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ORIGINAL ARTICLE

Factors predictive of obstructive sleep apnea in patients undergoing pre-operative evaluation for bariatric surgery and referred to a sleep laboratory for polysomnography

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Study carried out at the Sleep – Laboratório de Estudo dos Distúrbios do Sono, Centro Médico BarraShopping, and at the Instituto de Doenças do Tórax – IDT – Universidade Federal do Rio de Janeiro – UFRJ – Rio de Janeiro, Brasil.

ABSTRACT

Objective: To identify the main predictive factors for obtaining a diagnosis of obstructive sleep apnea (OSA) in patients awaiting bariatric surgery. **Methods:** Retrospective study of consecutive patients undergoing pre-operative evaluation for bariatric surgery and referred for in-laboratory polysomnography. Eight variables were evaluated: sex, age, neck circumference (NC), BMI, Epworth Sleepiness Scale (ESS) score, snoring, observed apnea, and hypertension. We employed ROC curve analysis to determine the best cut-off value for each variable and multiple linear regression to identify independent predictors of OSA severity. **Results:** We evaluated 1,089 patients, of whom 781 (71.7%) were female. The overall prevalence of OSA—defined as an apnea/hypopnea index (AHI) ≥ 5.0 events/h—was 74.8%. The best cut-off values for NC, BMI, age, and ESS score were 42 cm, 42 kg/m², 37 years, and 10 points, respectively. All eight variables were found to be independent predictors of a diagnosis of OSA in general, and all but one were found to be independent predictors of a diagnosis of moderate/severe OSA (AHI ≥ 15.0 events/h), the exception being hypertension. We devised a 6-item model, designated the NO-OSAS model (**N**C, **O**besity, **O**bserved apnea, **S**noring, **A**ge, and **S**ex), with a cut-off value of ≥ 3 for identifying high-risk patients. For a diagnosis of moderate/severe OSA, the model showed 70.8% accuracy, 82.8% sensitivity, and 57.9% specificity. **Conclusions:** In our sample of patients awaiting bariatric surgery, there was a high prevalence of OSA. At a cut-off value of ≥ 3, the proposed 6-item model showed good accuracy for a diagnosis of moderate/severe OSA.

Keywords: Polysomnography; Sleep apnea, obstructive; Bariatric surgery.

INTRODUCTION

Obstructive sleep apnea (OSA) is a major disease, affecting at least 2% of women and 4% of men, worldwide.[1] It is a sleep-related breathing disorder, characterized by recurrent upper-airway obstruction during sleep, resulting in a cycle of hypoxemia, increased respiratory effort, and frequent arousals, obesity being the most common known risk factor.[2] Recent data show that in the 2011-2012 period, the prevalence of obesity in the United States was 16.9% in juveniles and 34.9% in adults.[3] Obesity is a chronic disease that has become epidemic in the United States and worldwide; it is also a major risk factor for various disorders, including OSA.[4] In addition, over the last several decades, the criteria used in order to determine the prevalence of OSA have been redefined,[5] primarily because the prevalence of obesity continues to increase,[3] which in turn increases that of OSA.

In most cases, bariatric surgery results in dramatic weight loss and significant improvement in the indices of sleep-disordered breathing.[4] In addition, OSA is underdiagnosed in a significant proportion of obese patients undergoing bariatric surgery.[6-10] Most bariatric surgery programs now employ routine screening for OSA in all patients, regardless of whether or not they have sleep complaints, because most cases of OSA were previously not being diagnosed before the surgical procedure.[11] Bariatric surgery lowers body weight markedly and reduces the severity of comorbidities associated with obesity, as well as reducing that of OSA.[12,13] Worldwide, the accepted criteria for bariatric surgery include the following[14,15]: being 18-65 years of age and having a BMI ≥ 40 kg/m² or ≥ 35 kg/m² and having any obesity-related comorbidity (resistant hypertension, established heart disease, severe degenerative osteoarthritis, or respiratory failure). Although the exact pathophysiology of OSA in obese patients remains poorly understood, it is thought that the deposition of fatty tissue in the neck narrows the lumen of the upper airway, thereby inducing its collapse.[4,15]

The population of Brazil comprises a number of different ethnic, racial, and socioeconomic groups. Because of the considerable degree of miscegenation in the country, it is useful to identify the main clinical variables evaluated

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in making a diagnosis of OSA in patients belonging to those various groups. Although various studies have shown that OSA is quite prevalent among bariatric surgery patients, there is still a lack of data regarding the main clinical predictors of OSA in such patients, especially for those in Brazil.

