [b]	0,000 *	0,000 *	

p Value [a]; It shows the paranasal sinus comparison of Adana and Sivas regions according to gender groups.
p Value [b]; It shows gender comparison between Adana and Sivas regions. The significance level was taken as p <0.05.

Table 4. Comparison of paranasal sinus volumes (cm^3) in individuals aged 41-60 by region and gender.

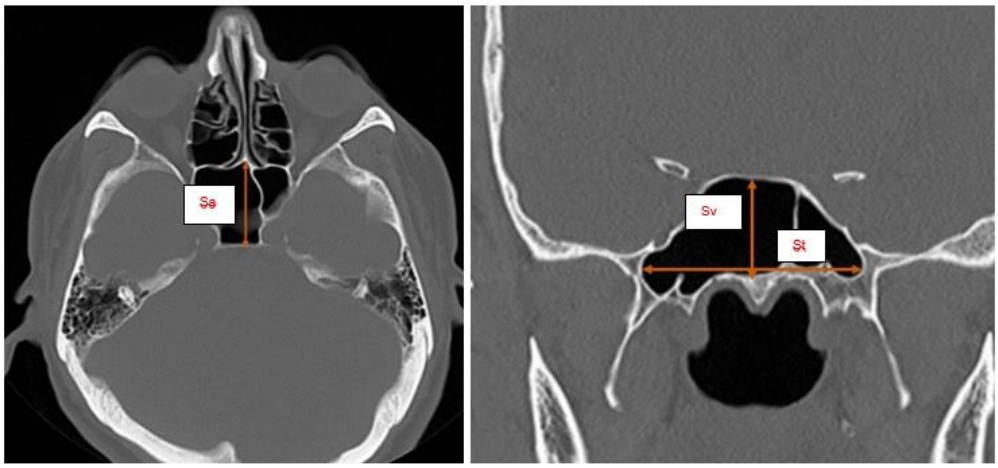
	Adana	Sivas	p-Value [a]
Sphenoid sinus volume			
Women (n = 45-84)	10.45 ± 2.38	9.10 ± 3.64	0,013 *
Male (n = 57-61)	11.65 ± 3.08	10,26 ± 3,94	0,035 *
p Value [b]	0,029 *	0,030 *	
Left maxillary sinus volume			
Women (n = 44-76)	19.10 ± 5.23	18,11 ± 5,24	.321
Male (n = 52-56)	20.57 ± 5.52	21,28 ± 6,20	.530
p Value [b]	.183	0,178	
Right maxillary sinus volume			
Women (n = 46-80)	17.93 ± 4.73	18.27 ± 6.03	.733
Male (n = 55-60)	20.18 ± 5.51	21.12 ± 6.46	.401
p Value [b]	0,030 *	0,030 *	
Left frontal sinus volume			
Women (n = 38-64)	4.68 ± 1.62	3.95 ± 1.94	0,046 *
Male (n = 47-57)	7.52 ± 3.23	6.28 ± 2.84	0.043 *
p Value [b]	0,000 *	0,000 *	
Right frontal sinus volume			
Women (n = 39-72)	5.69 ± 2.62	3.73 ± 2.37	0,000 *
Male (n = 52-56)	8.09 ± 2.93	6.79 ± 3.77	0,046 *
p Value [b]	0,000 *	0,000 *	

p-Value [a]; It shows the paranasal sinus comparison of Adana and Sivas regions according to gender groups.
p-Value [b]; It shows gender comparison between Adana and Sivas regions. The significance level was taken as p <0.05.

Table 5. Comparison of paranasal sinus volumes (cm ^{3}) in individuals aged 61 and over by region and gender

	Adana	Sivas	p-Value [a]
Sphenoid sinus volume			
Women (n = 11-26)	12.44 ± 3.93	9.68 ± 5.19	0.043 *
Male (n = 15-31)	12.99 ± 4.97	10.98 ± 4.92	.208
p-Value [b]	.763	0,336	
Left maxillary sinus volume			
Women (n = 10-24)	18.19 ± 4.64	19.49 ± 7.75	.552
Male (n = 14-29)	21.39 ± 7.95	20.73 ± 8.41	.806
p Value [b]	0,268	.579	
Right maxillary sinus volume			
Women (n = 10-24)	17.86 ± 3.94	20.28 ± 8.39	0,262
Male (n = 14-29)	21.62 ± 7.74	20.14 ± 7.05	.551
p-Value [b]	.174	0,950	
Left frontal sinus volume			
Women (n = 7-20)	7.62 ± 4.23	5.41 ± 3.30	.242
Male (n = 12-28)	7.65 ± 3.09	5.52 ± 2.71	0,035*
p Value [b]	0,985	.904	
Right frontal sinus volume			
Women (n = 8-19)	7.49 ± 4.41	5.74 ± 3.79	0,202
Male (n = 14-30)	8.07 ± 1.89	5.15 ± 2.13	0,000 *
p-Value [b]	.667	.488	

