Evaluation of a prediction model for sleep apnea in patients submitted to polysomnography*

Avaliação de um modelo de predição para apneia do sono em pacientes submetidos a polissonografia

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Abstract

Objective: To test a prediction model for sleep apnea based on clinical and sociodemographic variables in a population suspected of having sleep disorders and submitted to polysomnography. **Methods:** We included 323 consecutive patients submitted to polysomnography because of the clinical suspicion of having sleep disorders. We used a questionnaire with sociodemographic questions and the Epworth sleepiness scale. Blood pressure, weight, height, and SpO_2 were measured. Multiple linear regression was used in order to create a prediction model for sleep apnea, the apnea-hypopnea index (AHI) being the dependent variable. Multinomial logistic regression was used in order to identify factors independently associated with the severity of apnea (mild, moderate, or severe) in comparison with the absence of apnea. **Results:** The prevalence of sleep apnea in the study population was 71.2%. Sleep apnea was more prevalent in men than in women (81.2% vs. 56.8%; $p < 0.001$). The multiple linear regression model, using log AHI as the dependent variable, was composed of the following independent variables: neck circumference, witnessed apnea, age, BMI, and allergic rhinitis. The best-fit linear regression model explained 39% of the AHI variation. In the multinomial logistic regression, mild apnea was associated with BMI and neck circumference, whereas severe apnea was associated with age, BMI, neck circumference, and witnessed apnea. **Conclusions:** Although the use of clinical prediction models for sleep apnea does not replace polysomnography as a tool for its diagnosis, they can optimize the process of deciding when polysomnography is indicated and increase the chance of obtaining positive polysomnography findings.

Keywords: Sleep apnea syndromes; Polysomnography; Sleep apnea, obstructive; Body mass index.

Resumo

Objetivo: Testar um modelo de predição para apneia do sono a partir de variáveis sociodemográficas e clínicas em uma população com suspeita de distúrbio do sono e submetida à polissonografia. **Métodos:** Foram incluídos no estudo 323 pacientes consecutivos submetidos à polissonografia por suspeita clínica de distúrbio do sono. Utilizou-se um questionário com questões sociodemográficas e a escala de sonolência de Epworth. Foram medidos pressão arterial, peso, altura e SpO_2. A regressão linear múltipla, tendo o índice de apneia-hipopneia (IAH) como variável dependente, foi utilizada para construir um modelo de predição de apneia do sono. A regressão logística multinomial foi realizada para verificar fatores associados de forma independente à gravidade da apneia (leve, moderada ou grave) em comparação à ausência de apneia. **Resultados:** A prevalência de apneia do sono na população de estudo foi de 71,2%, e foi mais prevalente nos homens que nas mulheres (81,2% vs. 56,8%; $p < 0,001$). O modelo de regressão linear múltipla, com o log IAH como variável dependente, foi composto pelas seguintes variáveis independentes: circunferência do pescoço, apneia testemunhada, idade, IMC e presença de rinite alérgica. O melhor modelo de regressão linear encontrado conseguiu explicar 39% da variabilidade do IAH. Na regressão logística multinomial, a apneia leve esteve associada com IMC e circunferência do pescoço, e a apneia grave associou-se com idade, IMC, circunferência do pescoço e apneia testemunhada. **Conclusões:** Modelos de predição clínica para apneia do sono não substituem a polissonografia como ferramenta para o seu diagnóstico, mas podem otimizar sua indicação e aumentar a chance de positividade do exame.

Descritores: Síndromes da apneia do sono; Polissonografia; Apneia do sono tipo obstrutiva; Índice de massa corporal.

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Introduction

Sleep-disordered breathing is defined as a syndrome in which the frequency and severity of events are pathophysiologically associated with adverse health symptoms or outcomes.

