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The Possible Effects of Altitude and Climate on the Development of the Frontal Sinus in Adults

Los Posibles Efectos de la Altitud y el Clima sobre el Desarrollo del Seno Frontal en Adultos

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SUMMARY: Climatic and altitude features of living region may affect human body. Many changes in several tissues and organs and several health problems due to climatic and altitude effects were defined in the literature. However, there were limited number of studies which evaluated correlation between development of frontal sinus and climatic/altitude effect. In this study, widths, heights, AP lengths and volumes of frontal sinus were compared by Paranasal CT scans in populations living in Van which has colder climate and higher altitude and Manisa which has milder climate and lower altitude. It was found that widths, antero-posterior lengths and volumes of frontal sinus were higher in populations living in colder climate and higher altitude according to populations living in milder climate and lower altitude. Heights of frontal sinuses were on the contrary of this. These results were found appropriate to increasing of cephalic index in cold climate according to Allen's Rule. We suggest that larger population study should be made with peoples having the same or similar race and genetic structure in different climate and altitude regions and the proportional comparison of frontal sinus measurements with cephalic index should be considered in future studies.

KEY WORDS: Frontal Sinus; Paranasal CT scans; Altitude; Climate; Allen's Rule.

INTRODUCTION

Altitude is commonly defined to be "the vertical distance of a level, a point or an object considered as a point, measured from a specified datum". The standard atmospheric pressure in sea level decreases 3.5 mbar in each 30 meters in parallel with the increase of altitude. But reduction rate of atmospheric pressure together with the altitude is higher in cold regions due to high density of cold weather (Harrison, 2014).

It was reported that some changes may occur in organs such as lungs, heart and brain, and increases in blood hemoglobin, erythropoietin, a1-antitrypsin, ceruloplasmin levels and serum platelet counts and decreases in blood lipoprotein and prealbumin levels in regions with high altitude due to pressure reduce to the unit surface of the human body, differences in the rate of oxygen and climate changes (Peacock, 1998; Hudson *et al*., 1999; Lehmann *et al*., 2006; Yildirim *et al*., 2008; Ismailov, 2013). Several health problems were reported such as acute mountain sickness, high altitude pulmonary edema and high altitude cerebral edema due to acute high altitude exposure, subacute and chronic mountain sickness due to prolonged and permanent high altitude exposure, and increase of respiratory morbidity prevalence and non-occupational pneumoconiosis due to environmental pollution (Norboo *et al*., 2004). Also, Haws *et al*. (2009) reported that, bioenergetic dysfunction associated with affective illnesses was affected from decreased oxygen saturation at high altitude. In a study about the relationship between altitudes and suicides, a significant increase in suicide rates at high altitude was defined (Brenner *et al*., 2011).

Beals (1972) reported that cephalic index is higher in populations in cold climates than hot climates. Noback *et al*. (2011) defined significant correlations between nasal

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cavity shape and both of temperature and humidity. In their study, nasal cavity volume increased in humans living in cold and dry climate relative to hot and wet climate associated with greater turbulence during inspiration. Koertvelyessy (1972) claimed that there might be a relationship between low wind chill equivalent temperatures and small frontal sinus surface areas.

In the present study, it was aimed to evaluate the possible effects of altitude and climate on the development of the frontal sinus in adults above 20 years of age in populations living in Manisa and Van (Turkey) provinces which have different altitudes and climates.

MATERIAL AND METHOD

In this study, the following materials were used:

1) Paranasal CT scans of 5 mm thickness in the axial and coronal planes of cases above 20 years old taken by a 16-detector multislice computed tomography device (Somatom Emotion 16-Slice; CT2012E- Siemens AG, Berlin and Munich- Germany) in the Dursun Odabas Medical Center of Yuzuncu Yil University in Van.

2) Paranasal CT scans of 5 mm thickness in the axial and coronal planes of cases above 20 years old taken by a 16-detector multislice computed tomography device (Siemens Emotion Tomography Machine) in the Hafsa Sultan Hospital of Celal Bayar University in Manisa.

CT scans which seen apparent sinusoidal pathology of frontal sinus (FS) were excluded from this study. Also, patients with unilateral or bilateral FS absence were not included in this study.