p-Value [a]; It shows the paranasal sinus comparison of Adana and Sivas regions according to gender groups.
p-Value [b]; It shows gender comparison between Adana and Sivas regions. The significance level was taken as p <0.05.



Sa: Front-back diameter length

St: Transverse diameter length

Sv: Height

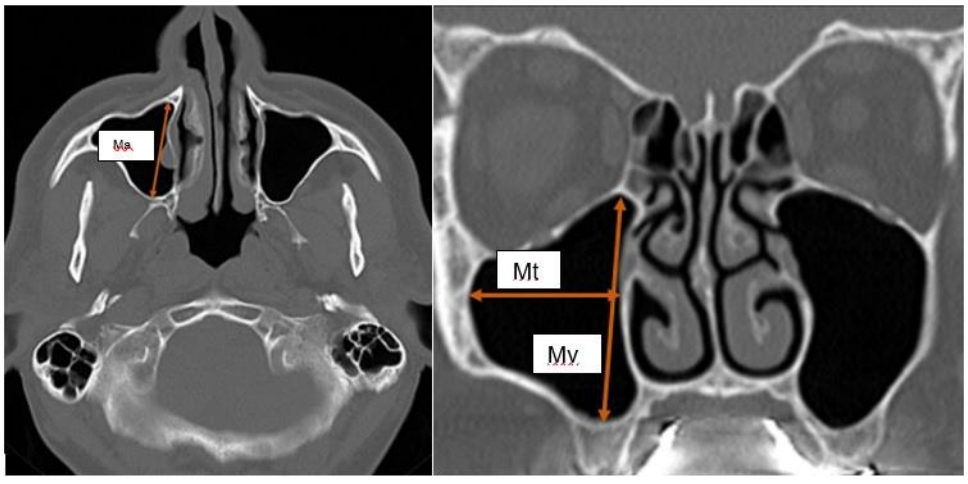
Figure 2. Measurements in sphenoid sinus in coronal and axial sections.

Table 6. Comparison of sinus diameter lengths (cm) between 21-40 years old individuals

	Adana	Sivas	p-Value
Sphenoid sinus diameter (n = 186-207)			
St	3.10 ± 0.50	2.89 ± 0.50	0,046 *
Sv	2.15 ± 0.43	2.13 ± 0.41	.554
Sa	3.05 ± 0.45	2.70 ± 0.45	0,000 *
Left Maxillary sinus diameter (n = 179-204)			
Mt.	2.57 ± 0.87	2.46 ± 0.45	.106
Mv	3.76 ± 0.56	3.78 ± 0.48	.146
Me	3.97 ± 0.30	3.88 ± 0.36	0,008 *
Right Maxillary sinus diameter (n = 180-202)			
Mt.	2.48 ± 0.43	2.49 ± 0.48	.827
Mv	3.68 ± 0.41	3.74 ± 0.60	0,271
Me	3.99 ± 0.32	3.87 ± 0.37	0.001 *
Left Frontal sinus diameter (n = 159-181)			
Ft	2.88 ± 0.59	2.70 ± 0.58	0,047 *
Fv	2.64 ± 0.80	2.11 ± 0.79	0,000 *
Fe	1.38 ± 0.25	1.35 ± 0.78	.687
Right Frontal sinus diameter (n = 172-181)			
Ft	2.76 ± 0.65	2.68 ± 0.68	0,313
Fv	2.59 ± 0.79	2.17 ± 0.75	0,000 *
Fe	1.39 ± 0.25	1.28 ± 0.22	0,002 *

Table 7. Percentage of aplasia and hypoplasia is seen in individuals participating in the study

	Adana	Sivas
Sphenoid Sinus	1.24%	1.75%
Left Maxillary Sinus	5.47%	6.05%
Right Maxillary Sinus	3.49%	4.49%
Left Frontal Sinus	16.41%	14.45%
Right Frontal Sinus	9.45%	12.10%