METHODS

This was a retrospective analysis of a prospectively maintained database. We analyzed data related to consecutive outpatients undergoing pre-operative evaluation for bariatric surgery between January of 2010 and October of 2014, all of whom were referred to our sleep laboratory for polysomnography, regardless of whether or not they had complained of sleep-related respiratory disturbances. Patients were referred by their respective attending physicians. All demographic and polysomnographic data were collected at our sleep laboratory. The inclusion criteria were being 18-65 years of age, being obese (BMI ≥ 35.0 kg/m^2), and not having been previously diagnosed with OSA. Patients for whom clinical data were missing were excluded, as were those with a total sleep time (TST) of < 3 h and those in whom portable sleep studies had been used for the diagnosis of OSA. Additional informed consent was not obtained for this study, because there was no intervention. The study was approved by the Research Ethics Committee of the Federal University of Rio de Janeiro (Protocol no. 666.608/2014).

Data collection

All studies were conducted in the Sleep Laboratory of the BarraShopping Medical Center, located in the city of Rio de Janeiro, Brazil, a relatively large sleep laboratory with 18 beds, sleep technicians, and two board-certified sleep physicians. The variables evaluated included sex, age, BMI, neck circumference (NC), snoring, observed apnea, hypertension, and degree of daytime sleepiness, as determined by the Epworth Sleepiness Scale (ESS).[16,17] On the evening of the polysomnography, all demographic variables were collected by qualified skilled sleep laboratory technicians. The BMI was calculated as weight in kilograms divided by height in meters squared, and NC measurements were taken at the level of the cricoid membrane with the patients in the supine position. The study population was stratified into four categories, by BMI: 35.0-39.9 kg/m^2; 40.0-49.9 kg/m^2; 50.0-59.9 kg/m^2; and ≥ 60.0 kg/m^2. Subjects with an arterial blood pressure ≥ 140/90 mmHg were classified as having systemic arterial hypertension, as were those being treated with antihypertensive medication. Self-reported snoring and observed apnea were evaluated as dichotomous (yes/no) variables.

All patients underwent one-night, in-laboratory polysomnography, performed with a digital system (EMBLA® S7000; Embla Systems, Inc., Broomfield, CO, USA), consisting of continuous polygraphic recording from surface leads (for electroencephalography, electrooculography, electromyography of the chin/legs, and electrocardiography), thermistors (for nasal/oral airflow), thoracic/abdominal impedance belts (for respiratory effort), and position sensors (for sleep position), together with pulse oximetry (for SpO_2) and audio recording via a tracheal microphone (for snoring). Polysomnographic recordings were scored manually and were interpreted by an experienced sleep physician in accordance with established guidelines.[18-20] The data interpreted included TST, sleep efficiency, sleep stages, rapid eye movement (REM) latency, sleep latency, arousals, apnea/hypopnea index (AHI), and SpO_2.

Sleep stages were scored based on established criteria.[18] Arousals were defined as episodes lasting ≥ 3 s in which there was a return of alpha activity associated with an increase in electromyographic activity. An apnea event was defined as a ≥ 10 s cessation of oronasal airflow. A hypopnea event was defined as a ≥ 30% reduction in the nasal pressure signal accompanied by ≥ 4% desaturation that lasted for > 10 s.[18] The AHI was defined as the sum of the apnea and hypopnea events per hour of sleep. The diagnosis of OSA was based on an AHI ≥ 5.0 events/h, and OSA severity was categorized on the basis of the AHI[18]: mild (5.0-14.9 events/h); moderate (15.0-29.9 events/h); or severe (≥ 30.0 events/h).

Statistical analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences, version 17.0 for Windows (SPSS Inc., Chicago, IL, USA). Continuous data are reported as mean ± standard deviation, whereas categorical data are reported as percentages of the total population. Comparisons between groups were performed with the chi-square test for dichotomous variables, Student's t-test for normally distributed continuous variables, and the Mann-Whitney U-test for non-normally distributed continuous variables. Correlations between continuous variables were evaluated by Spearman's rank correlation coefficient (r_s). For each continuous variable, we used a ROC curve, calculating the area under the curve (AUC) to obtain the cut-off value for use in the univariate and multivariate analyses. Univariate and multivariate tests were used in order to calculate the odds ratios and the corresponding 95% confidence intervals. Using 2 × 2 contingency tables, we calculated the following parameters for all variables: sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. We constructed predictive models using the main independent variables obtained for an AHI ≥ 15.0 events/h, aiming to optimize the screening for moderate/severe OSA in bariatric surgery patients. The best predictive model was selected according to the ROC curves. All tests were two-sided, and values of $p < 0.05$ were considered statistically significant.

RESULTS

In a period of 58 months, 1,480 consecutive patients were referred for polysomnography. Of those

1,480 patients, 391 were subsequently excluded: 308 because of missing data; 30 because they had been the subjects of home sleep studies; 28 because they had a TST of < 3 h; and 25 because they had previously been diagnosed with OSA. Therefore, 1,089 patients, of whom 781 (71.7%) were female and 308 (28.3%) were male, were considered eligible for further analysis. Demographic and polysomnographic characteristics of those 1,089 subjects are listed in Table 1. The overall prevalence of OSA was 74.8%, and the prevalence of moderate/severe OSA was 52.0%. In comparison with the females, the males were younger ($p = 0.080$), had higher BMIs ($p < 0.001$), and had larger NCs ($p < 0.001$). In terms of the prevalence of excessive daytime sleepiness (ESS score ≥ 10), the difference between males and females did not reach statistical significance ($p = 0.122$). The severity of OSA was greater in males than in females, as was the prevalence of moderate/severe OSA (84.7% vs. 39.1%) and severe OSA (68.5% vs. 18.6%), the last two being statistically significant differences ($p < 0.001$ for both). The continuous variables (NC, BMI, age, and ESS score) were correlated with the AHI ($r_s = 0.500$, $r_s = 0.308$, $r_s = 0.247$, and $r_s = 0.156$, respectively; $p < 0.001$ for all).