The frequency of apnea and hypopnea is expressed by the apnea-hypopnea index (AHI), which corresponds to the sum of the number of apneas and hypopneas divided by the total hours of sleep. Severity is classified, based on the AHI, as mild (5-15 events/h), moderate (15-30 events/h), or severe (> 30 events/h).[1]

A population-based study conducted in the city of São Paulo, Brazil, and using the second edition of the International Classification of Sleep Disorders, published by the American Academy of Sleep Medicine in 2005, showed the overall prevalence of obstructive sleep apnea to be 32.8% in the population studied.[2]

When an AHI ≥ 5 events/h was used as the diagnostic criterion, the prevalence of sleep apnea in men tested in sleep laboratories was found to be 17-26%.[3]

A prospective study on sleep conducted in the state of Wisconsin, USA, showed that, in terms of body weight, being 10% heavier at baseline was predictive of a 32% increase in the AHI (95% CI: 20-45%).[4] Conversely, being 10% lighter at baseline predicted a 26% decrease in the AHI (95% CI: 18-34%). Sleep apnea is also common in patients with craniofacial abnormalities.[5]

Sleep fragmentation with arousals at the end of an apneic episode causes excessive sleepiness in some patients. Apnea-related variations in sympathetic discharge produce a specific pattern of oxyhemoglobin desaturation followed by normalization of saturation, potentially damaging the neurons that promote wakefulness.[6,7] This injury contributes to learning disorders and is a possible explanation for the residual sleepiness found in sleep apnea patients despite appropriate treatment.[5]

Heart rate and arterial pressure increase approximately five to seven seconds after the end of apnea, coinciding with arousal and oxyhemoglobin desaturation.[8,9]

There seems to be a relationship between apnea severity and the development of arterial hypertension, an association that persists even after adjustments have been made for confounding variables.[4] Patients in whom severe sleep apnea goes untreated have been shown to be at a higher risk for cardiovascular events in a 10-year follow-up period than are controls with similar degrees of obesity.[10]

Overnight polysomnography is indicated for the diagnosis of various sleep disorders, especially respiratory disorders.[1] Portable systems for home sleep monitoring are quickly becoming widely available on the market and are principally being used for the diagnosis of obstructive sleep apnea-hypopnea. The American Sleep Disorders Association recommends that this monitoring be restricted to patients with acute clinical symptoms or to settings in which classic polysomnography is not available. Its use is also acceptable in the treatment of patients who have already been diagnosed through conventional polysomnography.[11] The clinical impression alone has low accuracy for the diagnosis of sleep-disordered breathing, and polysomnography therefore remains indispensable.[12,13] A meta-analysis of clinical studies for the diagnosis of obstructive sleep apnea revealed that clinical models have higher OR values for diagnosis and severity than do questionnaire-based models (10.49 and 17.24 vs. 5.02 and 10.12, respectively).[14] In that study, the clinical elements associated with an OR > 2 were BMI, arterial hypertension, and a history of nocturnal choking. The Epworth sleepiness scale showed an OR of 0.43 for diagnosis (95% CI: 0.13-1.48). Therefore, there is still a need for testing models that can improve the prediction of these disorders, optimizing the process of deciding when polysomnography is indicated. The overall objective of the present study was to test a clinical model designed to predict AHI based on clinical and sociodemographic variables in a population clinically suspected of having sleep disorders and referred for polysomnography.

Methods

This was a cross-sectional observational study. The study population comprised 323 consecutive patients referred, by physicians working within the private health care system in Brazil, to a sleep laboratory for polysomnography between December of 2006 and March of 2007. In all cases, the reason for the referral was clinical suspicion of having sleep disorders (snoring, sleep apnea, insomnia, excessive

daytime sleepiness, and periodic leg movements in sleep).

The exclusion criteria were being pregnant, being under 18 years of age, having a psychiatric disorder (history, treatment, or use of medications) or a mental disorder that prevented the completion of the questionnaires, being illiterate, and being or having been under treatment for sleep apnea.

The study was approved by the Research Ethics Committee of the Federal University of Minas Gerais (ruling no. 2006205212), and all participating patients gave written informed consent.