Ma: Front-back diameter length

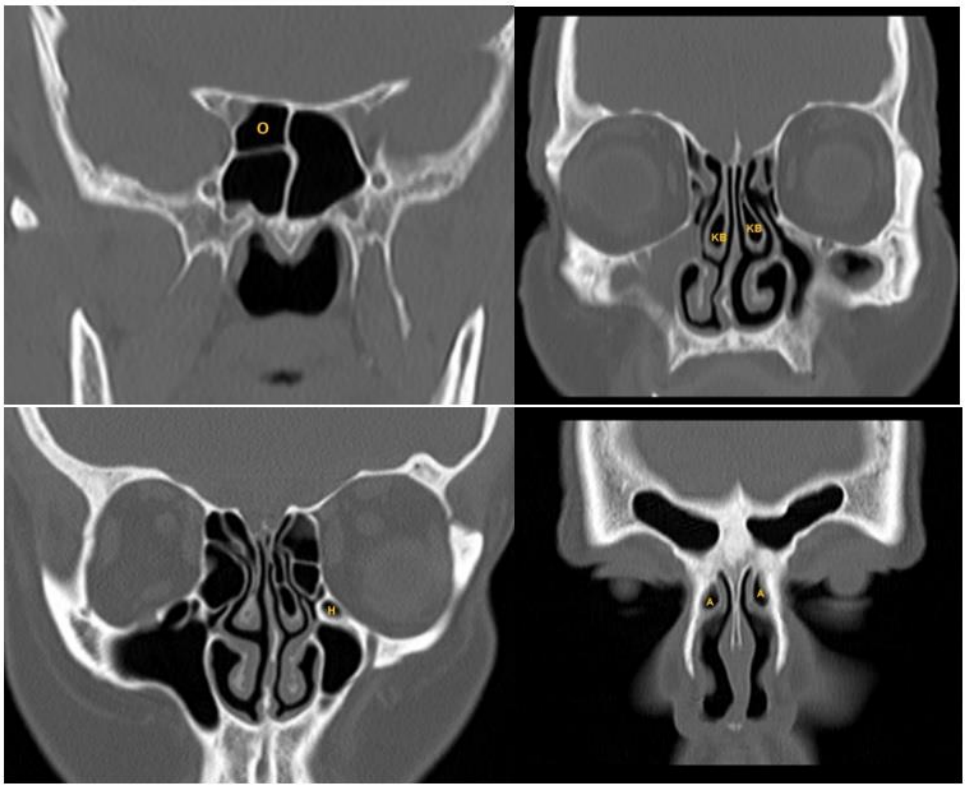
Mt: Transverse diameter length

My: Height

Figure 3. Measurements in maxillary sinus in coronal and axial sections.

Table 8. Percentage of individuals participating in the study for anatomical variation

	Adana		Sivas	
	Women (%)	**Male (%)**	**Women (%)**	**Male (%)**
Normal Anatomical Structure	**41.4**	**52.6**	**44.8**	**53.2**
Right Agger nasi air cells	3.7	2.8	4.7	5.6
Left Agger Nasi Cell	2.6	1.9	3.2	3.9
Double Agger Nasi Cell	5.2	2.4	6.1	2.6
Right Haller Cell	2.1	4.3	2.9	0.9
Left States Cell	3.7	2.8	1.8	4.7
Double States Cell	2.6	1.9	0.7	0
Right Onodi Cell	0.5	1.4	1.8	1.7
Left Onodi Cell	3.1	1.9	2.5	3.0
Double Onodi Cell	1.0	2.4	2.5	0.4
Right Concha Bullosa	4.2	3.8	4.7	3.9
Left Concha Bullosa	4.2	3.8	6.1	2.6
Double Concha Bullosa	6.8	3.3	7.9	5.2
Agger Nasi and Haller Cell	2.6	1.4	3.6	2.6
Agger Nasi and Onodi Cell	1.0	0	0.7	0
Agger Nasi and Concha Bullosa	4.2	3.8	2.5	3.4
Haller and Onodi	0.5	1.9	0.4	0.4
Haller and Concha Bullosa	6.3	5.2	2.2	2.6
Onodi and Concha Bullosa	1.6	0.5	0.4	2.6
Agger Nasi-Haller-Concha Bullosa	1.0	1.4	0.4	0.4
Agger Nasi-Haller-Onodi	1.0	0	0	0
Haller-Concha Bullosa-Onodi	0.5	0.5	0	0
Agger Nasi-Concha Bullosa-Onodi	0	0	0	0.4



