

Body Fat Composition: A Predictive Factor for Obstructive Sleep Apnea

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Objective: To investigate body fat composition, measured by bioelectrical impedance assay (BIA), for predicting the presence and severity of obstructive sleep apnea-hypopnea syndrome (OSAHS). Body fat composition was also compared with other well-known OSAHS predictors such as body mass index (BMI), neck circumference, and abdominal visceral fat. **Study Design:** A prospective study was designed. Fifty-one patients (41 male, 10 female), who were referred to Hacettepe University Faculty of Medicine, Department of Otorhinolaryngology, Head and Neck Surgery with suspected OSAHS, between April 2003 and June 2004, were included in the study. **Methods:** All patients underwent polysomnography (PSG) and were classified according to their apnea-hypopnea index (AHI) into four groups. The cross-sectional area of abdominal visceral fat was measured by computed tomography (CT) scanning in 33 of the patients. Neck circumference and BMI was measured for all patients. BIA was performed to determine body fat composition. The groups were compared, and correlation of the variables with AHI was investigated. **Results:** Of the variables, BMI and percentage of body fat (determined by BIA) were found to be significantly correlated with AHI ($r = 0.782$, $r = 0.647$). CT of cross-sectional area of abdominal visceral fat provided 100% sensitivity and specificity ($P < .001$) in differentiating simple snorers from OSAHS patients. By combining percentage of body fat and body fat mass, higher levels of sensitivity (95%) and specificity (100%) were achieved for diagnosis of OSAHS. **Conclusion:** It was concluded that the BIA could be an inexpensive and practical alternative to prePSG screening tests and should be included in the evaluation of

OSAHS patients. **Key Words:** Sleep apnea, body composition, fat, screening.

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INTRODUCTION

Obstructive sleep apnea-hypopnea syndrome (OSAHS) is a condition characterized by recurrent episodes of partial or complete obstruction of the upper airway, which results in oxygen desaturation and arousals from sleep by the consecutive mechanisms. The symptoms, which include excessive daytime sleepiness, nonrefreshing sleep, daytime fatigue, and decreased concentration, may cause marked impairment in social or occupational functioning. In addition to these symptoms that negatively affect quality of life, OSAHS causes severe morbidity associated with cardiovascular and cerebrovascular systems. In The United States, it was estimated that OSAHS might be responsible for 38,000 cardiovascular deaths per year.¹ The most common manifestation of OSAHS, excessive daytime sleepiness, leads to an increased risk of traffic accidents.²

Polysomnography (PSG) is routinely indicated for the diagnosis of sleep related breathing disorders including OSAHS. Although PSG is the gold standard for the diagnosis, there are limitations because of its expense and dependence on complex technical support. If the OSAHS prevalence is as high as 2% to 4% for middle-aged adults as estimated,³ it is necessary to develop simpler and less costly alternatives for screening.

Obesity, the most common predisposing factor, increases the risk of OSAHS development by approximately 10-fold, from 2% to 4% to 20% to 40% in those with a body mass index (BMI) greater than 30.⁴ In addition to increased body weight, fat distribution plays a major role in the development of OSAHS. Visceral obesity has been recognized to be associated more often with OSAHS than other forms of obesity.^{5,6} Therefore, BMI and anthropomorphic measurements such as neck circumference, waist circumference, and skin fold thickness could be used to predict the presence of OSAHS and its severity. In the literature, it was demonstrated that an increase in BMI was related to an increase in apnea-hypopnea index (AHI).^{7,8} Neck circumference is also known as a strong predictor of AHI and OSAHS.^{7,9,10} Along with BMI and neck circumference, adipose tissue quantification of the

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abdominal and neck regions with magnetic resonance imaging (MRI) or computed tomography (CT) scanning was found to be an important factor for predicting the severity of OSAHS or AHI.^{6,8} Bioelectrical impedance assay (BIA) is one of the easiest methods to determine body composition. It measures amount of fat tissue and fat free tissue by the difference of their resistances to electrical current.

In the present study, some of the anthropometric measures, body fat composition measured by BIA and visceral abdominal fat measured by CT, were evaluated as predictors of OSAHS. The identification of reliable predictors is of considerable importance to sleep laboratories. With the help of these predictors, it is possible to determine which patients have a priority for diagnosis and must undergo PSG. Partial-time or partial-channel polysomnograms and portable devices may be used in patients who have no priority for diagnosis. This evaluation process provides more efficient use of a sleep laboratory's resources. The predictive tests for determining OSAHS should be practical and cost effective. BIA, because of it being inexpensive and easy to perform, was evaluated as a new predictive test.

MATERIALS AND METHODS

Fifty-one patients (41 male, 10 female), who were referred to Hacettepe University Faculty of Medicine, Department of Otorhinolaryngology, Head and Neck Surgery with suspected OSAHS, between April 2003 and June 2004, were included in the study. The study protocol was approved by the Hacettepe University Ethics Committee, and all patients gave written informed consent to participate in the study.