Table 2 shows the differences among the various BMI categories, in relation to demographic, clinical, and polysomnographic variables. As BMI increased, there were statistically significant increases in the proportion of males, as well as in the proportions of subjects with hypertension, snoring, and observed apnea. In addition, NC and the ESS score increased in parallel with increases in BMI, although no such association was observed between age and BMI category ($p = 0.607$). Arousals and the AHI also increased progressively in parallel with increases in BMI, as did the numbers of apnea and hypopnea events per hour when calculated separately ($p < 0.001$ for all). Similarly, SpO_2 values worsened in parallel with increases in BMI ($p < 0.001$ for baseline, mean, and lowest SpO_2). As expected, there were linear increases in the prevalence of OSA, especially that of the severe form of the disease, corresponding to increases in the BMI: 253 (66.4%) of the 381 patients with a BMI 35.0-39.9 kg/m^2 were diagnosed with OSA, 81 (21.3%) of those patients being diagnosed with severe OSA; 460 (77.0%) of the 597 patients with a BMI 40.0-49.9 kg/m^2 were diagnosed with OSA, 200 (33.5%) of those patients being diagnosed with severe OSA; 88 (33,7%) of the 98 patients with a BMI 50.0-59.9 kg/m^2 were diagnosed with OSA, 65 (66.3%) of those patients being diagnosed with severe OSA; and all 13 of the patients with a BMI ≥ 60.0 kg/m^2 were diagnosed with OSA, 10 (76.9%) of those patients being diagnosed with severe OSA.

The ROC curve analyses of the relevant continuous variables yielded the following AUCs: 0.711 (95% CI: 0.679-0.744) for NC; 0.657 (95% CI: 0.620-0.694) for age; 0.625 (95% CI: 0.588-0.662) for BMI; and 0.557 (95% CI: 0.519-0.595) for ESS score. In addition, the ROC curves showed that the best cut-off values for NC, BMI, age, and ESS score (as diagnostic markers of OSA) were 42 cm, 42 kg/m^2, 37 years, and 10 points, respectively.

Table 3 shows the univariate and multivariate analyses of the eight variables evaluated in relation to three different AHI cut-off values (5.0 events/h, 15.0 events/h, and 30.0 events/h). All of those variables were thus found to be independent predictors of a diagnosis of OSA in general (AHI ≥ 5.0 events/h). All but one were found to be independent predictors of a diagnosis of moderate/severe OSA (AHI ≥ 15.0 events/h), the exception being hypertension ($p = 0.421$). All but two were found to be independent predictors of a diagnosis of severe OSA (AHI ≥ 30.0 events/h), the exceptions being hypertension ($p = 0.963$) and snoring ($p = 0.153$). The main predictor of a diagnosis of OSA in general was male sex, with an adjusted OR of 10.20 (95% CI: 5.07-20.83), followed by snoring, age ≥ 37 years, observed apnea, BMI ≥ 42 kg/m^2, ESS score ≥ 10, hypertension, and NC ≥ 42 cm. The main predictor of a diagnosis of moderate/severe OSA was also male sex, with an adjusted OR of 5.91 (95% CI: 3.92-8.92), followed by snoring, BMI ≥ 42 kg/m^2, age ≥ 37 years, observed apnea, NC ≥ 42 cm, ESS score ≥ 10, and hypertension. The main predictor of a diagnosis of severe OSA was again male sex, with an adjusted OR of 6.80 (95% CI: 4.62-10.00), followed by BMI ≥ 42 kg/m^2, age ≥ 37 years, observed apnea, snoring, NC ≥ 42 cm, ESS score ≥ 10, and hypertension.

As can be seen in Table 3, there were seven independent variables associated with a diagnosis of moderate/severe OSA: sex, snoring, BMI, age, observed apnea, NC, and ESS score. Among those variables, ESS score was seventh (i.e., last) in importance. That, together with the fact that the ESS comprises eight questions, prompted us to exclude ESS scores, thus simplifying the models. Therefore, we tested four models (Table 4): a 3-item model including male sex, snoring, and BMI ≥ 42 kg/m^2; a 4-item model encompassing the 3-item model plus age ≥ 37 years; a 5-item model encompassing the 4-item model plus observed apnea; and a 6-item model encompassing the 5-item model plus NC ≥ 42 cm. Of the four predictive models evaluated, the one found to be best at predicting OSA in general, moderate/severe OSA, and severe OSA was the 6-item model, which had AUCs of 0.777 (95% CI: 0.747-0.807), 0.784 (95% CI: 0.757-0.811), and 0.796 (95% CI: 0.769-0.824), respectively.

