Original Article / Çalışma - Araştırma

Effect of obesity on upper airway physical examination in obstructive sleep apnea-hypopnea syndrome

Obstrüktif uyku apne-hipopne sendromunda obezitenin üst solunum yolu fizik muayenesine etkisi

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ABSTRACT

Objectives: This study aims to evaluate anatomic abnormalities that may be associated with obesity and may cause sleep apnea in patients with obstructive sleep apnea-hypopnea syndrome (OSAHS) by physical examination and Müller maneuver.

Patients and Methods: This single center, prospective, cross-sectional study included 330 OSAHS patients (274 males, 56 females; mean age 47±11 years; range 17 to 79 years) who were performed polysomnography. Patients' clinical history as well as otolaryngology examination findings including pharyngeal soft tissues, anterior rhinoscopy and Müller maneuver were recorded.

Results: Mean body mass index (BMI) was 32±5 kg/m^2 (range 21.9 to 48.4 kg/m^2) and apnea-hypopnea index (AHI) was 27±24 episodes per hour (range 0 to 106 episodes/hour). The AHI and BMI were statistically significantly correlated with minimum oxygen saturation, neck circumference, waist circumference, Epworth Sleepiness Scale score, retropalatal and retroglossal grades, tonsil size, and modified Mallampati score. Patients with higher AHI or BMI had statistically significantly higher retropalatal, retroglossal, and combined retropalatal and retroglossal grades ($p \leq 0.001$).

Conclusion: Obesity affects the retropalatal and retroglossal grades and modified Mallampati scores of patients with OSAHS. High scores of those variables with low BMI may be attributed to upper airway soft tissue or craniofacial bony abnormalities. The retropalatal airway may narrow earlier than the retroglossal airway when fat accumulation starts in the lateral pharyngeal walls and tongue.

Keywords: Müller maneuver; obesity; obstructive sleep apnea.

ÖZ

Amaç: Bu çalışmada obstrüktif uyku apne-hipopne sendromu (OUAHS) olan hastalarda obeziteyle ilişkili olup uyku apnesine neden olabilecek anatomik anormallikler fizik muayene ve Müller manevrası ile değerlendirildi.

Hastalar ve Yöntemler: Bu tek merkezli, prospektif, kesitsel çalışmaya polisomnografi uygulanan 330 OUAHS hastası (274 erkek, 56 kadın; ort. yaş 47±11 yıl; dağılım 17-79 yıl) dahil edildi. Hastaların klinik öyküsü ile birlikte farengeal yumuşak dokuları, anterior rinoskopiyi ve Müller manevrasını içeren otolarengoloji muayenesi bulguları kaydedildi.

Bulgular: Ortalama vücut kütle indeksi (VKİ) 32±5 kg/m^2 (dağılım 21.9-48.4 kg/m^2) ve apne-hipopne indeksi saatte 27±24 epizod (dağılım 0-106 epizod/saat) idi. Apne-hipopne indeksi ve VKİ; minimum oksijen satürasyonu, boyun çevresi, karın çevresi, Epworth Uykululuk Skalası skoru, retropalatal ve retroglossal evre, tonsil büyüklüğü ve modifiye Mallampati skoru ile istatistiksel olarak anlamlı şekilde ilişkiliydi. Apne-hipopne indeksi veya VKİ'si daha yüksek olan hastalar istatistiksel olarak daha yüksek retropalatal, retroglossal ve kombine retropalatal ve retroglossal evreye sahipti ($p \leq 0.001$).

Sonuç: Obezite, OUAHS'li hastaların retropalatal ve retroglossal evrelerini ve modifiye Malampati skorlarını etkiler. Bu değişkenlere ait skorların yüksek, VKİ'nin düşük olması, üst solunum yolu yumuşak doku veya kraniyofasiyal kemik anormalliklerine bağlanabilir. Lateral farengeal duvarlarda ve dilde yağ birikimi başladığında retropalatal hava yolu, retroglossal hava yolundan önce daralabilir.

Anahtar Sözcükler: Müller manevrası; obezite; obstrüktif uyku apnesi.