All evaluations and measurements were done together by two scientists (Bora & Kartal) in the present study, with a Dicom viewer program and measurements were expressed in millimeters in HBYS & PACS program. Totally eight measurements were used in this study: 1) Width of right frontal sinus (WFS-R), 2) Width of left frontal sinus (WFS-L), 3) Height of right frontal sinus (HFS-R), 4) Height of left frontal sinus (HFS-L), 5) Anteroposterior length of right frontal sinus (APFS-R), 6) Anteroposterior length of left frontal sinus (APFS-L), 7) Volume of right frontal sinus (VFS-R) and 8) Volume of left frontal sinus (VFS-L) (Fig. 1). The measurements of widths and heights of both sinuses were measured on a coronal plane and the anteroposterior length on an axial plane. Volume was calculated in HBYS & PACS program. Values are in millimeters (mm) for widths, heights and AP lengths, and cubic centimeters (cc) for volumes.

Paranasal CT scans of 360 patients living in the city center of Van and 296 patients living in the city center of Manisa were evaluated in this study. Van is in the eastern region of Turkey at an altitude of 1727 m and is located at the shores of Van Lake. The climate of this city is hot - dry in summers and cold - snowy in winters, with a mean annual temperature of 9.1 °C (maximum 37.5 °C, minimum -28.7 °C). Manisa is in the western region of Turkey at an altitude of 71 m and is located at the foothills of Spil Mountain. The climate of this city is hot - dry in summers and mild - rainy in winters, with a mean annual temperature of 16.8 °C (maximum 45.5 °C, minimum -13.1 °C) between 1950 and 2015.

Descriptive statistics for studied variables were presented as mean, standard deviation, minimum and maximum values. One-way ANOVA test (including Post Hoc tests) was used to compare age groups and *sex*.

Statistical significance levels were considered as $p<0.05$. The SPSS (Version 13) statistical program was used for all statistical computations.

The study was approved by the Ethical Board of Medical Faculty Yuzuncu Yil University (Ref. no. 2016/02; 23.02.2016).

RESULTS

In this study, CT scans of 656 patients were evaluated with a mean age of 45.6 ± 16.8 years (range, 20-101 years). Van Group comprised 180 females (50.0 %) and 180 males (50.0 %) with a mean age of 49.9 ± 18.1 years. Manisa Group comprised 171 females (57.8 %) and 125 males (42.2 %) with a mean age of 40.3 ± 13.4 years. The distribution of cases according to age groups was shown at Table I.

Table I. The distribution of cases living in Van and Manisa according to age groups.

Age Groups	Van		Manisa		Total	
	n	%	n	%	n	%
20-29	60	16.7	76	25.7	136	20.7
30-39	60	16.7	59	19.9	119	18.1
40-49	60	16.7	91	30.8	151	23.0
50-59	60	16.7	48	16.2	108	16.5
60-69	60	16.6	14	4.7	74	11.3
70-71+	60	16.6	8	2.7	68	10.4
Total	360	100.0	296	100.0	656	100.0

Table II. The distribution of frontal sinus measurements in cases living in Van and Manisa according to sexes.

Measurements of FS in Females *	Van		Manisa		p
	Mean	SD	Mean	SD	
WFS-R	26.85	8.24	24.25	7.64	.002
WFS-L	27.37	8.10	26.24	7.30	.173
HFS-R	22.95	8.16	23.45	8.11	.563
HFS-L	23.83	7.48	24.80	8.12	.241
APFS-R	14.84	7.33	10.12	4.07	.001
APFS-L	16.01	7.86	10.90	4.13	.001
VFS-R	5.35	5.11	3.46	2.79	.001
VFS-L	5.95	4.99	4.18	3.42	.001
Measurements of FS in Males *	**Van**		**Manisa**		**p**
	Mean	SD	Mean	SD	
WFS-R	27.65	8.26	27.08	7.84	.548
WFS-L	28.11	8.35	28.46	7.98	.716
HFS-R	23.82	7.76	26.76	8.89	.002
HFS-L	24.09	7.70	28.39	9.04	.001
APFS-R	17.17	9.04	11.76	4.15	.001
APFS-L	17.87	8.90	13.22	5.20	.001
VFS-R	6.57	5.99	5.26	4.11	.034
VFS-L	7.15	6.86	6.56	5.72	.426
Measurements of FS in Total *	**Van**		**Manisa**		**p**
	Mean	SD	Mean	SD	
WFS-R	27.25	8.25	25.44	7.84	0.004
WFS-L	27.74	8.23	27.18	7.66	0.370
HFS-R	23.38	7.97	24.85	8.59	0.024
HFS-L	23.96	7.58	26.32	8.69	0.001
APFS-R	16.00	8.30	10.81	4.18	0.001
APFS-L	16.94	8.44	11.88	4.74	0.001
VFS-R	5.96	5.59	4.22	3.52	0.001
VFS-L	6.55	6.02	5.18	4.68	0.001