We used a general questionnaire, which was standardized by the clinical team and adapted to the study, containing questions related to sociodemographic, clinical, and lifestyle variables, together with the Epworth sleepiness scale (ESS).[15,16] The ESS is designed to measure subjective daytime sleepiness. It was developed in 1991[15] and has been validated for use in Brazil.[17] An ESS score of 10 was used as the cut-off point for distinguishing between normal and abnormal levels of daytime sleepiness.[16]

Arterial pressure, expressed in mmHg, was measured with a Missouri device (Embu, Brazil) by the indirect method, with auscultation. Patients with an arterial pressure ≥ 140/90 mmHg or being treated with antihypertensive medication were defined as having systemic arterial hypertension.[18]

Height, in centimeters, was measured with a stadiometer (Welmy S.A., Santa Bárbara do Oeste, Brazil). Weight, in kilograms, was measured with a scale (Welmy S.A.) The BMI was calculated as the weight in kilograms divided by the square of the height in meters weight (kg/m^2). Patients with a BMI of 25.0-29.9 kg/m^2 were classified as overweight, those with a BMI of 30.0-39.9 kg/m^2 were classified as obese, and those with a BMI > 40.0 kg/m^2 were classified as morbidly obese. Neck circumference, in centimeters, was measured at the level of the cricoarytenoid joint with a tape measure.

Overnight polysomnography with the recording of 16 channels for a minimum of 6 hours was conducted by a duly trained professional technician. All tests were performed with an Alice® 3 polysomnography system (Respironics, Murrysville, PA, USA).

Resting heart rate was measured with the electrocardiogram sensor of the polysomnography system, there being a rest period of at least 5 min.

Oxyhemoglobin saturation was measured with a digital oximeter (Healthdyne Technologies, Marietta, GA, USA).

The parameters for defining the events and syndromes, for establishing the degrees of severity, and for standardizing the measurement methods, as well as the technical considerations that were used for interpreting the polysomnography findings, making the diagnosis, and issuing the final polysomnography report, were those established by the American Academy of Sleep Medicine.[1]

The STATA statistical program, version 9.2 (Stata Corp., College Station, TX, USA), was used for statistical analysis.

Variables with normal distribution are expressed as means and standard deviations, whereas variables whose distribution is asymmetric or unknown are expressed as medians and interquartile ranges.

Pearson's chi-square test was used for determination of statistical significance for comparison of categorical variables. The Student's t-test was used for comparison of the means of the continuous variables with normal distribution, whereas the nonparametric Mann-Whitney test was used for comparison of the medians of the variables whose distribution was asymmetric or unknown.

Multiple linear regression was used in order to create a prediction model for sleep apnea, the AHI being the dependent variable. The variables that maintained a statistically significant association ($p < 0.05$) in the multivariate analysis remained in the final model. The linear regression model chosen was the one with the highest coefficient of determination (R^2) and whose variables showed, in addition to a statistically significant association, a strong clinical association with the AHI, based on data in the literature.

The F statistic was used for testing the statistical significance of the inclusion of each dependent variable in the model. The coefficient of determination R^2 was used for calculating the proportion of the total variation in AHI explained by each independent variable and by the set of independent variables. The adjusted

coefficient of determination R^2 was used for measuring the increase in variation explained in the multivariate model, after it had been decided that the variation in R^2 was simply random.

The appropriateness of the linear regression model was tested graphically, and the assumption tests for the validity of the linear regression model available in the STATA software package were used. To fit these assumptions (normality of the distribution of residuals, homoscedasticity, and appropriateness of the model in terms of the inclusion of all relevant variables), the AHI was log-transformed, the variable "log AHI" being created.

The normality of the distribution of residuals was tested graphically and confirmed by a p value > 0.05 on the Shapiro-Wilk W test.[19]

The assumption of homogeneity of variance of residuals (homoscedasticity) was also tested graphically and with the use of the decomposition of the information matrix test (STATA IM-test) as proposed by Cameron & Trivedi for regression models.[20] The strength of the correlations among the variables included in the model was tested by examining the variance inflation factor.

The appropriateness of the model in terms of the inclusion of all relevant variables was tested with the use of linktest and ovtest. The Ramsey regression specification error test was also used.

Finally, multinomial logistic regression analysis was used for identifying factors independently associated with the severity of apnea (mild, moderate, or severe) in comparison with the absence of apnea. Initially, univariate analysis was performed to determine the association of each independent variable with mild, moderate, and severe sleep apnea. After this analysis, all variables with a p value < 0.20 in the initial analysis were included in the multivariate analysis, whereas only those with a p value < 0.05 remained in the final model. The magnitude of the association was expressed in ORs and 95% CIs.