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The prevalence of obstructive sleep apnea-hypopnea syndrome (OSAHS) is 4% in middle aged men and 2% in women, but is much higher (20 to 40%) in obese people, possibly because of upper airway soft tissue enlargement.[1-3] Mild obesity may cause anatomic imbalance in people who have a small maxilla and mandible. Furthermore, lung volume reduction caused by excessive central fat deposition may decrease longitudinal tracheal traction forces and pharyngeal wall tension.[4] Weight loss may increase velopharyngeal airway volume, but changes in upper airway length may have a greater effect on the reduction in frequency of apnea.[5] Neurostructural interactions required for stable breathing may also be affected by obesity-related hormones and cytokines.[4]

Patients who have identical Apnea Hypopnea Index (AHI) scores but different body mass index (BMI) may have different anatomic abnormalities and may require different treatment.[6,7] However, regarding BMI, there is no consensus about physical findings associated with OSAHS.[8]

Imaging studies have shown that the size of upper airway structures (tongue, soft palate, parapharyngeal fat pads, lateral pharyngeal walls, and mandible) is an important determinant of upper airway caliber in patients who have sleep apnea.[9] Evaluation for surgery may include physical examination, fiberoptic endoscopy, and Müller maneuver, but more extensive methods of evaluating the upper airway may not be available or feasible because of time constraints on examination.[10,11]

Previous studies have evaluated the relation between upper airway examination and severity of OSAHS.[8,12,13] Although previous studies have compared the predictive value of physical findings with polysomnography, limited information is available about the effect of obesity on the upper airway physical findings.

The purpose of the present study was to evaluate anatomic abnormalities that may be associated with obesity and may cause sleep apnea, and to provide clinical evidence that may help the clinician, while evaluating the patient, about the possibility of fat deposition in upper airway structures.

PATIENTS AND METHODS

In this prospective, single center, cross-sectional study, consecutive patients who had OSAHS including snoring who were evaluated in the Department of Otolaryngology-Head and Neck Surgery, Faculty of Medicine, Başkent University Hospital between January 2011 and May 2013 were included. A total of 330 patients who were evaluated with overnight polysomnography met the inclusion criteria (274 males and 56 females; mean age 47±11 years; range, 17 to 79 years). Other patients were excluded for severe chronic kidney, heart, or liver failure, abnormal lung function, or other sleep disorders. Because the study was designed to collect data in the course of standard treatment of OSAHS, it was classified as exempted by the local institutional review board.

All patients had a clinical history and physical and otolaryngology examination including determination of BMI, measurement of neck and waist circumference, oropharyngeal examination, Müller maneuver with fiberoptic endoscopy, completion of Epworth Sleepiness Scale (ESS), and polysomnography. Patients were evaluated for hypertension, other cardiovascular diseases, diabetes mellitus, hypothyroidism, nasal obstruction, and allergic rhinitis. Nasal and pharyngeal configurations were assessed semi-quantitatively. Each patient performed Müller maneuver in the seated position to estimate the degree of obstruction at the base of the tongue and soft palate. All otolaryngology examinations were performed and graded by the same examiner, usually after polysomnography was completed (Table 1).

The BMI was calculated as body weight (kg) divided by the square of body height (m^2) and graded as previously described (Table 1).[14] Neck circumference was measured at the level of the cricothyroid membrane. Waist circumference was measured at the level of the umbilicus. Tonsil size was classified (Table 1). The oral cavity was inspected for the relative position of the palate and base of the tongue; patients were asked to open the mouth with the tongue relaxed inside the mouth, and examination findings were assessed and graded with modified Mallampati score (Table 1). The uvula was graded elongated (length >1.5 cm) and/or hypertrophic (width >1 cm) or normal (Table 1). Nasal examination

Table 1. Grading systems used for physical examination of patients evaluated for Obstructive Sleep Apnea-Hypopnea Syndrome

