Turkish Journal of Medical Sciences

Volume 42 | Number 6 Article 7

1-1-2012

Evaluation of the relationship between obstructive sleep apnea syndrome severity and cephalometric and clinical variables

SÜLEYMAN HAKAN TUNA

ÖNDER ÖZTÜRK

MUHAMMET HAKAN TÜRKKAHRAMAN

HÜSEYİN ALKIŞ

HÜSEYİN AVNİ BALCIOĞLU

See next page for additional authors

Evaluation of the relationship between obstructive sleep apnea syndrome severity and cephalometric and clinical variables

Authors
SÜLEYMAN HAKAN TUNA, ÖNDER ÖZTÜRK, MUHAMMET HAKAN TÜRKKAHRAMAN, HÜSEYİN ALKIŞ, HÜSEYİN AVNİ BALCIOĞLU, and AHMET AKKAYA

TÜBİTAK

Original Article

Turk J Med Sci
2012; 42 (6): 987-998
© TÜBİTAK
E-mail: medsci@tubitak.gov.tr
doi:10.3906/sag-1105-55

Evaluation of the relationship between obstructive sleep apnea syndrome severity and cephalometric and clinical variables

Süleyman Hakan TUNA[1], Önder ÖZTÜRK[2], Muhammet Hakan TÜRKKAHRAMAN[3], Hüseyin ALKIŞ[3], Hüseyin Avni BALCIOĞLU[4], Ahmet AKKAYA[2]

Aim: To evaluate the cephalometric features of patients with obstructive sleep apnea syndrome (OSAS) and to elucidate the relationship between the severity of OSAS and cephalometric and clinical variables.

Materials and methods: Ninety-three patients (71M/22W) with OSAS were classified into 3 subgroups according to the apnea-hypopnea index (AHI). Various cephalometric and clinical measurements were carried out for all patients.

Results: Inferior airway space (IAS), maximum soft palate thickness (MSPT), SNGoGn°, and distance of hyoid bone to mandibular plane (Hy-MPPerp) were found to be higher in severe OSAS for both sexes. Middle airway space, IAS, MSPT, and Hy-MPPerp were correlated positively with AHI; however, superior airway space (SAS) was correlated negatively. In the stepwise regression analysis, mean SaO2, neck circumferences for men, and mean SaO2 and uvula length (PNS-PA) for women were included in the model to estimate AHI properties.

Conclusion: The values of IAS, MSPT, SNGoGn°, and Hy-MPPerp showed a tendency to increase with the severity of OSAS. Although the cephalometric variables used to estimate OSAS severity had no effect in men, PNS-PA was found to have an influence in women. However, it is thought that it is difficult to use cephalometric variables to estimate AHI severity in both sexes.

Key words: Cephalometry, OSAS, AHI, polysomnography

Introduction

Obstructive sleep apnea syndrome (OSAS) is a common condition affecting at least 2% of adult women and 4% of adult men (1). It is characterized by loud snoring and periodic breathing with repetitive apneas, hypopneas, and arousals leading to fragmented sleep and excessive daytime sleepiness. Patients with OSAS have significantly impaired quality of life and social functioning and a high prevalence of minor psychiatric morbidity. There is some evidence that it is a progressive disorder and also an independent risk factor for cardiovascular morbidity and mortality (2-4). Although a higher mortality rate has been found in patients with severe OSAS than in those with mild-to-moderate OSAS, most of the patients (93% of women and 82% of men) with moderate-to-severe OSAS remain undiagnosed (5). As it is a serious condition and a progressive disease, the early diagnosis of OSAS is important (6). The gold standard diagnostic method for this syndrome is polysomnography (7), but it is a costly and labor-intensive technique that is uncomfortable for the patient and not available in all centers. Furthermore, protracted waiting lists for performing

Received: 02.06.2011 – Accepted: 06.03.2012

[1] Department of Prosthodontics, Faculty of Dentistry, Süleyman Demirel University, Isparta - TURKEY
[2] Sleep Disorders Center, Department of Chest Diseases, Faculty of Medicine, Süleyman Demirel University, Isparta - TURKEY
[3] Department of Orthodontics, Faculty of Dentistry, Süleyman Demirel University, Isparta - TURKEY
[4] Department of Anatomy, Faculty of Dentistry, İstanbul University, İstanbul - TURKEY
Correspondence: *Süleyman Hakan TUNA, Department of Prosthodontics, Faculty of Dentistry, Süleyman Demirel University, PK: 32100 Çünür, Isparta - TURKEY*
E-mail: shtuna@hotmail.com

this method result in diagnosis and treatment delays for patients with important symptoms of OSAS (8).

The importance of the morphology of the upper airway (soft palate, uvula, and tongue) and the craniofacial morphology in the pathogenesis of OSAS is widely acknowledged (8). Several methods exploiting advanced technologies have been used to evaluate the anatomic characteristics of the upper airway and the craniofacial structures that might predict OSAS and determine the sites of obstruction (9,10). However, the traditional cephalometric method has been the most practical (10). Lateral cephalometry is a readily available, inexpensive, and reliable technique for assessing the pharyngeal airways, whereby details of skeletal and soft tissue structures can be accurately measured and compared with extensive normative data (11). In addition to identifying cranio-facial anomalies, cephalometric measurements can also be used to quantify treatment options, such as surgery, appliances, or continuous positive airway pressure for OSAS (12,13).

The aims of this study were to evaluate the cephalometric features of patients with OSAS and to elucidate the relationship between severity of OSAS and cephalometric and clinical variables.