Table 5 shows the predictive parameters of the 6-item model, which was categorized into six possible cut-off values (to distinguish between high and low risk of OSA), in the three different situations: diagnosis of OSA in general, diagnosis of moderate/severe OSA, and diagnosis of severe OSA. Because the main objective of the model was to identify patients at high risk for moderate/severe OSA (AHI ≥ 15.0 events/h), we sought to determine the cut-off value that (within that category) achieved the best balance between

Table 1. Demographic, clinical, and polysomnographic characteristics of the patients evaluated.[a]

Characteristic	Total (N = 1,089)	Females (n = 781)	Males (n = 308)	p
Demographic variable				
Age, years	38.1 ± 10.0	38.4 ± 10.1	37.2 ± 9.7	0.080
Clinical variables				
BMI, kg/m^2	42.8 ± 5.4	42.1 ± 5.0	44.6 ± 5.8	< 0.001
BMI 35.0-39.9 kg/m^2, n (%)	381 (35.0)	310 (39.6)	71 (23.0)	< 0.001
BMI 40.0-49.9 kg/m^2, n (%)	597 (54.8)	416 (53.3)	181 (58.8)	< 0.001
BMI 50.0-59.9 kg/m^2, n (%)	98 (9.0)	49 (6.3)	49 (15.9)	< 0.001
BMI ≥ 60.0 kg/m^2, n (%)	13 (1.2)	6 (0.8)	7 (2.3)	< 0.001
NC, cm	42.3 ± 4.7	40.3 ± 3.3	47.5 ± 3.6	< 0.001
ESS score, points	8.9 ± 4.5	8.8 ± 4.5	9.2 ± 4.6	0.306
ESS score ≥ 10, n (%)	449 (41.2)	313 (40.1)	136 (44.2)	0.122
Hypertension, n (%)	445 (40.9)	296 (37.9)	149 (48.4)	< 0.001
Snoring, n (%)	1,010 (92.7)	704 (90.1)	306 (99.4)	< 0.001
Observed apnea, n (%)	369 (33.9)	228 (29.2)	141 (45.8)	< 0.001
Polysomnographic variables				
Total sleep time, min	337.7 ± 70.0	340.9 ± 69.3	329.5 ± 71.2	0.019
Sleep efficiency, %	77.4 ± 14.9	77.7 ± 14.8	76.6 ± 15.1	0.250
Sleep stage N1, %	4.8 ± 5.9	4.3 ± 4.7	6.3 ± 7.9	< 0.001
Sleep stage N2, %	66.3 ± 12.0	64.8 ± 11.6	70.2 ± 12.2	< 0.001
Sleep stage N3, %	12.7 ± 9.1	14.1 ± 9.0	9.2 ± 8.6	< 0.001
Sleep stage R, %	15.5 ± 7.8	16.1 ± 7.6	14.0 ± 8.0	< 0.001
Arousals, events/h	29.9 ± 27.7	21.8 ± 21.5	50.5 ± 30.9	< 0.001
Sleep latency, min	41.8 ± 40.4	43.0 ± 39.9	38.7 ± 41.4	0.112
REM latency, min	150.3 ± 81.3	147.7 ± 80.0	157.3 ± 84.5	0.095
AHI, events/h	27.2 ± 29.5	18.1 ± 22.6	50.4 ± 32.2	< 0.001
AI, events/h	12.1 ± 23.4	5.6 ± 14.9	28.6 ± 31.6	< 0.001
HI, events/h	15.1 ± 15.3	12.5 ± 14.1	21.8 ± 16.1	< 0.001
Baseline SpO_2, %	95.7 ± 2.1	96.1 ± 2.1	95.0 ± 2.0	< 0.001
Mean SpO_2, %	93.7 ± 3.1	94.2 ± 3.0	92.5 ± 3.2	< 0.001
Lowest SpO_2, %	81.8 ± 9.1	83.6 ± 8.3	77.3 ± 9.6	< 0.001
Prevalence of OSA[b]				
No OSA, n (%)	275 (25.2)	265 (33.9)	10 (3.3)	< 0.001
Mild OSA, n (%)	248 (22.8)	211 (27.0)	37 (12.0)	< 0.001
Moderate OSA, n (%)	210 (19.3)	160 (20.5)	50 (16.2)	< 0.001
Severe OSA, n (%)	356 (32.7)	145 (18.6)	211 (68.5)	< 0.001