Parameter	Definition
Apnea Hypopnea Index	Apnea and hypopnea episodes/hour
1 (Snoring)	<5.0
2 (Mild sleep apnea)	5.0 to 14.9
3 (Moderate sleep apnea)	15 to 30
4 (Severe sleep apnea)	>30
Body Mass Index	Weight (kg)/height^2 (m^2)
1	<25
2	25 to 29.9
3	30 to 40
4	>40
Tonsil size	Tonsils
0	Previous tonsillectomy
1	Inside tonsillar fossa lateral to posterior pillars
2	Occupying 25 to 49% oropharynx
3	Occupying 50 to 74% oropharynx
4	Occupying ≥75% oropharynx, almost meeting in midline
Modified Mallampati score	Examination
1	Soft palate, pillars, and tonsils clearly visible
2	Uvula, pillars, and upper poles of tonsils visible
3	Only part of soft palate visible; tonsils, pillars, and base of uvula could not be seen
4	Only hard palate visible
Uvula	
0	Normal
1	Elongated (length >1.5 cm)/hypertrophic (width >1 cm)
Nasal obstruction	Septal deviation and/or turbinate hypertrophy
1	0 to 25%
2	>25 to 50%
3	>50 to 75%
4	>75 to 100%
Retropalatal Müller grade	Collapse of pharyngeal walls during Müller maneuver
1	<25%
2	25 to 49%
3	50 to 75%
4	>75 to 100%
Retroglossal Müller grade	Examination
1	Vallecula completely visible
2	Vallecula partly visible
3	Tongue base touching epiglottis
4	Tongue base pushing epiglottis
Combined collapsibility*	
0	
1	Retropalatal grade 3, 4 and retroglossal grade 3, 4
High palatal archus	
0	(-)
1	(+)
Epworth Sleepiness Scale score	
1	<11
2	11≤ ESS ≤14
3	14< ESS ≤18
4	>18

* Combined collapsibility: retropalatal and retroglossal; ESS: Epworth Sleepiness Scale score.

was performed with anterior rhinoscopy using a speculum, with the patient seated and the head tilted slightly backward, and findings were graded according to septal deviation, inferior turbinate hypertrophy, or other nasal obstructive pathology (Table 1).

The upper airway was evaluated with fiberoptic endoscopy through the nose with the subject seated erect and the head and neck placed in neutral position by aligning the Frankfort Horizontal Plane running from the lowest point of the infraorbital rim to the highest point on the upper margin of the external auditory canal opening, parallel to the floor. Topical nasal anesthesia was achieved with 10% lidocaine spray. The fiberoptic endoscope was passed through a nostril and advanced until the epiglottis was well visualized. The Müller maneuver was performed (forced inspiratory suction with mouth and nose closed) and the endoscope was used to inspect the oropharynx (endoscope at the level of the uvula tip and the nasopharynx) and hypopharynx (endoscope at the level of the supraglottis). The Müller maneuver was repeated ≥3 times until the patient had strong inspiratory suction. Upper airway collapse was graded at the retropalatal space (oropharynx) and retroglossal space (hypopharynx) with Müller grade. Combined collapsibility was defined as obstruction (grade 3, 4) in both retropalatal and retroglossal spaces (Table 1).

All patients had overnight polysomnography (E-series 44-channel system, Compumedics, Abbotsford, Australia) at the Baskent University Alanya Hospital Chest Disease Sleep Laboratory, supervised throughout by an experienced technician. The recordings included a two-channel electroencephalogram, electromyogram, electrocardiogram, electro-oculogram, body position, chest and abdominal excursions, naso-oral airflow assessed with a nasal cannula, and oxyhemoglobin saturation monitoring (finger pulse oximetry). A single polysomnographic study throughout one night was used to assess nighttime breathing and snoring disorder and the presence of sleep apnea. Apnea was defined as cessation of breathing for ≥10 seconds. Hypopnea was a decreased effort to breathe at least 50% less than baseline and with at least a 4% decrease in oxygen saturation (SaO_2). The AHI was graded from the total number of apnea and hypopnea episodes per hour (Table 1).[15]

Statistical analysis

Data analysis was performed with IBM SPSS for Windows, Version 21.0 statistical software (IBM Corp., Armonk, NY, USA). Continuous variables were reported as mean ± standard deviation. Categorical variables were reported as number (%). Associations between categorical variables were evaluated with chi-square (χ^2) test. Normality of continuous variables was verified with Shapiro-Wilk test. Differences between continuous variables were evaluated with t-test for independent samples. Mann-Whitney U test was used when parametric test assumptions were not satisfied. Comparisons of >2 groups (continuous variables) were evaluated with one-way analysis of variance or Kruskal-Wallis test. Paired samples were compared with Tukey or Siegel-Castellan test. Relations between continuous variables were evaluated with Spearman rank correlation. Statistical significance was defined as $p \leq 0.05$.