Materials and methods

Patients and polysomnography

Ninety-three Caucasian adults (71 men and 22 women) who had been referred to the sleep clinic because of suspected OSAS were recruited. All patients were examined by 1 of 2 pulmonologists experienced in sleep medicine. The patients were recruited on the basis of the following inclusion criteria: dentate in both jaws, between 35 and 65 years of age, AHI > 5 events per hour, and no apparent craniofacial deformities. The patients were excluded if there was any previous history of pharyngeal surgery, orthognathic surgery, or poor general dental health. All patients gave informed consent before participating in the study.

On the evening of the sleep study, a comprehensive physical examination that included anthropometric measurements such as height and weight for the calculation of body mass index (BMI), neck circumference [(NC) at the level of the cricothyroid membrane], and waist circumference [(WC) at the level of the umbilicus] was performed. The patients filled out a self-administered questionnaire that included questions about the symptoms normally associated with OSAS (snoring, presence of apneas, sleep quality, and daytime somnolence). In addition, the Epworth sleepiness scale (ESS), previously translated into Turkish and validated, was administered (14). The sleep functions of patients were evaluated using overnight polysomnography (Compumedics, 44 channels E series, Australia). Oronasal flow was measured using a nasal cannula, and thoracic and abdominal movements were detected using 2 piezoelectric belts. A pulse oximeter continuously recorded digital oximetry. A desaturation event (dip) was considered when oxygen saturation (SaO_2) diminished by 3% or greater in relation to the baseline. The sleep studies were staged according to the Rechtschaffen and Kales (15) criteria by 2 trained sleep clinicians who were blind to the clinical characteristics of each patient.

Apnea was defined as the cessation of airflow for 10 s or longer. Hypopnea was defined as an airflow reduction of at least 50% over preceding epochs or an amplitude reduction of at least 50% of the thoracoabdominal belts (also compared to prior epochs), together with the presence of either arterial oxygen desaturation equal to or greater than 3% or an arousal. The patients with an AHI of 5 or higher were considered to have OSAS. They were divided into 3 groups according to the AHI values (16): Group I (mild OSAS) with AHI 5-15/h included 24 patients (18 men, 6 women); Group II (moderate OSAS) with AHI 15-30/h included 35 patients (26 men, 9 women); and Group III (severe OSAS) with AHI > 30/h included 34 patients (27 men, 7 women) (Table 1).

Cephalometric analysis

A standard cephalometric radiograph was obtained for each subject with the teeth in centric occlusion and the Frankfort horizontal plane parallel to the floor at the end of the expiration phase and without swallowing. Each radiograph was scanned into digital format at 300 dpi resolution, stored in TIFF format, and transferred to Dolphin imaging software (Dolphin, Chatsworth, CA, USA) for digitization of landmarks. Each image was digitally traced twice

Table 1. The demographic characteristics, polysomnographic and cephalometric data of all patients. Values are expressed as mean ± SD.

Demographic features	**Men** (n = 71)			**Women** (n = 22)		
	OSAS mean ± SE					
	Mild (n = 18)	**Moderate** (n = 26)	**Severe** (n = 27)	**Mild** (n = 6)	**Moderate** (n = 9)	**Severe** (n = 7)
Age	47.22 ± 2.66	49.85 ± 1.49	48.56 ± 2.01	48.83 ± 3.11	51.78 ± 1.05	47.71 ± 3.29
Height	172.28 ± 1.21	170.42 ± 0.79	168.11 ± 1.66	158.67 ± 2.67	158.67 ± 1.17	161.14 ± 0.94
Weight	80.89 ± 2.67	85.69 ± 2.45	97.44 ± 3.52	76.17 ± 6.25	88.78 ± 3.52	83.71 ± 6.30
BMI	27.27 ± 0.89	29.46 ± 0.72	34.65 ± 1.36	30.07 ± 2.55	35.33 ± 1.53	32.11 ± 2.18
NC	39.39 ± 0.59	39.73 ± 0.42	42.07 ± 0.60	35.17 ± 1.11	35.33 ± 0.73	35.86 ± 1.26
WC	96.11 ± 2.83	97.58 ± 3.09	108.85 ± 2.51	96.67 ± 8.43	107.78 ± 64.9	104.86 ± 4.03
Polysomnographic data						
AHI	7.87 ± 0.63	21.33 ± 0.79	63.04 ± 4.57	7.62 ± 0.95	19.70 ± 1.70	62.59 ± 8.07
Arousal index	13.11 ± 1.90	20.05 ± 2.79	32.01 ± 3.47	16.30 ± 3.86	10.33 ± 1.85	16.30 ± 4.59
Awake mean SaO_2	94.39 ± 0.43	93.69 ± 0.33	92.93 ± 0.34	94.50 ± 0.67	93.89 ± 0.39	94.57 ± 0.48
Lowest SaO_2	85.89 ± 0.75	79.65 ± 1.32	73.52 ± 1.89	84.67 ± 1.26	79.00 ± 1.92	69.57 ± 4.04
Mean SaO_2 Des.%	4.00 ± 0.19	5.15 ± 0.35	8.37 ± 0.74	4.33 ± 0.21	4.78 ± 0.43	9.86 ± 2.32
ESS	3.78 ± 0.71	6.35 ± 0.92	8.04 ± 0.91	2.17 ± 1.08	3.44 ± 0.73	6.00 ± 2.00
Cephalometric data						
IAS	10.54 ± 0.77	12.22 ± 0.73	13.82 ± 0.65	11.00 ± 1.21	12.10 ± 1.07	13.93 ± 1.61
SAS	19.54 ± 0.66	20.52 ± 0.69	17.53 ± 0.90	19.57 ± 0.86	18.73 ± 0.65	17.01 ± 0.85
MAS	7.43 ± 0.59	7.86 ± 0.47	9.28 ± 0.57	7.13 ± 0.83	8.16 ± 0.80	8.06 ± 1.17
MSPT	12.06 ± 0.53	12.82 ± 0.29	13.73 ± 0.52	10.42 ± 0.45	11.04 ± 0.47	11.41 ± 0.74
SNGoGn°	31.18 ± 1.56	31.03 ± 1.26	32.47 ± 1.16	28.72 ± 3.67	29.39 ± 1.54	35.39 ± 3.03
Go-Gn	88.21 ± 1.73	93.35 ± 1.04	90.42 ± 0.95	88.15 ± 1.67	86.28 ± 2.09	84.03 ± 2.41
ANB°	3.73 ± 0.52	3.77 ± 0.61	3.20 ± 0.40	4.33 ± 1.34	2.21 ± 0.65	4.13 ± 0.78
Ant. FH	137.01 ± 1.67	139.24 ± 1.56	142.36 ± 1.37	129.10 ± 2.19	127.20 ± 1.76	128.87 ± 2.91
Post. FH	68.94 ± 1.36	73.96 ± 2.56	72.56 ± 2.37	67.65 ± 3.26	69.13 ± 2.53	68.66 ± 3.59
Hy-MPPerp	22.99 ± 1.21	20.32 ± 1.31	24.37 ± 1.23	19.12 ± 1.40	16.73 ± 1.73	20.81 ± 2.72
PNS-PA	43.37 ± 1.16	44.51 ± 1.01	43.41 ± 1.17	41.47 ± 1.42	39.70 ± 1.83	36.74 ± 1.41
ANS-Me	76.52 ± 1.80	78.52 ± 1.25	78.64 ± 1.16	70.18 ± 1.27	71.19 ± 1.32	70.61 ± 1.50