NC: neck circumference; ESS: Epworth Sleepiness Scale; REM: rapid eye movement; AHI: apnea/hypopnea index; AI: apnea index; HI: hypopnea index; and OSA: obstructive sleep apnea. [a]Values expressed as mean ± SD, except where otherwise indicated. [b]No OSA: AHI < 5.0 events/h; mild OSA: AHI = 5.0-14.9 events/h; moderate OSA: AHI = 15.0-29.9 events/h; and severe OSA: AHI ≥ 30.0 events/h.

sensitivity and specificity. For moderate/severe OSA, the best diagnostic performance was obtained at the cut-off value of ≥ 3, which had an accuracy of 70.8%, a sensitivity of 82.8%, and a specificity of 57.9%. The use of the ≥ 3 cut-off value in the 6-item model showed an accuracy, sensitivity, and specificity, respectively, of 73.0%, 74.3%, and 69.4% for a diagnosis of OSA in general; 70.8%, 82.8%, and 57.9% for a diagnosis of moderate/severe OSA; and 62.9%, 90.1%, and 49.7% for a diagnosis of severe OSA. After choosing the 6-item model as the best model, we created a mnemonic device for it, designating it the **N**C ≥ 42 cm, **O**besity (BMI ≥ 42 kg/m^2), **O**bserved apnea, **S**noring, **A**ge ≥ 37 years, and male **S**ex (NO-OSAS) model. Therefore, this model consists of six yes/no questions (maximum possible total score, 6 points).

DISCUSSION

In this study, which involved a large sample of consecutive bariatric surgery patients, we showed that all of the variables evaluated (sex, NC, BMI, age, ESS score, snoring, observed apnea, and hypertension) were independent predictors of the AHI, regardless of the cut-off value used, the only exceptions being hypertension at two of the AHI cut-off values (≥ 15.0 events/h and ≥ 30.0 events/h), and snoring at the AHI cut-off value of ≥ 30.0 events/h. At three different cut-off values (AHI ≥ 5.0 events/h, ≥ 15.0 events/h,

Table 2. Demographic, clinical, and polysomnographic parameters, by BMI category, for the 1,089 patients evaluated.[a]

Parameter	BMI				p
	35.0-39.9 kg/m² (n = 381)	40.0-49.9 kg/m² (n = 597)	50.0-59.9 kg/m² (n = 98)	≥ 60.0 kg/m² (n = 13)	
Demographic variables					
Male sex, n (%)	71 (18.6)	181 (30.3)	49 (50.0)	7 (53.8)	< 0.001
Age, years	38.2 ± 9.9	38.0 ± 10.0	38.4 ± 10.5	34.5 ± 7.9	0.607
Clinical variables					
NC, cm	40.2 ± 3.7	42.9 ± 4.4	46.7 ± 5.0	47.6 ± 4.2	< 0.001
BMI, kg/m²	37.8 ± 1.3	43.9 ± 2.7	53.0 ± 2.4	63.4 ± 3.1	< 0.001
ESS score, points	8.7 ± 4.3	8.8 ± 4.6	10.4 ± 4.4	11.0 ± 5.5	0.004
ESS score ≥ 10, n (%)	149 (39.1)	236 (39.5)	57 (58.2)	7 (53.8)	0.003
Hypertension, n (%)	125 (32.8)	263 (44.1)	49 (50.0)	8 (61.5)	< 0.001
Snoring, n (%)	340 (89.2)	562 (94.1)	95 (96.9)	13 (100.0)	0.007
Observed apnea, n (%)	108 (28.3)	213 (35.7)	39 (39.8)	9 (69.2)	0.002
Polysomnographic variables					
Arousals, events/h	21.8 ± 20.1	30.8 ± 27.8	51.6 ± 33.8	66.3 ± 41.7	< 0.001
AHI, events/h	18.4 ± 21.5	28.1 ± 29.6	51.3 ± 35.6	67.1 ± 43.4	< 0.001
AI, events/h	6.5 ± 14.8	12.6 ± 24.3	27.4 ± 32.3	34.8 ± 39.6	< 0.001
HI, events/h	11.8 ± 12.6	15.4 ± 14.8	22.7 ± 20.2	32.2 ± 25.3	< 0.001
Baseline SpO_2, %	96.2 ± 1.7	95.6 ± 2.3	95.1 ± 2.0	94.9 ± 2.5	< 0.001
Mean SpO_2, %	94.5 ± 2.5	93.5 ± 3.2	91.9 ± 3.6	90.5 ± 5.1	< 0.001
Lowest SpO_2, %	84.6 ± 7.8	81.2 ± 8.9	76.1 ± 10.6	71.7 ± 13.0	< 0.001
Prevalence of OSA[b]					
No OSA, n (%)	128 (33.6)	137 (23.0)	10 (10.2)	-	< 0.001
Mild OSA, n (%)	111 (29.1)	125 (20.9)	10 (10.2)	2 (15.4)	< 0.001
Moderate OSA, n (%)	61 (16.0)	135 (22.6)	13 (13.3)	1 (7.7)	< 0.001
Severe OSA, n (%)	81 (21.3)	200 (33.5)	65 (66.3)	10 (76.9)	< 0.001