(*) Values are in millimeters (mm) for widths, heights and AP lengths, and cubic centimeters (cc) for volumes.

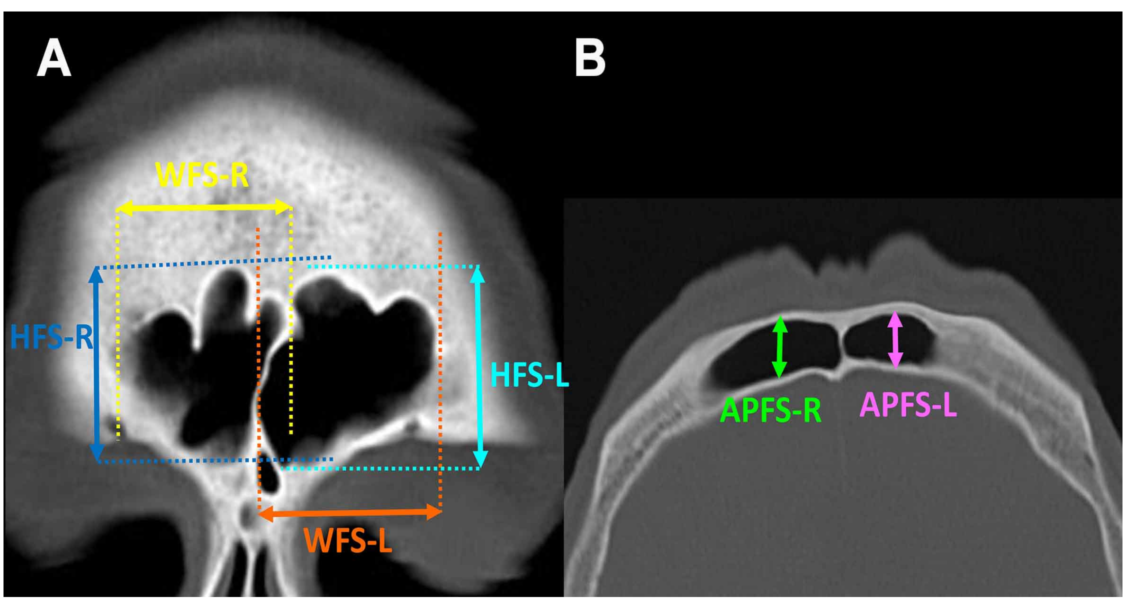


Fig. 1. The measurements of widths and heights of both sinuses on a coronal plane (a) and the anteroposterior length on an axial plane (b)

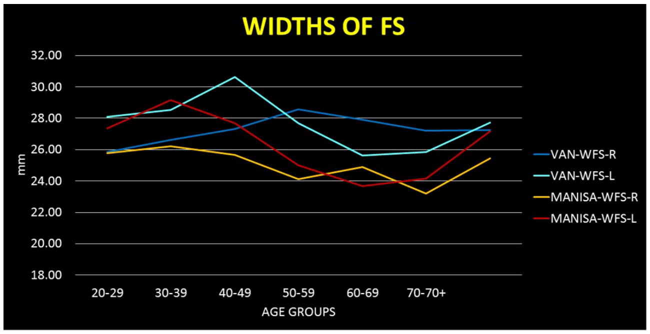
In female patients, WFS-R, WFS-L, APFS-R, APFS-L, VFS-R, VFS-L were higher in Van and HFS-R, HFS-L in Manisa. The differences were statistically significant for WFS-R, APFS-R, APFS-L, VFS-R, VFS-L whereas WFS-L, HFS-R, HFS-L were not statistically significant. In male patients, WFS-R, APFS-R, APFS-L, VFS-R, VFS-L were higher in Van and WFS-L, HFS-R, HFS-L in Manisa. The differences were statistically significant for HFS-R, HFS-L, APFS-R, APFS-L, VFS-R and VFS-L whereas WFS-R, WFS-L were not statistically significant. In totally, WFS-R, WFS-L, APFS-R, APFS-L, VFS-R, VFS-L were higher in Van and HFS-R, HFS-L in Manisa. The differences were statistically significant ($p<0.05$) for all measurements except WFS-L (Table II).