Overnight PSGs were arranged for the 51 patients, all of whom presented with suspected OSAHS based on history and current symptoms. Anthropomorphic measurements including weight, height, and neck circumference (measured at the level of cricothyroid membrane) were performed for all of the patients. Body fat composition of the patients was determined by BIA. Normal thyroid hormone levels were noted in all patients. The entire study group underwent cephalometric evaluation, and there was neither any craniofacial abnormality nor retrognathism detected.

Polysomnography

Each patient underwent overnight PSG (Somnologica 2; Flaga hf. Medical Devices, Reykjavik, Iceland) in a sleep laboratory. Each test included the following recordings: electroencephalography, electro-oculography, submental and anterior tibialis electromyography, chest and abdominal plethysmography, combined oronasal airflow by way of a thermistor, heart rate, and oxygen saturation. Apnea was defined as total cessation of airflow for at least 10 seconds. Hypopnea was defined as reduction in airflow of 50% or more for at least 10 seconds in association with arousal or a minimum 3% fall in oxygen saturation. The total number of apnea and hypopnea episodes was divided by total sleep time to calculate the apnea index and the hypopnea index. AHI was calculated by the sum of the apnea index and the hypopnea index.

OSAHS was considered to be present if AHI was 5 or greater. Patients were grouped by their total AHI. AHI ranged from 0 to 4.9 for group 1 (simple snorers), from 5 to 14.9 for group 2 (mild OSAHS), from 15 to 29.9 for group 3 (moderate OSAHS), and 30 or greater for group 4 (severe OSAHS).¹¹

Bioelectrical Impedance Assay

BIA was performed on all patients (Bodystat 1500; Douglas, Isle of Man, UK). Heavy physical exercise was restricted 24 hours before the test. Impedance was measured between the right wrist and right ankle using a tetrapolar electrode system. The subjects lay supine with arms separated from the body, and legs not touching each other. Signal electrodes were positioned in the middle of the dorsal surface of the hand and feet proximal to the metacarpophalangeal and metatarsophalangeal joints. Detecting electrodes were positioned more proximal from the others at the ankle and the wrist. An excitation current of 500 μ A at 50 kHz was applied to the distal electrodes, and the voltage was detected by proximal electrodes. The data were analyzed using the manufacturer's software, and body fat mass as well as percentage of body fat was calculated for each patient.

Abdominal Visceral Adipose Tissue by way of Computed Tomography

CT was performed on 33 patients who had agreed to the test. The CT section was obtained from the level of the umbilicus. The cross-sectional visceral adipose tissue was determined in the -40 to +140 Hounsfield units interval.

Data Analysis

The differences of normally distributed variables between groups were tested by analysis of variance and by the Tukey method for post hoc analysis. Kruskal-Wallis nonparametric test and Mann-Whitney test were used for measuring differences between groups for abnormally distributed data. Using the Pearson correlation coefficient, we assessed the correlation between concerned variables and AHI. Receiver operating characteristics (ROC) curves were used for assessing cut-off values as predictors of AHI. ROC curves were also used for evaluating sensitivities and specificities of the concordant variables. The most concordant variable was found by calculating the area under the curves of each variable. SPSS software was used for the statistical analysis (Chicago, IL). $P \geq .05$ was considered to indicate statistical significance. Bonferroni correction was applied to P values of the results that were achieved by Mann-Whitney U test.

RESULTS

All of the 51 patients (41 male, 10 female) had a PSG evaluation. Nine (17.6%) patients with AHI less than 5 were diagnosed as simple snorers. Of the remaining 42 patients, 14 (27.5%) had an AHI 5 or greater and less than 14.9 (mild OSAHS), 15 (29.4%) had an AHI greater than 15 and less than 29.9 (moderate OSAHS), and, finally, 13 (25.5%) had an AHI 30 or greater (severe OSAHS). Based on a cut-off point of 5 for AHI, these 42 (82.4%) patients were diagnosed as OSAHS. The characteristics of all 51 patients are shown in Table I. CT was performed on 6 patients from group 1, 11 patients from group 2, 8 patients from group 3, and 8 patients from group 4.

Although age was found to be significantly different between group 1 (simple snorers) and the other groups ($P < .001$), there was no significant age difference between mild, moderate, and severe OSAHS patients. Compared with group 1, there was a statistically significant difference in neck circumference in group 3 and group 4 ($P < .001$ and $P = .001$, respectively). Similarly, it was shown that the increase in percentage of body fat, measured by BIA, and cross-sectional abdominal visceral adipose tissue area, measured by CT, represented the increase in AHI. Where the percentage of body fat was concerned, a statis-

TABLE I.
Summarized Characteristics of the Study Group.