NC: neck circumference; ESS: Epworth Sleepiness Scale; AHI: apnea/hypopnea index; AI: apnea index; HI: hypopnea index; and OSA: obstructive sleep apnea. [a]Values expressed as mean ± SD, except where otherwise indicated. [b]No OSA: AHI < 5.0 events/h; mild OSA: AHI = 5.0-14.9 events/h; moderate OSA: AHI = 15.0-29.9 events/h; and severe OSA: AHI ≥ 30.0 events/h.

and ≥ 30.0 events/h), the main predictor of a diagnosis of OSA was male sex. The prevalence of moderate/severe and severe OSA was higher among the males than among the females ($p < 0.001$). The 6-item NO-OSAS model, at a cut-off value of ≥ 3, showed good diagnostic performance for distinguishing between high-risk patients and low-risk patients, in relation to a diagnosis of OSA, regardless of the degree of severity.

In our sample of patients awaiting bariatric surgery, with or without clinical features of suspicion of OSA, the overall prevalence of OSA was high (74.8%), as was the prevalence of severe OSA (32.7%). Our results are consistent with those of previous studies involving bariatric surgery patients, all of which have reported a high (69.9-93.6%) prevalence of OSA[10,11,15,21-27] and a high (21.0-48.0%) proportion of subjects classified as having the severe form of the disease.[9-11,15,21-25] Our findings indicate that this population differs from the general population of patients with OSA.[1,5] We found that, in comparison with the general population of OSA patients, that of bariatric surgery patients had a greater proportion of females and comprised younger patients. In addition, the prevalence of OSA was much higher in our sample of bariatric surgery patients than in the general population.

In accordance with the findings of previous studies,[11,24] we observed linear increases in the prevalence and severity of OSA in parallel with increases in BMI. In one previous study,[28] the authors identified 10 variables that were predictive of OSA in bariatric surgery patients: NC, systolic blood pressure, waist/hip ratio, waist, loud snoring, frequent snoring, weight, BMI, hypertension, and male sex. Using five or more of these variables it was possible to obtain a model with a sensitivity of 77% and a specificity of 77% in predicting an AHI ≥ 15.0 events/h.[28]

Using ROC curve analysis, we found the main cut-off values of the continuous variables in our sample to be age ≥ 37 years, BMI ≥ 42 kg/m², NC ≥ 42 cm, and ESS score ≥ 10. Dixon et al. showed that advanced age, male sex, observed apnea, and severe obesity (especially central obesity) increase the risk of a higher AHI.[29] Those authors also used ROC curve analysis for determining the appropriate cut-off values for continuous variables, which they found to be NC ≥ 43 cm, age ≥ 38 years, and BMI ≥ 45 kg/m², which are quite similar to the cut-off values identified in our study. However, those authors included only patients with clinical suspicion of OSA, whereas our sample

Table 3. Predictive parameters for a diagnosis of obstructive sleep apnea, by level of severity, in the patients evaluated.