For each province, the mean values of each measurement of FS which classified to age groups were shown at Table III. Widths of FS were bilaterally higher in all age groups in Van except value of WFS-L in 30-39 age group ($p>0.05$ bilaterally). Heights of FS were bilaterally higher up to 40-49 years old in Manisa, in the following years old, they were bilaterally higher in Van ($p>0.05$ for HFS-R and $p<0.05$ for HFS-L). Also AP-Lengths and Volumes of FS were bilaterally higher in all age groups in Van ($p<0.05$ bilaterally for both measurements) (Fig.2).

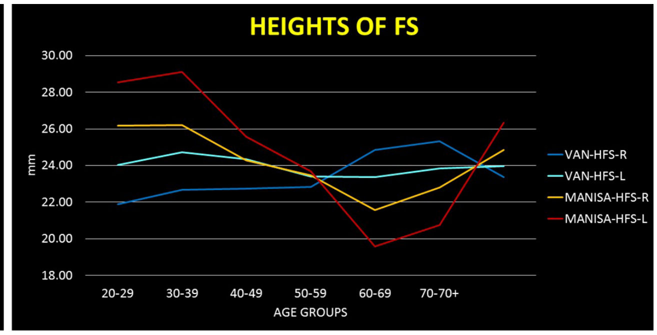
Table III. For each province, the mean values of each measurement of FS which classified to age groups.

CITY	AGE GROUPS	WFS-R		WFS-L		HFS-R		HFS-L		APFS-R		APFS-L		VFS-R		VFS-L	
		Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
VAN	20-29	25.863	6.90052	28.0940	7.35346	21.9015	7.44955	24.0472	7.83500	16.1693	8.36853	18.0318	7.67903	4.8165	3.51863	6.3460	4.44394
	30-39	26.6207	9.91407	28.5213	9.06813	22.6867	9.09202	24.7407	8.60349	16.8740	9.04781	17.6733	8.75959	6.7118	7.24420	7.5437	7.67006
	40-49	27.3278	8.72049	30.6387	8.40378	22.7240	8.09176	24.3388	8.17001	14.8752	7.73721	15.4330	7.54950	5.4835	5.59473	6.9242	7.14607
	50-59	28.5583	7.57859	27.6880	8.29582	22.8262	7.27365	23.3935	7.04942	15.7992	8.46911	16.5218	9.92162	5.8085	4.78711	6.1450	5.53410
	60-69	27.9092	8.30054	25.6333	7.35177	24.8427	7.41256	23.3735	6.30302	16.9663	9.79192	17.3680	9.95366	6.7083	6.07869	6.0578	5.42614
	70-71+	27.2132	7.82168	25.8633	8.03651	25.3140	8.06875	23.8578	7.53138	15.3418	6.02484	16.5975	6.20361	6.2355	5.59381	6.3025	5.41516
	Total	27.2487	8.24872	27.7398	8.22636	23.3825	7.96511	23.9586	7.58166	16.0043	8.30011	16.9376	8.43810	5.9607	5.58980	6.5532	6.02257
	p values	0.560		0.009		0.117		0.915		0.700		0.585		382.000		0.748	
MANISA	20-29	25.7605	6.85923	27.3566	7.42406	26.1697	7.24066	28.5566	8.08530	10.8026	4.08581	11.3026	3.51006	4.3571	3.47229	5.2070	3.28106
	30-39	26.2068	7.57457	29.1441	8.29007	26.2068	9.83843	29.1085	10.28689	11.7627	4.35628	13.2373	5.52218	4.8961	3.69586	7.1954	7.43578
	40-49	25.656	8.14029	27.7044	7.64633	24.2824	7.94862	25.5659	7.80083	10.5934	3.90720	12.1319	5.09075	4.0837	3.53860	5.0308	3.94199
	50-59	24.1312	9.16536	25.0042	7.13597	23.4542	9.67895	23.6750	8.17723	10.7292	4.73439	11.6250	4.98348	3.8952	3.54455	4.0819	3.36915
	60-69	24.8786	7.64583	23.6929	6.47343	21.5571	9.03308	19.5786	5.40145	9.2143	3.09288	8.7857	2.15473	3.1607	3.46696	2.3857	1.64073
	70-71+	23.2125	7.86719	24.1500	6.19885	22.8000	8.56671	20.7500	4.27183	9.7500	4.43203	11.5000	3.81725	3.3375	2.02859	3.2738	2.12019
	Total	25.4426	7.84049	27.1784	7.66122	24.8473	8.58836	26.3199	8.69014	10.8142	4.17611	11.8818	4.74176	4.2215	3.52046	5.1810	4.67622
	p values	0.732		0.029		0.189		0.001		0.318		0.029		0.468		0.001	