RESULTS

In the 330 patients, the mean BMI was 32±5 kg/m^2 (range, 21.9-48.4 kg/m^2) and AHI was 27±24 episodes per hour (range, 0-106 episodes/h). Patients were classified according to the AHI as having snoring (50 patients [15%]), mild sleep apnea (84 patients [26%]), moderate sleep apnea (77 patients [23%]), and severe sleep apnea (119 patients [36%]).

Patients who had different grades of AHI had significantly different mean tonsil size, modified Mallampati score, retropalatal grade, retroglossal grade, combined collapsibility grade, and ESS score (Table 2). Patients who had different grades of BMI had significantly different mean modified Mallampati score, retropalatal grade, retroglossal grade, combined collapsibility grade, high palatal arch grade and ESS score (Table 2). The AHI and BMI were significantly correlated with lowest oxygen saturation, neck circumference, waist circumference, ESS score, retropalatal grade, retroglossal grade, and modified Mallampati score (Table 3). In addition, AHI was significantly correlated with BMI and tonsil size (Table 3). The AHI and BMI grades were significantly correlated with modified Malampati, retropalatal, retroglossal, and combined collapsibility grades with Müller maneuver (Table 4 and 5).

DISCUSSION

The present result showed that AHI and BMI were significantly correlated with several parameters from the clinical examination including lowest oxygen saturation, neck circumference, waist circumference, ESS score, retropalatal grade, retroglossal grade, and modified Mallampati score (Table 3).

Despite problems in standardizing the description of the locations and dynamic patterns of upper airway collapse, awake fiberoptic nasopharyngeal endoscopy typically is the first diagnostic technique performed.[12,16]

Table 2. Relation between apnea hypopnea index or body mass index with clinical characteristics of patients evaluated for obstructive sleep apnea-hypopnea syndrome (n=330)

			Apnea Hypopnea Index		Body Mass Index	
Parameter	n	%	Mean±SD	*p*	Mean±SD	*p*
Tonsil size†				0.001		NS
0 (previous tonsillectomy)	15	4.5	23.3±26.7		31.1±4.6	
1	119	36.1	23.3±23.8		30.8±4.7	
2	175	53	29.3±23.2		32.3±5.2	
3	21	6.4	38.1±21.7		32.6±2.8	
Modified Mallampati score				<0.001		<0.001
1	33	10	15±16.7		29.5±4.9	
2	178	53.9	22.9±20.5		30.9±4.5	
3	110	33.3	36.3±25.5		33.4±5.0	
4	9	2.7	53±31		35.5±5.0	
Nose‡				NS		NS
1	83	25.2	23±20.5		31.6±5.3	
2	221	67	29.2±24.6		31.9±4.8	
3-4	26	7.9	23.2±22.1		30.1±5.1	
Retropalatal grade				<0.001		<0.001
1	60	18.2	9.6±10.5		28.4±3.6	
2	101	30.6	21.2±19.3		31.3±5	
3	95	28.8	31.6±22.5		32.7±4.6	
4	74	22.4	45±25.2		33.7±4.9	
Retroglossal grade				<0.001		<0.001
1	116	35.2	21.1±18.7		29.8±4	
2	163	49.4	26.4±24.2		31.9±4.7	
3	44	13.3	43.5±24.9		34.4±5.3	
4	7	2.1	52.7±20.5		40.7±5.2	
Combined collapsibility grade§				<0.001		<0.001
0	296	89.7	24.8±22.4		31.2±4.6	
1	34	10.3	49.9±23.5		36.3±5.6	
Uvula				NS		NS
0	271	82.1	26.4±23.4		31.6±5.1	
1	59	17.9	32.1±24.9		32.1±4.2	
High palatal arch				NS		0.011
0	318	96.4	27±23.6		31.8±4.9	
1	12	3.6	38.4±26.2		28.1±4.6	
Epworth Sleepiness Scale score¶				<0.001		0.005
1	189	57.3	22.5±20.8		31.1±4.7	
2	57	17.3	30.1±23.8		31.8±5.4	
3	56	17	30.1±23.6		32.6±5	
4	28	8.5	49.3±28.8		34±4.9	

SD: Standard deviation; † There were no patients who had grade 4 tonsil size; ‡ Previous septoplasty was reported by 24 patients (7%); § Combined collapse: retropalatal and retroglossal; ¶ Mean ESS score, 10.2±5.6 (range, 0-24). Day time sleepiness (ESS ≥11) was reported by 141 patients (43%).