Results

Of the 323 patients, 191 (59.13%) were male and 132 (40.87%) were female. Patient ages ranged from 18 to 79 years, the median age was 34.7 years, and the mean age was 44.6 ± 12.0 years. Approximately 75% of the patients were between 30 and 60 years of age. There was a predominance of married patients and of patients with a high level of education (90% had completed at least high school and 53.7% had completed college). Of the patients evaluated, 39.3% were overweight, 33.1% were obese, and 5.6% were morbidly obese.

Table 1 shows the gender distribution of the study population by the characteristics under investigation. There were no gender-related differences in terms of age or marital status. Men and women differed significantly in terms of the distribution of BMI values, the percentage of obese patients being higher among men and the percentage of morbidly obese patients being higher among women. The median neck circumference was 40 cm, and there was a significant gender-related difference. The comorbidities most often reported were arterial hypertension, gastroesophageal reflux, allergic rhinitis, and depression. In comparison with the men, the women more often reported hypothyroidism ($p < 0.001$), depression ($p < 0.001$), and allergic rhinitis ($p < 0.002$).

The prevalence of sleep apnea in the study population was 71.2%, sleep apnea being classified as mild in 30.7% of the cases, as moderate in 10.0%, and as severe in 22.6%. Apnea was more common among men than among women (81.2% vs. 56.8%; $p < 0.001$), as were severe cases (30.4% vs. 11.4%). The median AHI was significantly higher for men than for women (14.3 events/h vs. 6.2 events/h; $p < 0.0001$; Table 2).

Although obstructive sleep apnea was the most common type of sleep apnea among men and women, the prevalence of all types of apnea was higher among men ($p < 0.001$).

There was no significant difference between the groups of patients with and without sleep apnea in terms of age. However, the prevalence of the disease increases in parallel with increasing age (60.5% among patients aged 18-29 years vs. 85.7% among patients aged 60 years or older). There were also no significant differences between the patients with and without apnea in terms of marital status or level of education. There was a statistically significant difference between the groups of patients with and without sleep apnea in terms of BMI, the prevalence of apnea increasing in parallel with increases in BMI (45.1%, 73.2%, 82.2%, and 94.4% for

Table 1 - Sociodemographic characteristics and aspects of health of 191 men and 132 women submitted to polysomnography.[a]

Variable	Men		Women		p
Age, years					
18.0-29.9	27	14.14	16	12.12	0.136**
30.0-44.9	79	41.36	40	30.30	
45.0-59.9	66	34.55	60	45.45	
≥ 60.0	19	9.95	16	12.12	
Marital status					
Single	39	20.42	33	25.00	0.555**
Married	125	65.45	79	59.85	
Others	27	14.14	20	15.15	
Level of education					
High school (incomplete)	12	6.32	16	12.31	0.039**
College (incomplete)	66	34.74	54	41.54	
College (complete)	112	58.95	60	46.15	
BMI, kg/m^2					
18.0-24.9	33	17.28	38	28.79	0.008**
25.0-29.9	86	45.03	41	31.06	
30.0-40.0	65	34.03	42	31.82	
> 40.0	7	3.66	11	8.33	
Neck circumference in cm, median (25th/75th percentiles)	42 (40/44)		37 (34/40)		0.0001*
Self-reported morbidity					
Angina or infarction	3	1.59	3	2.38	0.614**
Hypothyroidism	6	3.24	27	21.09	0.001**
Diabetes	13	6.99	12	9.52	0.418**
Asthma	20	10.70	14	11.11	0.908**
Depression	41	21.81	72	54.96	0.001**
Allergic rhinitis	51	27.27	58	44.27	0.002**
Gastroesophageal reflux	53	28.96	39	30.23	0.808**
Arterial hypertension	55	29.57	41	32.03	0.642**

[a]Results expressed as n (%), except where otherwise indicated. *Student's t-test. *Chi-square test.

individuals classified as normal BMI, overweight, obese, and morbidly obese, respectively).