by the same investigator (H.A.). In each lateral cephalogram, 14 landmark points were identified (Figure 1). Upper airway space was measured at 3 different levels (15); the angles and linear measurements are given in Figure 2.

Statistical analysis

All statistical analyses were performed using SPSS (version 16.0, SPSS, Chicago, IL, USA). The results of the study were evaluated using factorial design ANOVA. The sex factor consisted of 2 levels and

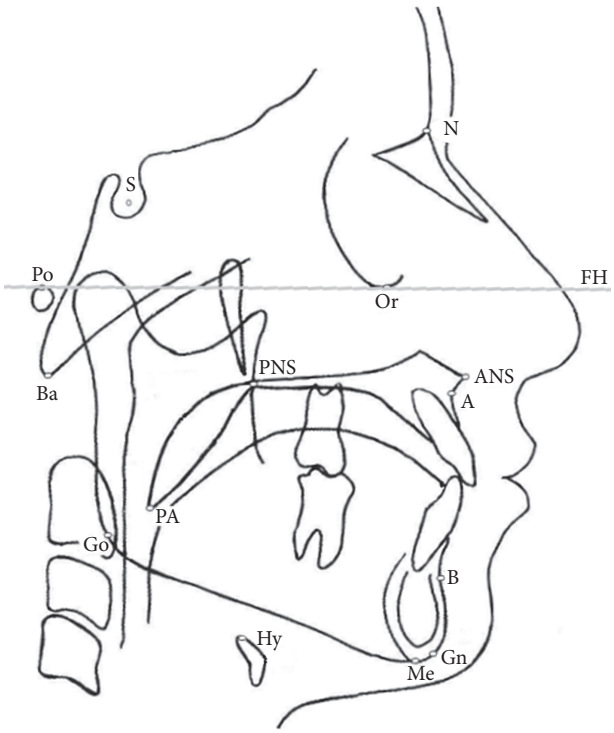

Figure 1. Landmarks on lateral cephalograms: S: sella; N: nasion; Or: orbitale; ANS: anterior nasal spine; PNS: posterior nasal spine; A: point A; B: point B; G: gnathion; Me: menton; Go: gonion; Hy: hyoid bone; PA: tip of uvula; Po: porion; Ba: basion.

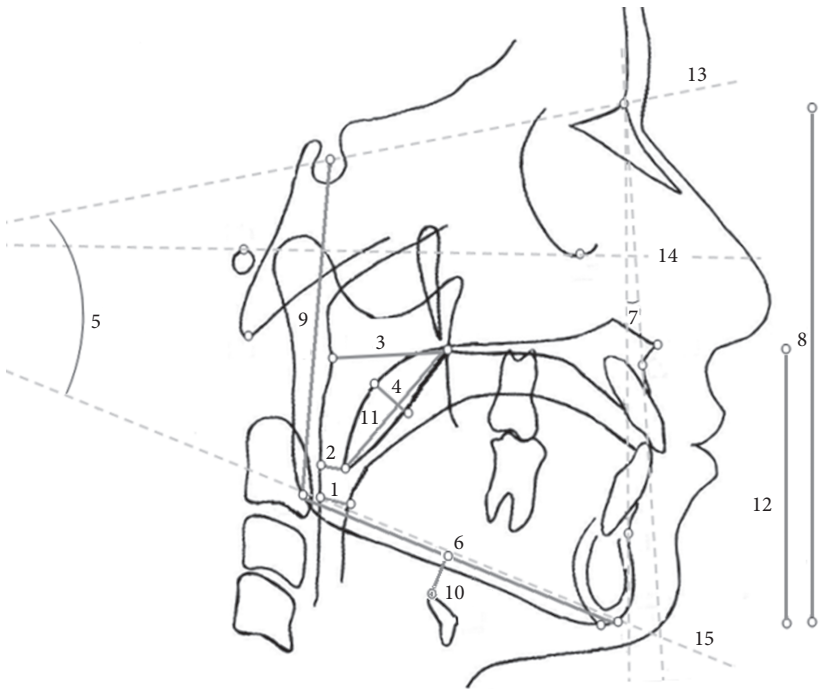

Figure 2. Linear and angle measurements on lateral cephalograms: 1: inferior airway space (IAS); 2: middle airway space (MAS); 3: superior airway space (SAS); 4: maximum soft palate thickness (MSPT); 5: SNGoGn°; 6: mandibular body length (Go-Gn); 7: ANB°; 8: anterior face height (Ant. FH); 9: posterior face height (Post. FH) 10: distance of hyoid bone to mandibular plane (Hy-MPPerp); 11: uvula length (PNS-PA); 12: lower face height (ANS-Me); 13: sella-nasion plane (SN); 14: Frankfort horizontal plane (FH); 15: mandibular plane (MP).