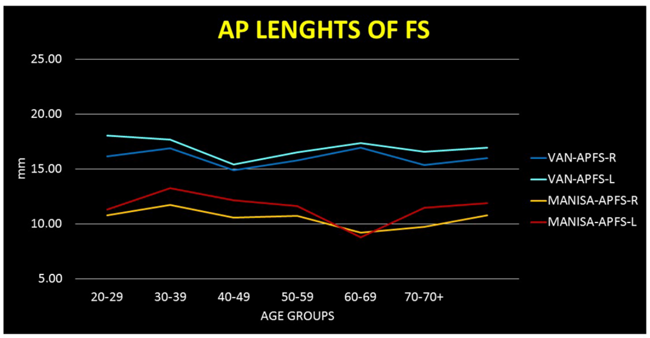
(*) Values are in millimeters (mm) for widths, heights and AP lengths, and cubic centimeters (cc) for volumes.



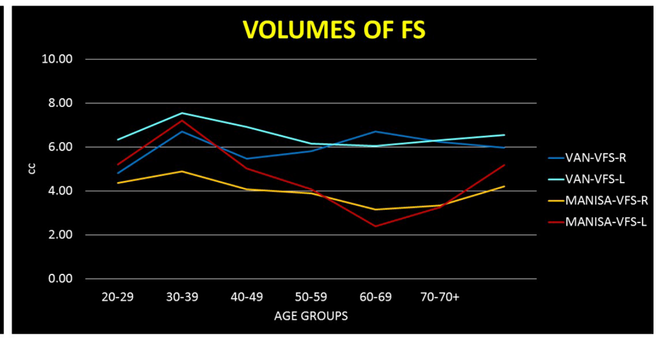
P=0.084 for WFS-R and P=0.897 for WFS-L



P=0.229 for HFS-R and P=0.024 for HFS-L



P=0.000 for APFS-R and P=0.000 for APFS-L



P=0.000 for VFS-R and P=0.000 for VFS-L

Fig. 2. The differences of frontal sinus widths according to age groups and cities.
Fig. 3. The differences of frontal sinus heights according to age groups and cities.
Fig. 4. The differences of frontal sinus AP lengths according to age groups and cities.
Fig. 5. The differences of frontal sinus volumes according to age groups and cities.