The mean neck circumference in the groups of patients with and without sleep apnea was 38 cm and 42 cm, respectively ($p < 0.001$). Arterial hypertension ($p = 0.010$) and diabetes ($p = 0.001$) were the most common comorbidities in the group of patients with sleep apnea (Table 3).

The multiple linear regression model that best fit the assumptions and obtained the highest R^2, using log AHI as the dependent variable, was composed of the following independent variables: neck circumference (cm); witnessed apnea (yes = 1); age (years); BMI (kg/m^2); and allergic rhinitis (yes = 1). This model explained approximately 39% of the variation in the log

Table 2 - Gender comparison of polysomnographic measures in the patients evaluated.

Variable	Men		Women		p*
	Median	25th/75th percentiles	Median	25th/75th percentiles	
Sleep efficiency[a]	91.14	85.63/96.04	88.91	81.38/93.59	0.0023
Sleep latency[b]	12	6/28	19	8/41	0.0016
AHI, events/h	14.3	05.9/38.0	6.2	03.1/16.7	0.0001
Mean SpO_2, %	93	92/95	94	92/96	0.0180
Minimum SpO_2, %	83	70/88	85	77/89	0.0204
SpO_2 < 90%	2.66	0.24/16.87	0.61	0.00/4.61	0.0002

AHI: apnea-hypopnea index. [a]Total sleep time/total recording time × 100. [b]Sleep induction time in minutes. *Nonparametric Mann-Whitney test (medians).

Table 3 - Sociodemographic and clinical characteristics of the groups of patients with and without sleep apnea, as determined by polysomnography, using the apnea-hypopnea index cut-off point of 5 events/h.[a]

Variable	Without apnea	With apnea	p
Gender			0.001*
Male	36 (18.85)	155 (81.15)	
Female	57 (43.18)	75 (56.82)	
Age. years			0.072*
18.0-29.9	17 (39.53)	26 (60.47)	
30.0-44.9	38 (31.93)	81 (68.07)	
45.0-59.9	33 (26.19)	93 (73.81)	
≥ 60.0	05 (14.29)	30 (85.71)	
Marital status			0.627*
Single	24 (33.33)	48 (66.67)	
Married	56 (27.45)	148 (72.55)	
Others	13 (27.66)	34 (72.34)	
Level of education			0.636*
High school (incomplete)	10 (35.71)	18 (64.29)	
College (incomplete)	36 (30.00)	84 (70.00)	
College (complete)	47 (27.33)	125 (72.67)	
BMI. kg/m^2			0.001*
18.0-24.9	39 (54.93)	32 (45.07)	
25.0-29.9	34 (26.77)	93 (73.23)	
30.0-40.0	19 (17.76)	88 (82.24)	
> 40.0	01 (05.56)	17 (94.44)	
Neck circumference in cm, median (25th/75th percentiles)	38 (35/40)	42 (39/44)	0.001**
Self-reported morbidity			
Arterial hypertension	18 (18.75)	78 (81.25)	0.010*
Allergic rhinitis	36 (33.03)	73 (66.97)	0.245*
Angina or infarction	1 (16.67)	5 (83.33)	0.515*
Asthma	11 (32.35)	23 (67.65)	0.623*
Depression	32 (28.32)	81 (71.68)	0.879*
Hypothyroidism	7 (21.21)	26 (78.79)	0.312*
Diabetes	0 (0.00)	25 (100.00)	0.001*
Gastroesophageal reflux	26 (28.26)	66 (71.74)	0.883*

[a]Results expressed as n (%), except where otherwise indicated. *Chi-square test; $p < 0.05$. **Nonparametric Mann-Whitney test.

AHI. The equation of the final linear regression model is described below:

$$log\ AHI = 4.5552 + [witnessed\ apnea \times (0.5173)] + [BMI \times (0.3803)] + [age \times (0.2604)] + [neck\ circumference \times (0.1071)] + [allergic\ rhinitis \times (-0.2510)]$$

The multinomial logistic regression analysis (Tables 4 and 5), used for investigating the association of several independent variables with the severity of sleep apnea (mild, moderate, or severe), revealed that mild apnea was significantly associated with BMI and neck circumference, whereas severe apnea was associated with age, BMI, neck circumference, and witnessed apnea.