the diagnostic factor had 3 levels (mild, moderate, and severe). Tukey's test was used to evaluate the differences between groups. Kruskal-Wallis and Mann-Whitney U tests were used to evaluate the parameters [arousal index, oxygen saturation (mean and minimum), height, MSPT, Post. FH, ESS], which did not provide the precondition of parametric tests. The Bonferroni-Dunn method was used, finding statistically significant differences for Kruskal-Wallis. The correlation coefficient was used to examine positive relations between the study parameters. The correlation coefficients were measured and interpreted for each sex and diagnosis. Stepwise regression analysis was done using AHI as a dependent variable. The diagnoses done using AHI were studied using discriminant analysis with other parameters.

Results

The demographic features and polysomnographic and cephalometric data of patients with OSAS are given in Table 1.

The sex/diagnosis interaction and the differences between sex factor means and diagnostic factor means were not statistically significant for the awake mean SaO_2%, waist circumference, neck circumference, MAS, Go-Gn, Ant. FH, Hy-MPPerp, PNS-PA, ANS-Me, SNGoGn°, or ANB°. The differences between the mean of neck circumference, Go-Gn, ANS-Me, Ant. FH ($P < 0.01$), Hy-MPPerp ($P < 0.05$), and PNS-PA ($P < 0.001$) of men and women were statistically significant. The sex/diagnosis interaction and the differences between the level of sex factor means were not statistically significant for weight, IAS, or SAS. However, the differences between the diagnostic factor means were significant ($P < 0.05$) (Table 2). The sex/diagnosis interaction for BMI was found to be statistically significant ($P < 0.05$). The differences between the mean of BMI varied due to the severity of OSAS. Tukey's test was performed, and the results are shown in Table 2.

The mean level of arousal index varied due to the severity of OSAS, and the difference was significant (Kruskal-Wallis, $P < 0.001$). The difference between the rank means of diagnosis was statistically significant for arousal index of men for the Kruskal-Wallis test when we compared the means of diagnostic factor ($P < 0.001$). The differences between the severity of OSAS after the Bonferroni-Dunn test are shown in Table 3. For the arousal index for women, the difference between the rank means of diagnosis was not statistically significant.

The rank means of men and women were evaluated for arousal index for mild OSAS. It was not statistically significant for mild OSAS, but was significant for moderate and severe OSAS (Mann-Whitney U, $P < 0.05$).

The rank means of diagnosis were statistically significant in the comparison of diagnostic level means using Kruskal-Wallis for the lowest SaO_2 of men and women ($P < 0.05$ and $P < 0.01$, respectively). However, there was no statistically significant difference between men and women for mild, moderate, or severe OSAS.

The difference in the diagnostic rank means was statistically significant in the comparison of diagnostic level means using Kruskal-Wallis for the mean SaO_2 desaturation of men and women ($P < 0.001$ and $P < 0.05$, respectively). The differences between the severity of OSAS after Bonferroni-Dunn are shown in Table 3. However, there was no statistically significant difference between men and women for mild, moderate, or severe OSAS.

The difference in the diagnostic rank means was statistically significant in the comparison of diagnostic level means using Kruskal-Wallis for the height of men ($P < 0.05$). The differences between the severity of OSAS after the Bonferroni-Dunn test are shown in Table 3. The difference between the rank means of men and women for height was statistically significant for mild, moderate, and severe OSAS (Mann-Whitney U, $P < 0.001$, $P < 0.001$ and $P < 0.05$, respectively). However, the difference between the rank means of diagnosis was not significant in the comparison of diagnostic level means using Kruskal-Wallis for the height of women.

The difference of the diagnostic rank means was not significant in the comparison of diagnostic level means using Kruskal-Wallis for the MSPT of men and women. For mild OSAS, the difference between the rank means of men and women was not significant (Mann-Whitney U, $P > 0.05$), but, for moderate

Table 2. Sex × diagnosis interaction table showing the differences that were statistically significant.