(O; Onodi cell, KB; Concha Bullosa, H; Haller Cell, A; Agger Nasi Cell)

Figure 4. Anatomical variations

Discussion

Since humankind lives in a very different kind of environment, the human body needs to adapt where he/she lives. In one way, while humans change the environment, the environment changes him/her as well. Literature states that the climate difference can be a vital factor to observed differences in the anthropometric measurements. [12] Yu et al. reported that the volume of the frontal sinuses affected brain contusion and that larger frontal sinuses have a protective role for brain contusion resulting from head trauma.[13] In the current study, frontal sinus volumes were found to be larger in males than in females, so it could be said that males are less likely than females to have had a brain contusion.

The respiratory system is one of the areas, which is one of the most exposed the environmental conditions. It has been known that, in a cold climate, the nasal area adapts itself by narrowing the opening, nasal morphologically, and functionally in increasing turbulence and thereby the mixture of the humidity of the inspired air. [14] In the present study, Axial and coronal CT sections were used for volume measurements in the paranasal sinuses. Volumes were measured and compared between two cities and within age groups and genders. Maxillary sinus volume was similar between Adana and Sivas. There was no statistically significant correlation between the volume of maxillary sinuses with age or side. Similar to the present study, Selcuk et al. could not find any difference in the maxillary sinus volumes between two regens where the air is cold-dry in one place (Ağrı) and hot and humid in the other place (Antalya) which is similar to our regens.[15]

Interestingly enough, as they mentioned in their study, some recent studies have demonstrated that the maxilla is most closely correlated with climate among the cranial regions. [16,17] On the other hand, Selcuk et al. could not find any difference in the volumes of the frontal and sphenoid sinus in a cold and dry, temperate, and humid climate.[14] Nonetheless, the present study shows that the frontal sinus volumes measured in the hot and humid places are significantly higher than the volumes which are measured in the cold and dry place in all age groups except (0-20). Consistent with our study, Koertvelyessy reported that mean frontal sinus surface areas were smaller in Eskimo populations living in cold temperatures than in India populations living in warmer temperatures, and the cause of small frontal sinuses in Eskimo population was explained as an adaptation to minimize interference with heat loss.[18]
Similar to the frontal sinus volumes, there was a statistically significant difference between the sphenoid volumes measured in Adana and Sivas. The volumes measured in Adana were significantly higher than the volumes measured in the Sivas, which is

possibly due to adaptation to the hot and humid weather.

In the present study, we not only measured the volumes but also evaluated the CT scans for paranasal anatomical variations. There are very limited number of studies about paranasal anatomical variations. In one of them, Yucel et al. showed that the most common paranasal anatomical variations are Ager Nasi Cell, septum deviation, and concha bullosa, respectively. Similarly, in the current study, we found that the most common paranasal anatomical variations at both Sivas and Adana are Haller-Conca Bullosa, Ager Nasi Cella, and Conca Bullosa. Although the frequency of the paranasal anatomical variations is similar, there were significant differences in some variations between Adana and Sivas, which may be resulted in climate changes. The incidence of Agger nasi air cells is significantly higher in Sivas than Adana. Furthermore, Double Concha Bullosa is also more frequent in Sivas. On the other hand, Haller cell and Concha Bullosa is more frequent in people who live in hot and humid climates like Adana.

In conclusion, climate and altitude are a crucial factor in the development of paranasal sinus. We suggest that a hot and humid climate affects the paranasal sinus and makes paranasal sinus bigger for more effective ventilation and temperature control. These adaptations naturally change the anatomy of paranasal sinus and adjacent structures, which may result in creating different anatomical variations of the site.

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Authors' Contributions

YT designed the study, interpreted the data, and had a major contribution in writing and revising the manuscript. AO; evaluation of data and statistical evaluation, IS and AS; collecting and transferring data, HT and AA; making it ready for publication, VS; monitoring the research process. All authors read and approved the final manuscript.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Compliance with Ethical Standards

Funding

None

Conflict of Interest

The authors declare that they have no conflict of interest

Ethical Approval

Approval was obtained from the Human Ethics Committee at Sivas Cumhuriyet University (No: 2019-12/55).

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