Discussion

In the present study, sleep apnea was diagnosed in more than two thirds of the study population, suggesting that clinical screening identified and eliminated most of the false-positive results. The prevalence of sleep apnea found in the present study was much higher than that reported in studies based on the general population, although it is similar to that reported in clinical studies of populations suspected of having this disease.[21,22]

The frequency of sleep apnea was significantly higher in male patients, the male/female ratio being 1.43:1.00. More recent

Table 4 - Results of the univariate multinomial logistic regression analysis (sociodemographic aspects and objective measures), sleep apnea-hypopnea being the dependent variable categorized by severity.

Variable	SAH	OR	95% CI
Gender	mild	0.3769	0.2104-0.6752
	moderate	0.4150	0.2121-0.8123
	severe	0.1633	0.0807-0.3304
Age	mild	1.0041	0.9797-1.0291
	moderate	1.0474	1.0173-1.0784
	severe	1.0553	1.0264-1.0849
Level of education	mild	1.2114	0.7838-1.8725
	moderate	1.3942	0.8289-2.3448
	severe	1.0242	0.6439-1.6290
Shift work	mild	2.1481	0.9790-4.7136
	moderate	1.8333	0.7221-4.6544
	severe	0.8700	0.3387-2.2348
BMI	mild	1.1146	1.0437-1.1904
	moderate	1.1925	1.1109-1.2800
	severe	1.2446	1.1610-1.3342
Neck circumference	mild	1.1592	1.0712-1.2544
	moderate	1.2451	1.1317-1.3700
	severe	1.5706	1.4069-1.7534
Weight	mild	1.0504	1.0287-1.0726
	moderate	1.0635	1.0390-1.0886
	severe	1.0907	1.0656-1.1164

SAH: sleep apnea-hypopnea; and BMI: body mass index.

population-based studies have shown prevalence ratios ranging from 2:1 to 3:1.[23] One of the hypotheses to explain this higher frequency in men is that the clinical presentation of sleep apnea is less typical in women and this would lead to underdiagnosis, which means that a gender bias is likely. The clinical presentation of sleep apnea is more typical in men, there being a higher frequency of snoring and witnessed apnea. The female population has less specific symptoms, such as depression, excessive sleepiness, and fatigue, which are often believed to have causes other than sleep apnea; this explains why these patients are less frequently referred for polysomnography. Studies of sleep apnea symptoms in clinical populations have shown that 40% of women with the disease report no witnessed apnea, nocturnal choking, or nonrestorative sleep, whereas most men do.[24]

Another group of authors, studying gender-related differences in sleep apnea and using the AHI cut-off point of 5 events/h for diagnosis, reported a prevalence of 9% for women and a prevalence of 24% for men.[25]

In the present study, sleep apnea was more common in men. However, gender was not a statistically significant factor in the final linear regression model, possibly due to the fact that gender was strongly associated with the variables that remained in the final model, especially BMI, neck circumference, and witnessed apnea.

The prevalence of obesity—overall obesity, as measured by BMI, and localized obesity, as estimated by neck circumference—was high in the study population. These two variables were also significant in predicting log AHI and were independently associated with sleep apnea of any level of severity, as shown in the multinomial regression model. In middle-aged adults, obesity is the major risk factor for sleep apnea.[5,26]

We found that sleep apnea was associated with hypertension and diabetes but not with other comorbidities or lifestyle. A population-based case-control study in which patients with sleep apnea were matched to controls for age, gender, zip code, and physician they had seen in the last 2 years revealed that treatment for cardiovascular diseases in general was more common among the patients with sleep apnea, as was treatment for arterial hypertension, congestive heart failure, cardiac arrhythmia, and chronic obstructive airway disease.[27] These

Table 5 - Results of the univariate multinomial logistic regression analysis (comorbidities, habits, signs, and symptoms), sleep apnea-hypopnea being the dependent variable categorized by severity.