´Parameters	Sex	OSAS (mean ± SE)			Total
		Mild	Moderate	Severe	
BMI	Men	27.27bA ± 1.25	29.46bB ± 1.04	34.65aA ± 1.02	30.46 ± 0.64
	Women	30.07aA ± 2.16	35.33aA ± 1.76	32.11aA ± 2.00	32.51 ± 1.14
	Total	28.67 ± 1.25	32.40 ± 1.02	33.38 ± 1.12	
Weight	Men	80.89 ± 3.44	85.70 ± 2.86	97.44 ± 2.81	88.01 ± 1.76
	Women	76.17 ± 5.96	88.78 ± 4.86	83.71 ± 5.51	82.89 ± 3.15
	Total	78.53b ± 3.44	87.24ab ± 2.82	90.58a ± 3.09	
NC	Men	39.39 ± 0.63	39.731 ± 0.524	42.074 ± 0.514	40.39A ± 0.322
	Women	35.17 ± 0.09	35.33 ± 0.89	35.86 ± 1.01	35.45B ± 0.58
	Total	37.28 ± 0.63	37.53 ± 0.51	38.97 ± 0.57	
IAS	Men	10.54 ± 0.82	12.22 ± 0.68	13.82 ± 0.67	12.19 ± 0.42
	Women	11.00 ± 1.42	12.10 ± 1.16	13.93 ± 1.32	12.34 ± 0.75
	Total	10.77b ± 0.82	12.16ab ± 0.67	13.87a ± 0.74	
SAS	Men	19.54 ± 0.84	20.52 ± 0.70	17.53 ± 0.53	19.19 ± 0.43
	Women	19.57 ± 1.45	18.73 ± 1.18	17.01 ± 1.34	18.44 ± 0.77
	Total	19.55ab ± 0.84	19.62a ± 0.69	17.27b ± 0.75	
Go-Gn	Men	88.21 ± 1.36	93.35 ± 1.13	90.42 ± 1.11	90.66 ± 0.70
	Women	88.15 ± 2.36	86.28 ± 1.92	84.03 ± 2.20	86.15 ± 1.25
	Total	88.18 ± 1.36	89.82 ± 1.12	87.22 ± 1.22	
Ant. FH	Men	137.01 ± 1.70	139.24 ± 1.41	142.36 ± 1.38	139.54A ± 0.88
	Women	128.10 ± 2.93	127.20 ± 2.40	128.87 ± 2.71	128.06B ± 1.55
	Total	132.56 ± 1.70	133.22 ± 1.39	135.62 ± 1.52	
Hy-MPPerp	Men	22.99 ± 1.44	20.32 ± 1.20	24.37 ± 1.20	22.56A ± 0.74
	Women	19.12 ± 2.72	16.73 ± 2.03	20.81 ± 2.30	18.89B ± 1.37
	Total	21.05 ± 1.54	18.53 ± 1.18	22.59 ± 1.29	
PNS-PA	Men	43.37 ± 1.24	44.51 ± 1.03	43.41 ± 1.02	43.76A ± 0.64
	Women	41.47 ± 2.15	39.70 ± 1.76	36.74 ± 1.99	39.30B ± 1.14
	Total	42.42 ± 1.24	42.11 ± 1.02	40.08 ± 1.12	
ANS-Me	Men	76.52 ± 1.44	78.52 ± 1.20	78.64 ± 1.17	77.89A ± 0.73
	Women	70.18 ± 2.48	71.19 ± 2.03	70.61 ± 2.30	70.66B ± 1.32
	Total	70.35 ± 1.43	74.85 ± 1.18	74.63 ± 1.30	

* Small letters indicate the differences between diagnoses. Capital letters indicate the differences between the sexes.

Table 3. The result of nonparametric test after Bonferroni-Dunn.

Variables				OSAS			Rank mean
				Mild	Moderate	Severe	
Arousal index	Men	OSAS	Mild	1.00000	*	*	22.7
			Moderate	0.09384	1.00000	*	33.3
			Severe	0.00008	0.01198	1	47.5
	Women		Mild	1.00000	0.28387	*	13.3
			Moderate	*	1.00000	*	9.7
			Severe	0.77177	0.42339	1	12.3
Lowest SaO_2 %	Men	OSAS	Mild	1.00000	*	*	55.5
			Moderate	0.00225	1.00000	*	36.2
			Severe	0.00000	0.01861	1	22.9
	Women		Mild	1.00000	0.06496	*	17.9
			Moderate	*	1.00000	*	11.6
			Severe	0.00083	0.07819	1	5.9
Mean Sa O_2 Des.%	Men	OSAS	Mild	1.00000	*	*	19.3
			Moderate	0.03486	1.00000	*	32.3
			Severe	0.00000	0.00087	1	50.7
	Women		Mild	0.66656	1.00000	*	8.2
			Moderate	0.00000	*	*	9.6
			Severe	0.01784	0.01065	1	16.9
Height	Men	OSAS	Mild	1.00000	*	*	43.9
			Moderate	0.36440	1.00000	*	38.2
			Severe	0.01383	0.08654	1	28.6
	Women		Mild	0.55480	1.00000	*	11.7
			Moderate	1.00000	*	*	9.7
			Severe	0.21130	0.56678	1	13.7
MSPT	Men	OSAS	Mild	1.00000	*	*	28.7
			Moderate	0.25702	1.00000	*	35.9
			Severe	0.05000	0.36511	1	41
	Women		Mild	0.53118	1.00000	*	9.6
			Moderate	1.00000	*	*	11.7
			Severe	0.72822	0.36388	1	12.9
Post. FH	Men	OSAS	Mild	1.00000	*	*	35.1
			Moderate	0.76997	1.00000	*	37.0
			Severe	0.92951	0.81938	1	35.7
	Women		Mild	0.70881	1.00000	*	10.7
			Moderate	1.00000	*	*	11.9
			Severe	0.92655	0.78694	1	11.6

and severe OSAS, the differences were found to be significant (Mann-Whitney U, $P < 0.01$ and $P < 0.05$, respectively).

The difference in the diagnostic rank means was not significant in the comparison of diagnostic level means using Kruskal-Wallis for the Post. FH of men and women. Furthermore, no statistically significant difference was shown between the rank means of men and women for Post. FH for mild, moderate, or severe OSAS.

The correlations between polysomnographic and demographic data with cephalometric measurements of sex factors are shown in Table 4.

In the stepwise discriminant analysis, the lowest SaO_2% and mean SaO_2 desaturation% parameters were included in Fisher's linear discriminant function. The results obtained from the discriminant analysis are shown in Table 5a. The total result for this discrimination was 60.2%. If the diagnosis was made using parameters other than AHI, the estimated success of discrimination was 60.2%. The estimated successes were distributed as follows: mild group with 83.3%, moderate group with 54.3%, and severe group with 50% (Table 5b).

In the regression analysis, 2 parameters were included in the model to estimate AHI: lowest SaO_2% and arousal index. All parameters used to estimate R square were found to be 72% ($P < 0.01$), but it was not statistically significant in predicting the severity of OSAS.