Table 3. Relation between apnea hypopnea index or body mass index with clinical characteristics of patients evaluated for obstructive sleep apnea-hypopnea syndrome*

Variable	Apnea Hypopnea Index		Body Mass Index	
	r	*p*≤	r	*p*≤
Lowest oxygen saturation	-0.787	0.001	-0.453	0.001
Neck circumference	0.404	0.001	0.526	0.001
Waist circumference	0.471	0.001	0.832	0.001
Epworth Sleepiness Scale score	0.226	0.001	0.192	0.001
Retropalatal grade	0.537	0.001	0.360	0.001
Retroglossal grade	0.268	0.001	0.346	0.001
Body mass index	0.473	0.001	-	-
Modified Mallampati score	0.339	0.001	0.294	0.001
Tonsil size	0.215	0.001	0.140	0.011

* Spearman rank correlation.

The use of the Müller maneuver may be helpful because of the significant correlation observed between the AHI and BMI grades and modified Malampati, retropalatal, retroglossal, and combined collapsibility grades with Müller maneuver (Table 4 and 5). A previously reported staging system was based on palate position, tonsil size, and BMI, but the pattern and degree of pharyngeal collapse observed during Müller maneuver was not included as a predictor

Table 4. Relation between apnea hypopnea index grade and clinical characteristics of patients evaluated with Müller maneuver for obstructive sleep apnea-hypopnea syndrome

	Apnea Hypopnea Index									
	AHI <5		5≤ AHI ≤14.9		15≤ AHI ≤30		AHI >30			
Parameter	n	%	n	%	n	%	n	%	r	*p*≤
Patients	50		84		77		119			
Modified Mallampati score									0.330	0.001
1	13	26	7	8.3	9	11.7	4	3.4		
2	28	56	56	66.7	44	57.1	50	42		
3	9	18	21	25	22	28.6	58	48.7		
4	0	0	0	0	2	2.6	7	5.9		
Retropalatal grade									0.524	0.001
1	23	46	25	29.8	10	13	2	1.7		
2	20	40	31	36.9	25	32.5	25	21		
3	5	10	19	22.6	30	39	41	34.5		
4	2	4	9	10.7	12	15.6	51	42.9		
Retroglossal grade									0.247	0.001
1	19	38	36	42.9	33	42.9	28	23.5		
2	30	60	42	50	36	46.8	55	46.3		
3	1	2	6	7.1	7	9.1	30	25.2		
4	0	0	0	0	1	1.3	6	5		
Combined airway collapsibility grade†									0.301	0.001
1	50	100	81	96.4	74	96.1	91	76.5		
2	0	0	3	3.6	3	3.9	28	23.5		

AHI: Apnea Hypopnea Index; † Combined retropalatal and retroglossal.

Table 5. Relation between body mass index grade and clinical characteristics of patients evaluated with Müller maneuver for obstructive sleep apnea-hypopnea syndrome

	Body Mass Index									
	BMI <25		25≤ BMI ≤29.9		30≤ BMI ≤40		BMI >40			
Parameter	n	%	n	%	n	%	n	%	r	*p*≤
Patients	22		100		183		25			
Modified Mallampati score									0.255	0.001
1	6	27.3	12	12	14	7.7	1	4		
2	13	59.1	64	64	91	49.7	10	40		
3	3	13.6	22	22	73	39.9	12	48		
4	0	0	2	2	5	2.7	2	8		
Retropalatal grade									0.321	0.001
1	11	50	30	30	19	10.4	0	0		
2	7	31.8	34	34	52	28.4	8	32		
3	3	13.6	19	19	63	34.4	10	40		
4	1	4.5	17	17	49	26.8	7	28		
Retroglossal grade									0.289	0.001
1	12	54.5	48	48	53	29	3	12		
2	10	45.5	44	44	96	52.5	13	52		
3	0	0	8	8	29	15.8	7	28		
4	0	0	0	0	5	2.7	2	8		
Combined airway collapsibility grade†									0.224	0.001
0	22	100	96	96	161	88	17	68		
1	0	0	4	4	22	12	8	32		

BMI: Body mass index; † Combined retropalatal and retroglossal.

because it was considered subjective and dependent on the patient's effort.[17] However, the Müller maneuver may be easy to perform, provide a thorough assessment of the upper airway, enable exclusion of other lesions, and be valid when marked collapse is present (Müller grade 3 or 4).[18]

In the present study, all otolaryngology examinations were performed and graded by the same otolaryngologist, and the otolaryngology evaluation was performed in consultation with a pulmonologist. More reliable associations may be observed in a study with two independent examiners (each examiner blinded to the score of the other). In addition, the use of more extensive methods such as sleep endoscopy or cephalometry may show stronger correlations between upper airway anatomy and obesity. However, the diagnostic use of sleep endoscopy and cephalometry may be limited by difficulty in understanding complex cephalometric analysis and may be unrealistic in routine otolaryngology evaluation.