Variable	SAH	OR	95% CI
Arterial hypertension	mild	1.2432	0.6193-2.4959
	moderate	1.600	0.7360-3.4780
	severe	4.875	2.4290-9.7841
Diabetes	mild	3.05	
	moderate	1.25	3.57-4.36
	severe	1.61	5.00-5.17
Myocardial infarction or angina	mild	4.60	
	moderate	1.6481	0.1010-26.8967
	severe	5.2353	0.5721-47.9113
Use of hypnotics	mild	0.6915	0.3492-1.3690
	moderate	0.6117	0.2679-1.3967
	severe	0.4043	0.1749-0.9348
Use of anxiolytics	mild	0.8971	0.4860-1.6557
	moderate	0.6778	0.3214-1.4295
	severe	0.7154	0.3619-1.4142
Smoking	mild	1.4370	0.6291-3.2827
	moderate	0.8601	0.2999-2.4670
	severe	1.3226	0.5385-3.2481
Alcohol consumption at bedtime	mild	1.9722	0.8637-4.5034
	moderate	2.2364	0.8951-5.5873
	severe	1.5033	0.5998-3.7679
Snoring	mild	4.5888	1.4620-14.403
	moderate	10.8552	1.3922-84.6406
	severe	14.0132	1.8041-108.845
Witnessed apnea	mild	2.3179	1.2929-4.1553
	moderate	2.1607	1.0998-4.2451
	severe	7.2527	3.4804-15.1138
Excessive sleepiness (ESS)	mild	1.0100	0.9498-1.0740
	moderate	1.0371	0.9669-1.1123
	severe	1.0737	1.0056-1.1463
Insomnia (*Athens* scale)	mild	0.9196	0.8694-0.9726
	moderate	0.9314	0.8721-0.9948
	severe	0.9277	0.8727-0.9862
Daytime fatigue	mild	0.7241	0.3768-1.3916
	moderate	0.8913	0.4090-1.9422
	severe	0.8330	0.4065-1.7068
Sleepiness-related traffic accident	mild	1.2747	0.4249-3.8239
	moderate	1.0741	0.2898-3.9804
	severe	2.8525	1.0151-8.0155
GHQ score	mild	0.9233	0.8573-0.9944
	moderate	0.9168	0.8399-1.0007
	severe	0.9598	0.8877-1.0377
SF-12 score	mild	1.0257	1.0054-1.0465
	moderate	1.0279	1.0040-1.0523
	severe	1.0210	0.9992-1.0432

SAH: sleep apnea-hypopnea; ESS: Epworth Sleepiness Scale; GHQ: General Health Questionnaire; SF-12: 12-Item Short-Form Health Survey.

findings are similar to ours in terms of arterial hypertension. Our finding that, in the final model, sleep apnea did not correlate with the remaining comorbidities can be explained by a lack of statistical power, due to the small number of cases.

Our linear regression model for predicting log AHI explained 39% of the variation in the variable "response". The use of upper-airway anatomical findings, identified by physical examination, as has been done in some previous studies but not in the present study, might have increased the efficiency of these models.

After adjusting for the various confounding variables in the multinomial logistic regression, we found that age, BMI, neck circumference, and witnessed apnea remained statistically associated with mild, moderate, or severe sleep apnea, BMI being the variable with the greatest strength of association for all degrees of severity. There have been several attempts to predict sleep apnea without the use of polysomnography. Those models differ in terms of the variables included and the case definitions, making it difficult to compare the results across studies.[12,13,27,28]

The use of multiple regression analyses with the inclusion of clinical variables has produced good prediction models. In a prospective study evaluating four AHI prediction models, their sensitivity was found to be high (85-98%), although their specificity was low (33-39%).[29] The variables included in those models were witnessed apnea, arterial hypertension, BMI, age, snoring, neck circumference, and gender.[30]

Our study was based on a selected population of patients, which limits the external validity of our results in terms of estimating the prevalence of sleep apnea. Although it is not possible to extrapolate our findings to the general population or to a population qualitatively different from that of the present study, the use of prediction models is an important tool for screening patients suspected of having sleep disorders and optimizing the process of deciding when polysomnography is indicated. The use of clinical and sociodemographic variables added little value to the identification of patients with sleep apnea among patients clinically suspected of having sleep disorders and referred for polysomnography. It is possible that the information included in the present study more appropriately explains the AHI variation in the general population not submitted to clinical screening.

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