For the stepwise regression analysis, the mean SaO_2 desaturation, arousal index, BMI, and MAS were included in the model. The regression equation was found to be AHI = 44.904 +4.171/mean SaO_2 desaturation +0.524/arousal index + 0.978 BMI + 1.331 MAS. The R square found by the regression equation was 67% and was statistically significant ($P < 0.01$). The included variables varied according to sex: mean SaO_2 and neck circumference (R square 61%, $P < 0.001$) in men and mean SaO_2 and PNS-PA (R square 67%, $P < 0.05$) in women.

Discussion

Cephalometric analysis is a valuable tool for the diagnosis of OSAS and should be considered among routine examinations (17). However, ethnicity and sex should be considered in the evaluation of cephalometry.

It was reported that the collapse mechanism of UA in men and women is different and related to local anatomical differences (18). There are obvious sex differences in the craniofacial skeletal characteristics that contribute to OSAS severity and, to evaluate OSAS severity, different anthropometric and cephalometric measurements should be used for men and women (10). In our study, we found statistically significant differences in some cephalometric measurements [Go-Gn, ANS-Me, Ant. FH ($P < 0.01$), Hy-MPPerp ($P < 0.05$), PNS-PA ($P < 0.001$)] between men and women. However, these measurements were not valuable in predicting OSAS severity without the sex factor, but it was found that PNS-PA had an effect on women in the stepwise regression analysis (R square 67%, $P < 0.05$).

Tsai et al. (10) stated that BMI increased with the severity of OSAS in both sexes. In our study, the difference in BMI between men and women varied according to the severity of OSAS, but the changes in the BMI of women were different from those of men. The level of BMI in women did not increase with the severity of OSAS. Obesity has been thought to be a primary cause of OSAS, but not all obese patients have OSAS. Pae et al. (19,20) stated that face type in some non-obese patients had a significant role in the diagnosis of OSAS. Although the BMI of women did not increase according to the severity of OSAS, there were differences in the face types of women in our study. Face divergence increased with the severity of OSAS. However, anterior face height measurements correlated with the severity of OSAS in men. In addition, a greater lower facial height was also related to an overall increase in OSAS severity in men.

The measurements of neck circumference were significantly different between men and women. They increased with the increase in AHI in both sexes. However, we found no differences for waist circumferences in either sex or for the severity of OSAS. Ryan et al. (21) showed that obese patients with large necks tend to have a more easily collapsible velopharynx during wakefulness. Obesity, through fat deposits around the upper airway in the neck, might narrow the pharynx and alter its shape and

Table 4. The correlations between polsomnographic and demographic data with cephalometric measurements due to sex factors. (*P < 0.005. **P < 0.001)

Sex factors	Parameters	Cephalometric measurements											
		IAS	SAS	MAS	MSPT	SNGoGn°	Go-Gn	ANB°	Ant. FH	Post. FH	Hy-MPPerp	PNS-PA	ANS-Me
Men	AHI	0.410**	–0.249*	0.302*	0.337**	0.163	0.052	–0.092	0.393**	0.066	0.302*	0.037	0.231
	Arousal index	0.279*	–0.113	0.161	0.286*	0.296*	–0.007	0.112	0.333**	–0.009	0.090	–0.046	0.125
	Awake SaO_2%	–0.138	–0.046	–0.140	–0.149	–0.090	–0.225	0.089	–0.235*	0.097	–0.087	–0.225	–0.150
	Lowest SaO_2	–0.282*	0.099	–0.121	–0.225	–0.264*	–0.085	–0.041	–0.339**	0.034	–0.288*	–0.012	–0.262*
	MeanSaO_2 Des.	0.310**	–0.235*	0.154	0.304**	0.327**	0.001	–0.034	0.378**	0.049	0.351**	0.076	0.249*
	BMI	0.246*	–0.253*	0.193	0.223	0.098	0.129	–0.147	0.303*	0.086	0.105	–0.038	0.210
	NC	0.322**	–0.184	0.313**	0.289*	–0.054	0.103	–0.082	0.301*	0.022	0.129	–0.002	0.262*
	WC	0.187	–0.110	0.167	0.178	0.119	0.057	–0.083	0.285*	–0.066	0.218	–0.010	0.195
	ESS	0.410**	0.059	0.222	0.223	–0.053	0.217	0.58	0.043	0.140	0.299*	0.129	0.008
Women	AHI	0.327	–0.353	0.252	0.192	0.316	–0.245	0.018	–0.073	0.030	0.359	–0.385	–0.202
	Arousal index	–0.342	0.205	0.181	–0.145	0.084	–0.125	–0.120	–0.329	0.262	0.083	–0.251	–0.558**
	Awake SaO_2%	–0.345	–0.158	0.030	0.157	0.210	0.099	–0.152	0.136	0.073	–0.030	–0.141	–0.183
	Lowest SaO_2	–0.397	0.269	–0.198	–0.082	–0.066	0.430*	0.084	0.183	–0.127	–0.410	0.165	0.072
	MeanSaO_2 Des.	0.287	–0.250	0.168	0.005	0.025	–0.429*	–0.115	–0.298	0.221	0.528*	–0.115	–0.298
	BMI	0.255	–0.187	0.059	0.269	–0.166	–0.043	0.031	–0.054	0.008	0.269	0.025	0.103
	NC	0.004	–0.328	–0.110	0.344	–0.014	–0.067	0.323	0.161	0.083	0.419	–0.043	0.115
	WC	0.392	–0.185	0.211	0.181	0.296	0.178	–0.035	–0.152	0.127	0.259	–0.061	–0.080
	ESS	0.350	–0.482*	0.312	0.039	–0.354	–0.172	–0.224	–0.379	0.381	0.463	–0.167	–0.118

Table 5a. The result of discriminant analysis.