DISCUSSION

Guglielmino-Matessi *et al*. (1979) stated that climate could be a contributing factor to the observed differences in skull and anthropometric measurements. In a study it was shown that human facial shape was associated with a climatic effect, rather than genetic effect, especially in arctic populations (Harvati & Weaver, 2006). In the literature there were limited studies about the differences of nasal cavity volume and outer nasal shape differences in different climates. Noback *et al*. reported that there were significant correlations between nasal cavity morphology and both temperature and vapor pressure variables, and they found that nasal cavities from cold–dry climates were relatively higher and narrower compared with those of hot–humid climates. Evteev *et al*. (2014) stated that midfacial morphology was more strongly associated with climate than with genetic relatedness. There were limited number of studies which evaluated correlation between development of frontal sinus and climatic effect in the literature. Selcuk *et al*. (2015) reported that there was not any difference between the paranasal volumes in a cold and dry climate and in a temperate and humid climate. Whereas Koertvelyessy reported that mean frontal sinus surface areas were smaller in Eskimo populations living in cold temperatures than India populations living in warmer temperatures, and the cause of small frontal sinuses in Eskimo population was explained as an adaptation in order to minimize interference with heat loss. However, there was no study which evaluated correlation between development of frontal sinus and altitude effect in the literature.

In the present study, WFS-R, APFS-R, APFS-L, VFS-R and VFS-L were statistically significantly higher in females; APFS-R, APFS-L, VFS-R and VFS-L were statistically significantly higher in males living in Van which has colder climate and higher altitude than those living in Manisa which has milder climate and lower altitude. Contrarily, HFS-R and HFS-L were statistically significantly higher in males living in Manisa which has milder climate and lower altitude than those living in Van which has colder climate and higher altitude. Also, HFS-L, APFS-R, APFS-L, VFS-R and VFS-L were statistically significantly higher in all age groups living in Van which has colder climate and higher altitude than those living in Manisa which has milder climate and lower altitude. The increase of widths, AP lengths and volumes of frontal sinus in colder climate and higher altitude may be explained with findings which indicates that "cephalic index increases while temperature decreases" according to Allen's Rule in the study of Beals. Nevertheless, the presence of racial and genetic differences between populations living in Van and Manisa is the biggest obstacle in front of properly interpretation of the results of this study by us.

We think that morphological changes of frontal sinus cannot be explained only with climate and altitude effects associated with temperature, moisture, atmospheric pressure and partial oxygen pressure changes. Racial and genetic factors may have more important role on the development of frontal sinus morphology. However the proportional comparison of frontal sinus measurements with cephalic index can help scientists for achieving more accurate results in their future studies.

CONCLUSION

In the present study, we found that widths, antero-posterior lengths and volumes of frontal sinus were higher in a population living in colder climate and higher altitude than a population living in milder climate and lower altitude. Heights of frontal sinus were on the contrary of this. These results were found appropriate to increasing of cephalic index in cold climate according to Allen's Rule. However, the presence of racial and genetic differences between two populations was an obstacle for properly interpretation of the results of this study.

We suggest that larger population studies should be made with peoples having the same or similar race and genetic structure in different climate and altitude regions and the proportional comparison of frontal sinus measurements with cephalic index should be considered in future studies.

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RESUMEN: Las características climáticas y de altitud de una región pueden afectar al cuerpo humano. En la literatura se han identificado muchos cambios en varios tejidos y órganos, como así también numerosos problemas de salud debido a los efectos climáticos y de altitud. Sin embargo, existe un número limitado de estudios que han evaluado la correlación entre el desarrollo del seno frontal y el efecto climático / altitud. En este estudio, los anchos, alturas, longitudes antero-posteriores y volúmenes de seno frontal se compararon mediante tomografía computarizada paranasal en poblaciones que viven en Van, que tiene un clima más frío y mayor altitud, y Manisa, que tiene un clima más suave y menor altitud. Se encontró que los anchos, las longitudes antero-posteriores y los volúmenes de los senos frontales eran mayores en poblaciones que vivían en un clima más frío y de mayor altitud respecto a poblaciones que vivían en clima más suave y con menor altitud. En relación a la altura de los senos frontales, se dio la situación contraria a lo anterior. Estos resultados se encontraron adecuados con el aumento del índice cefálico en la región de clima frío, de acuerdo con la Regla de Allen. Sugerimos que se realice un estudio poblacional más amplio con poblaciones de raza y estructura genética iguales o similares en diferentes regiones climáticas y de altitud. La comparación proporcional de las mediciones de los senos frontales con índice cefálico debería considerarse en futuros estudios.

PALABRAS CLAVE: Seno frontal; Escaner TC paranasal; Altitud; Clima; Regla de Allen.

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