OSA severity, by AHI[a]	Analysis		Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
Parameter	Univariate OR (95% CI)	Multivariate OR (95% CI)					
Mild/moderate/severe							
Sex							
Male vs. female	15.30 (8.01-29.23)	10.20 (5.07-20.83)	36.6	96.3	96.7	33.9	51.6
Snoring							
Yes vs. no	5.03 (3.14-8.08)	2.30 (1.38-3.86)	96.0	17.0	77.4	59.4	76.1
Age, years							
≥ 37 vs. < 37	2.55 (1.92-3.40)	2.25 (1.61-3.15)	56.2	66.5	83.2	33.9	58.8
Observed apnea							
Yes vs. no	3.17 (2.25-4.47)	1.85 (1.26-2.71)	39.5	82.9	87.2	31.6	50.5
BMI, kg/m^2							
≥ 42 vs. < 42	2.21 (1.66-2.94)	1.60 (1.14-2.23)	53.0	66.1	82.2	32.2	56.3
ESS score							
≥ 10 vs. < 10	1.69 (1.26-2.26)	1.56 (1.12-2.16)	44.3	68.0	80.4	29.2	50.3
Hypertension							
Yes vs. no	2.69 (1.97-3.66)	1.52 (1.06-2.17)	46.5	75.6	84.9	32.2	53.8
NC, cm							
≥ 42 vs. < 42	4.01 (2.97-5.41)	1.45 (1.01-2.09)	60.0	72.7	86.7	38.0	63.2
Moderate/severe							
Sex							
Male vs. female	8.66 (6.15-12.20)	5.91 (3.92-8.92)	46.1	91.0	84.7	60.9	67.6
Snoring							
Yes vs. no	5.59 (3.10-10.10)	2.41 (1.27-4.56)	97.5	12.4	54.6	82.2	56.6
BMI, kg/m^2							
≥ 42 vs. < 42	2.66 (2.08-3.40)	2.12 (1.58-2.84)	59.7	64.2	64.3	59.5	61.8
Age, years							
≥ 37 vs. < 37	1.98 (1.56-2.52)	2.09 (1.54-2.83)	58.6	58.3	60.3	56.5	58.4
Observed apnea							
Yes vs. no	2.78 (2.13-3.62)	1.84 (1.35-2.51)	44.5	77.6	68.2	56.3	60.4
NC, cm							
≥ 42 vs. < 42	4.44 (3.44-5.73)	1.63 (1.18-2.26)	68.9	66.7	69.1	66.4	67.8
ESS score							
≥ 10 vs. < 10	1.59 (1.25-2.03)	1.49 (1.11-2.00)	46.6	64.6	58.7	52.8	55.2
Hypertension							
Yes vs. no	1.96 (1.53-2.51)	1.13 (0.83-1.52)	48.5	67.4	61.7	54.8	57.6
Severe							
Sex							
Male vs. female	9.54 (7.06-12.88)	6.80 (4.62-10.00)	59.2	86.7	68.5	81.4	77.7
BMI, kg/m^2							
≥ 42 vs. < 42	2.70 (2.08-3.52)	2.14 (1.56-2.94)	64.6	59.7	43.8	77.6	61.3
Age, years							
≥ 37 vs. < 37	1.72 (1.33-2.22)	2.02 (1.45-2.81)	59.5	53.8	38.5	73.2	55.7
Observed apnea							
Yes vs. no	2.73 (2.09-3.56)	1.85 (1.34-2.55)	49.4	73.6	47.6	75.0	65.7
Snoring							
Yes vs. no	5.43 (2.47-11.92)	1.84 (0.79-4.29)	98.0	9.8	34.5	91.1	38.6
NC, cm							
≥ 42 vs. < 42	5.70 (4.16-7.45)	1.73 (1.18-2.52)	78.0	60.9	49.2	85.1	66.5
ESS score							
≥ 10 vs. < 10	1.64 (1.27-2.12)	1.54 (1.12-2.52)	49.4	62.7	39.1	71.8	58.4
Hypertension							
Yes vs. no	1.68 (1.30-2.17)	1.00 (0.72-1.36)	49.4	63.3	39.5	72.0	58.7

OSA: obstructive sleep apnea; AHI: apnea/hypopnea index; PPV: positive predictive value; NPV: negative predictive value; ESS: Epworth Sleepiness Scale; and NC: neck circumference. [a]Mild/moderate/severe = AHI ≥ 5.0 events/h; moderate/severe = AHI ≥ 15.0 events/h; and severe = AHI ≥ 30.0 events/h.

Table 4. ROC curves for the models evaluated, by the level of severity of obstructive sleep apnea.

Models	OSA severity, by AHI[a]		
	Mild/moderate/severe AUC (95% CI)	Moderate/severe AUC (95% CI)	Severe AUC (95% CI)
3-item Male sex Snoring BMI ≥ 42 kg/m²	0.716 (0.683-0.748)	0.739 (0.710-0.769)	0.759 (0.729-0.790)
4-item Male sex Snoring BMI ≥ 42 kg/m² Age ≥ 37 years	0.752 (0.719-0.785)	0.756 (0.727-0.784)	0.765 (0.735-0.794)
5-item Male sex Snoring BMI ≥ 42 kg/m² Age ≥ 37 years Observed apnea	0.764 (0.733-0.796)	0.765 (0.738-0.793)	0.771 (0.742-0.800)
6-item Male sex Snoring BMI ≥ 42 kg/m² Age ≥ 37 years Observed apnea NC ≥ 42 cm	0.777 (0.747-0.807)	0.784 (0.757-0.811)	0.796 (0.769-0.824)

OSA: obstructive sleep apnea; AHI: apnea/hypopnea index; AUC: area under the curve; NC: neck circumference. [a]Mild/moderate/severe = AHI ≥ 5.0 events/h; moderate/severe = AHI ≥ 15.0 events/h; and severe = AHI ≥ 30.0 events/h.

included all patients awaiting bariatric surgery, with or without symptoms of OSA.

In the present study, there were significant differences between males and females: males had higher BMIs and higher NCs, as well as a higher prevalence of hypertension, snoring, and observed apnea. In addition, males had higher AHIs, lower nadir SpO_2 values, higher arousal indices, together with a higher prevalence of moderate/severe and severe OSA. These differences between sexes have also been reported in some other studies of bariatric surgery patients.[9-11,13,15,21-23,25,30]

Patients awaiting bariatric surgery should be screened for OSA to decrease the occurrence of peri-and post-operative complications. Bariatric surgery is the most effective weight loss therapy for morbidly obese patients; it improves OSA in most patients and has a relatively low mortality rate.[4] Due to the high prevalence of OSA, especially of the severe forms, previous studies[6,11,23,26] have underscored the need for polysomnography in all patients awaiting bariatric surgery, regardless of the presence or absence of symptoms of OSA.