	OSAS severity		
	Mild	**Moderate**	**Severe**
Lowest SaO_2 %	3.964	3.787	3.802
Mean SaO_2 Des. %"	8.313	8.084	8.557
(Constant)	–187.667	–172.061	–176.448

Fisher's linear discriminant functions

Table 5b. The distribution of estimated success according to the severity of OSAS.

	Diagnosis	Predicted group membership			Total
		Mild OSAS	Moderate OSAS	Severe OSAS	
n	**Mild OSAS**	20	4	0	24
	Moderate OSAS	11	19	5	35
	Severe OSAS	5	12	17	34
%	**Mild OSAS**	**83.3**	16.7	0.0	100.0
	Moderate OSAS	31.4	**54.3**	14.3	100.0
	Severe OSAS	14.7	35.3	**50.0**	100.0

60.2% of original grouped cases correctly classified.

mechanical properties, predisposing patients to sleep-related obstruction (21). Although neck and waist circumferences correlated with BMI in our study, upper airway space (IAS, MAS) measurements increased and correlated positively with neck circumferences. Maximum soft palate thickness increased in our patients with the increase in neck circumference and correlated with the severity of OSAS.

In our study, the mean levels of IAS and SAS were not statistically different for sex, but in the variance analysis these measurements were statistically significant for the severity of OSAS. SAS measurements correlated negatively with AHI, BMI, MSPT, and Post. FH. We assume that the decrease in SAS measurements is associated with the increase in soft palate thickness and pharyngeal wall fat deposits. The most important finding obtained with cephalometry in apnea patients is the reduction in the velopharyngeal space (22). We found that SAS measurements increased in patients with long uvulas. This may be associated with conducting the cephalometric radiology in an upright position. Furthermore, we found no relationship between uvula length and severity of OSAS in our study.

The position of the hyoid bone becomes more inferior as the condition becomes more severe (8), as found in our study. The hyoid bone was located inferior in men with smaller mandibular body length, but this was not seen in women. The hyoid bone's inferior location in women was more closely associated with BMI in women than in men (mean BMI: 32.87 >

30), but it was not related to the mandibular body length. Tangugsorn et al. (23) found a significantly lower position of the hyoid bone in obese patients. The cause of an inferiorly located hyoid bone may be diffuse fat deposits due to obesity or small mandibular body length. Contrary to the findings of Pae et al. (20), there was no relationship between the face type and the hyoid position in our study. However, anterior face height was associated with the severity of OSAS in obese and non-obese patients.

We found correlations (positive and negative) between AHI and some cephalometric measurements. It is interesting that most of these correlations were found in men. These measurements increased with the severity of OSAS. These findings were also supported by the other parameters of the polysomnographic data. We documented the fact that mandibular body length was important in predicting the severity of OSAS. Although it was not significant, a gradual decrease in mandibular body length was seen with increased severity of OSAS. The lowest oxygen saturation measured during the polysomnography correlated positively with mandibular body length. Mean oxygen desaturation correlated positively with hyoid bone position, which increased with the severity of OSAS in women. We found no correlation between demographic parameters and cephalometric parameters in women. OSAS is more common in men than in women, despite the fact that women with OSAS tend to be more obese and have smaller upper airways than men (24). We also noted this sex difference in our study, and men had significantly higher AHI than women, although the BMI value was greater in women. However, BMI played a significant role and correlated with cephalometric measurements in men.

The ESS is a self-administered questionnaire measuring the subject's general level of daytime sleepiness (25). Although ESS is a subjective test, it was found to correlate with AHI. However, there was no correlation with BMI and cephalometric measurements except for Hy-MPPerp in both sexes.

In the discriminant analysis, 2 polysomnographic data points were effective in estimating the diagnosis with 60.2% accuracy. In the regression analysis, we needed all parameters to estimate the diagnosis with 72% accuracy. When we used stepwise regression, we had 4 parameters to estimate the diagnosis with 67% accuracy. The only cephalometric measurement in this model was MAS, and we found that MAS increased due to the severity of OSAS in our study. The upper airway was found to be narrow in patients with severe OSAS. The upper airway shows anatomic differences during awake and sleep periods, and an occlusion occurs at different levels along the upper airway in patients with OSAS (26). The obstruction begins with fat deposits on the lateral pharyngeal wall, where it cannot be seen in cephalometric graphs. The purpose of this study was not to define the level of obstruction but to examine the changes related to the OSAS.

The limitations of our study included the fact that we performed the cephalometric examinations on patients in an awake state and an upright position. However, upper airway resistance increases during sleeping in normal subjects and patients with OSAS (27). The cephalometric graphs were taken at the end of expiration. Schwab et al. (27) demonstrated that airway caliber is the smallest at the end of expiration in normal and OSAS subjects. Previous studies have also revealed that the upper airway is smaller during certain phases of the respiratory cycle, and the difference is more significant during sleep (28). The group of women was small in our study. We assumed that this may be the reason for the failure to show a correlation between cephalometric and polysomnographic parameters. We need further studies with larger groups with different ethnic backgrounds, sexes, and ages to examine the cephalometric graphs.

In conclusion, this study evaluated the cephalometric measurements with polysomnographic and demographic parameters to predict the severity of OSAS. The changes in oxygen saturation correlated with AHI may be used to evaluate the cephalometric measurements. The cephalometric measurements are not sufficient to predict the severity of OSAS. However, the cephalometric measurements with BMI may give a useful indication of the severity of OSAS.

Acknowledgment

The authors would like to thank Dr Özgür Koşkan for his valuable help with the statistical evaluation.