There is controversy about the importance of the clinical history in detecting OSAHS.[12] In the present study, AHI and BMI had a weak correlation with ESS score (Table 3). The ESS score was normal (grade 1; <11) in most patients (57%) (Table 2), but snoring without sleep apnea was observed in only 15% of patients and body weight was normal (BMI <25 kg/m^2) in only 7% of patients. Therefore, the ESS score may be normal in many patients who have OSAHS or obesity.

There was no association observed between the degree of nasal obstruction and AHI or BMI, consistent with previous reports.[8,12,13] Therefore, upper airway surgery such as nasal septal reconstruction and cauterization may not correct OSAHS.[11] However, the presence of a blocked nose may interfere with acceptance of and compliance with positive airway pressure therapy, and the need for higher pressure may be uncomfortable for patients. In addition, nasal obstruction may cause mouth breathing, with the mandible displaced downward and backward, which may facilitate obstruction at the base of the tongue.[8]

The mean AHI and BMI grades were similar for patients who had elongated or hypertrophic or normal uvulas (Table 2). High palatal arch was independent of AHI but associated with lower BMI (Table 2), consistent with the suggestion that mild obesity may cause anatomic imbalance in patients who have a small maxilla and mandible.[4] Conversely, larger tonsil size was associated with AHI but not BMI (Table 2). Elongated or hypertrophic uvulas, and nasal obstructions were not associated with obesity (Table 2). In contrast, narrower retropalatal and retroglossal spaces and higher modified Mallampati scores were positively associated with both AHI and BMI. Therefore, obesity may have a direct effect on modified Mallampati score. Although obstruction may occur at any level along the pharyngeal airway, it is most frequently observed in the retropalatal and/or retroglossal regions.[4]

The variation observed for the association between retropalatal or retroglossal score and BMI subgroups (Table 5) suggests that less obesity may narrow the retropalatal than retroglossal airway. This is consistent with previous findings that obesity is more frequently associated with retropalatal airway closure.[19] The tongue is anterior to the soft palate and the retropalatal airway is narrower than the retroglossal airway. Therefore, the retropalatal airway may narrow earlier than the retroglossal airway when fat accumulates in the lateral pharyngeal wall and tongue.[4] In the present study, presence of combined collapsibility (retropalatal and retroglossal) was associated with AHI and BMI (Table 4 and 5).

Upper airway soft tissue enlargement may be more important in the development of obstructive sleep apnea in obese than non-obese patients, and bony structure discrepancies may be the dominant contributing factor for obstructive sleep apnea in non-obese than obese patients.[3] Most patients who have OSAHS may have a combination of soft tissue and bony factors that may contribute to the syndrome. In patients who have grade 3 or 4 BMI scores, marked collapsibility at retropalatal (grade 3 or 4) and/or retroglossal levels (grade 3 or 4) and high modified Mallampati scores may be expected. Combined collapsibility may be expected especially with grade 4 BMI. Discrepancies between those variables and BMI in patients with OSAHS may be an indication for evaluation of craniofacial or soft tissue abnormalities with cephalometric analysis or sleep endoscopy. When those physical variables and BMI are consistent with each other, nonoperative treatment such as weight loss, positional therapy, oral appliances, or positive airway pressure therapy, may be preferred.

In conclusion, in patients who have OSAHS, physical examination with Müller maneuver shows that BMI is associated with modified Mallampati, retropalatal, retroglossal, and combined retropalatal and retroglossal collapsibility scores. Lower levels of obesity may cause retropalatal than retroglossal narrowing from excessive fat deposition in the soft tissues around the upper airway. When scores of those obesity-related physical variables are inconsistent with BMI score, upper airway soft tissue or craniofacial bony abnormalities that may be indications for surgical treatment may be investigated.

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