Our study has some limitations. Patient selection occurred retrospectively in a sleep laboratory, which increased the possibility of selection bias. In addition, this was a single-center study, and the implications of our findings for the general population might therefore be limited. Furthermore, we did not evaluate comorbidities (other than hypertension) or other sleep complaints such as nocturia, nasal symptoms, morning headaches, and nocturnal choking or gasping. Moreover, data regarding regional obesity (waist circumference, hip circumference, neck-to-waist ratio, or waist-to-hip ratio) were not available. Conversely, our study has certain strengths. First, it involved a large sample of consecutive patients, all of whom were evaluated with full polysomnography at a sleep center, regardless of whether or not they had sleep complaints. In addition, the medical charts of the patients included in our final sample contained complete information about all eight of the variables of interest. Furthermore, the possibility of confounding was reduced in the analysis by the use of a multivariate logistic model including all variables with a p-value < 0.05. Therefore, we believe that the limitations of the study were outweighed by its strengths and did not affect the interpretation of the results.

In conclusion, our findings suggest that, among patients awaiting bariatric surgery, there is a high prevalence of OSA in general and of moderate/severe OSA. Our data also indicate that the variables sex, age, NC, BMI, ESS score, snoring, observed apnea, and hypertension can be used in order to confirm the suspicion of OSA and to assess its severity. The 6-item NO-OSAS model, at a cut-off value ≥ 3 to identify high-risk patients, showed good diagnostic accuracy for OSA in general, as well as for moderate/

Table 5. Predictive parameters of the 6-item model in relation to the level of severity of obstructive sleep apnea.

OSA severity, by AHI[a] Parameter	High risk n (%)	Low risk n (%)	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %	OR (95% CI)
Mild/moderate/severe								
≥ 1 vs. < 1	1,056 (97.0)	33 (3.0)	98.8	8.7	76.2	72.7	76.1	8.55 (3.92-18.64)
≥ 2 vs. < 2	915 (84.0)	174 (16.0)	91.0	36.7	80.9	58.0	77.3	5.89 (4.18-8.30)
≥ 3 vs. < 3	689 (63.3)	400 (36.7)	74.3	69.4	87.8	47.7	73.0	6.58 (4.87-8.89)
≥ 4 vs. < 4	431 (39.6)	658 (60.4)	48.7	87.6	92.1	36.6	58.5	6.74 (4.59-9.91)
≥ 5 vs. < 5	187 (17.2)	902 (82.8)	22.6	98.9	98.3	30.1	41.8	26.48 (8.38-83.59)
6 vs. < 6	52 (4.8)	1,037 (95.2)	6.3	100.0	100.0	26.5	30.0	-
Moderate/severe								
≥ 1 vs. < 1	1,056 (97.0)	33 (3.0)	99.4	5.7	53.3	90.9	54.4	11.42 (3.46-37.64)
≥ 2 vs. < 2	915 (84.0)	174 (16.0)	95.7	28.6	59.2	86.2	63.5	9.08 (5.78-14.25)
≥ 3 vs. < 3	689 (63.3)	400 (36.7)	82.8	57.9	68.0	75.7	70.8	6.65 (5.03-8.80)
≥ 4 vs. < 4	431 (39.6)	658 (60.4)	59.3	81.8	77.9	65.0	70.1	6.58 (4.98-8.69)
≥ 5 vs. < 5	187 (17.2)	902 (82.8)	29.8	96.5	90.3	55.9	61.8	11.94 (7.21-19.75)
6 vs. < 6	52 (4.8)	1,037 (95.2)	8.6	99.4	94.2	50.1	52.2	16.42 (5.08-53.04)
Severe								
≥ 1 vs. < 1	1,056 (97.0)	33 (3.0)	99.7	4.3	33.6	96.9	35.5	16.20 (2.20-119.07)
≥ 2 vs. < 2	915 (84.0)	174 (16.0)	97.4	22.5	37.9	94.8	47.0	11.20 (5.65-22.19)
≥ 3 vs. < 3	689 (63.3)	400 (36.7)	90.1	49.7	46.5	91.2	62.9	9.09 (6.23-13.27)
≥ 4 vs. < 4	431 (39.6)	658 (60.4)	69.9	75.1	57.7	83.7	73.4	7.04 (5.31-9.33)
≥ 5 vs. < 5	187 (17.2)	902 (82.8)	39.0	93.4	74.3	75.9	75.6	9.14 (6.36-13.12)
6 vs. < 6	52 (4.8)	1,037 (95.2)	12.6	99.0	86.5	70.0	70.2	15.00 (6.69-33.64)

OSA: obstructive sleep apnea; AHI: apnea/hypopnea index; PPV: positive predictive value; and NPV: negative predictive value. [a]Mild/moderate/severe = AHI ≥ 5.0 events/h; moderate/severe = AHI ≥ 15.0 events/h; and severe = AHI ≥ 30.0 events/h.

severe and severe OSA. Further studies, especially prospective ones, are necessary to validate the use of the NO-OSAS model as a means of screening for OSA in bariatric surgery patients.

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