References

1. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep- disordered breathing among middle-aged adults. N Engl J Med 1993; 328: 1230-35.
2. Peker Y, Hedner J, Norum J, Kraiczi H, Carlson J. Increased incidence of cardiovascular disease in middle-aged men with obstructive sleep apnea: a 7-year follow-up. Am J Respir Crit Care Med 2002; 166: 159-65.
3. Kanbay A, Çiftçi TU, Köktürk O. Could obstructive sleep apnea syndrome be a component of metabolic syndrome? Turk J Med Sci 2009; 39: 161-6.
4. Şahin M, İnal Berçik B, Öğreden Ş, Yiğit Ö, Aral H, Güvenen G. Metabolic profile and insulin resistance in patients with obstructive sleep apnea syndrome. Turk J Med Sci 2011; 41: 443-54.
5. He J, Kryger MH, Zorick FJ, Conway W, Roth T. Mortality and apnea index in obstructive sleep apnea. Experience in 385 male patients. Chest 1988; 94: 9-14.
6. Svanborg E, Larsson H. Development of nocturnal respiratory disturbance in untreated patients with obstructive sleep apnea syndrome. Chest 1993; 104: 340-3.
7. American Thoracic Society. Medical Section of the American Lung Association. Indications and standards for cardiopulmonary sleep studies. Am Rev Respir Dis 1989; 139: 559-68.
8. Julià-Serdà G, Pérez-Peñate G, Saavedra-Santana P, Ponce-González M, Valencia-Gallardo JM, Rodríguez-Delgado R et al. Usefulness of cephalometry in sparing polysomnography of patients with suspected obstructive sleep apnea. Sleep Breath 2006; 10: 181-7.
9. Schwab RJ, Gupta KB, Gefter WB, Metzger LJ, Hoffman EA, Pack AI. Upper airway and soft tissue anatomy in normal subjects and patients with sleep-disordered breathing. Significance of the lateral pharyngeal walls. Am J Respir Crit Care Med 1995; 152: 1673-89.
10. Tsai HH, Ho CY, Lee PL, Tan CT. Sex differences in anthropometric and cephalometric characteristics in the severity of obstructive sleep apnea syndrome. Am J Orthod Dentofacial Orthop. 2009; 135: 155-64.
11. Smith AM, Battagel JM. Non-apneic snoring and the orthodontist: radiographic pharyngeal dimension changes with supine posture and mandibular protrusion. J Orthod 2004; 31: 124-31.
12. Godt A, Koos B, Hagen H, Göz G. Changes in upper airway width associated with Class II treatments (headgear vs activator) and different growth patterns. Angle Orthod 2011; 81: 440-6.
13. Ronchi P, Novelli G, Colombo L, Valsecchi S, Oldani A, Zucconi M et al. Effectiveness of maxillo-mandibular advancement in obstructive sleep apnea patients with and without skeletal anomalies. Int J Oral Maxillofac Surg 2010; 39: 541-7.
14. MY Ağargün, AS Çilli, H Kara, M Bilici, M Telcioğlu, ÜB Semiz et al. Epwort uykululuk ölçeği'nin geçerliği ve güvenirliği. Türk Psikiyatri Dergisi 1999; 10: 261-7.
15. Rechtschaffen A, Kales A. A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. In: Rechtschaffen A, Kales A, eds. National Institute of Health Publication, Washington DC: US Government Printing Office; p.1-12, 1968.
16. The Report of an American Academy of Sleep Medicine Task Force. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. Sleep 1999; 22: 667-89.
17. Salles C, Campos PS, de Andrade NA, Daltro C. [Obstructive sleep apnea and hypopnea syndrome: cephalometric analysis]. Braz J Otorhinolaryngol 2005; 71: 369-72.
18. Mohsenin V. Gender differences in the expression of sleep-disordered breathing: role of upper airway dimensions. Chest 2001; 120: 1442-7.
19. Pae EK, Ferguson KA. Cephalometric characteristics of nonobese patients with severe OSA. Angle Orthod 1999; 69: 408-12.
20. Pae EK, Quas C, Quas J, Garrett N. Can facial type be used to predict changes in hyoid bone position with age? A perspective based on longitudinal data. Am J Orthod Dentofacial Orthop 2008; 134: 792-7.
21. Ryan CF, Love LL. Mechanical properties of the velopharynx in obese patients with obstructive sleep apnea. Am J Respir Crit Care Med 1996; 154: 806-12.
22. Finkelstein Y, Wexler D, Horowitz E, Berger G, Nachmani A, Shapiro-Feinberg M et all. Frontal and lateral cephalometry in patients with sleep-disordered breathing. Laryngoscope 2001; 111: 634-41.
23. Tangugsorn V, Krogstad O, Espeland L, Lyberg T. Obstructive sleep apnoea: multiple comparisons of cephalometric variables of obese and non-obese patients. J Craniomaxillofac Surg 2000; 28: 204-12.
24. Welch KC, Foster GD, Ritter CT, Wadden TA, Arens R, Maislin G et al. A novel volumetric magnetic resonance imaging paradigm to study upper airway anatomy. Sleep 2002; 25: 532-42.
25. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 1991; 14: 540-5.
26. Yagi H, Nakata S, Tsuge H, Yasuma F, Noda A, Morinaga M et al. Morphological examination of upper airway in obstructive sleep apnea. Auris Nasus Larynx 2009; 36: 444-9.
27. Schwab RJ, Gefter WB, Hoffman EA, Gupta KB, Pack AI. Dynamic upper airway imaging during awake respiration in normal subjects and patients with sleep disordered breathing. Am Rev Respir Dis 1993; 148: 1385-400.
28. Ciscar MA, Juan G, Martínez V, Ramón M, Lloret T, Mínguez J et al. Magnetic resonance imaging of the pharynx in OSA patients and healthy subjects. Eur Respir J 2001; 17: 79-86.