Variables	AHI			
	0–4.9	5–14.9	15–29.9	≥30
Number of patients (%)	9 (17.6)	14 (27.5)	15 (29.4)	13 (25.5)
Age	32 (26–35)	47.5 (35–60)	45 (28–60)	50 (41–59)
BMI	25.2 ± 1.5	27.4 ± 2.7	30.2 ± 2.6	33 ± 2.5
Neck circumference (cm)	39 (33.5–42.5)	40 (36–42)	41 (34–45.5)	43 (36–45)
Parameters determined by BIA				
Body fat mass (kg)	13.5 (12.1–20.9)	17.8 (12.2–28.6)	23.9 (17.7–30.7)	30.7 (21.7–40.1)
Percentage body fat (%)	17.8 (17.2–26)	24.4 (17.9–38.7)	28.3 (21.9–38)	35.1 (26.1–41)
Parameters determined by CT				
Cross-sectional abdominal visceral adipose tissue area (cm ²)	91 (85.4–104)	140.7 (108.4–263.3)	163.8 (123–235)	178 (130–234)

Data are presented as mean ± standard deviation and median (minimum–maximum). Median and ranges for abnormally distributed variables, mean and standard deviation for normally distributed variables are shown for each group. AHI = Apnea/hypopnea index; BMI = body mass index; BIA = bioelectrical impedance assay; CT = computed tomography.

tically significant difference between all groups was observed ($P < .01$). Compared with group 1, cross-sectional abdominal visceral adipose tissue area had significant differences in all other groups (P values for the differences between group 1 and 2, group 1 and 3, and group 1 and 4 were .01, .02, and .02, respectively).

Bivariate analysis revealed significant correlations between AHI and BMI, body fat mass and percentage body fat measured by BIA, cross-sectional abdominal visceral adipose tissue area measured by CT, neck circumference, and age. The Pearson correlation coefficients and P values of the variables are shown in Table II. Body fat mass and BMI had the highest Pearson correlation coefficients ($r = 0.782$, $P < .001$ for both). Percentage of body fat also had a highly significant correlation with AHI ($r = 0.647$, $P < .001$). In addition, the cross-sectional abdominal visceral tissue and the neck circumference had statistically significant correlations with AHI ($r = 0.481$, $P = .005$ and $r = 0.516$, $P < .001$). Age had the weakest correlation with AHI among all other variables ($r = 0.370$, $P < .008$).

TABLE II.
Pearson Correlation Coefficients and their Significance for Each Variable.

Variables	n	r Value	P Value
Age	51	0.370	.008
BMI	51	0.782	<.001
Neck circumference	51	0.516	<.001
Parameters determined by BIA			
Body fat mass	51	0.782	<.001
Percentage body fat	51	0.647	<.001
Parameters determined by CT			
Cross-sectional abdominal visceral adipose tissue area	33	0.481	.005

Higher r values indicate higher correlation of the variables with apnea/hypopnea index.

BMI = body mass index; BIA = bioelectrical impedance assay; CT = computed tomography.

ROC curves indicated that percentage of body fat is a good predictor for the presence of OSAHS. If percentage of body fat measured by BIA was greater than 25.95%, OSAHS could be predicted with 100% specificity and 69% sensitivity. With the combination of body fat mass and percentage of body fat (both measured by BIA), the best balance of sensitivity and specificity was achieved. A person with a body fat mass greater than 15.1 kg and a percentage of body fat greater than 25.95% could be diagnosed as OSAHS with 100% specificity and 95% sensitivity. Cross-sectional abdominal visceral adipose tissue provided the best sensitivity (100%) and specificity (100%) for predicting the diagnosis of OSAHS. OSAHS could be precisely diagnosed if the cross-sectional abdominal visceral adipose tissue area is larger than 106.2 cm². ROC curves, coordinates of the curves, and the area under the curve for each variable that represented the power of concordance are shown in Figure 1, Table III, and Table IV.

DISCUSSION

In practice, most assessments of obesity are based on anthropomorphic measurements, various body diameters, and circumferences. BMI has been the most widely used parameter to describe obesity. It is known that there is a strong correlation between the degree of sleep-related breathing disorders and anthropomorphic measurements of obesity. Hoffstein and Mateika¹⁰ found that apneic patients had significantly higher BMI and neck circumferences than nonapneic controls. In their study, the mean BMI and neck circumference was 32.3 (±7.6) and 42.7 (±4.4), respectively, in the apneic group, whereas the mean BMI and neck circumference was 28 (±5.3) and 38.4 (±3.9) in the nonapneic group. After performing multivariate analyses, Schafer et al.⁸ suggested that the percentage of body fat, measured by BIA, and BMI were the only significant predictors for identifying the presence of OSAHS, defined as AHI greater than 10, among other demographic, anthropomorphic, and biochemical variables. In addition to age and neck circumference, BMI is

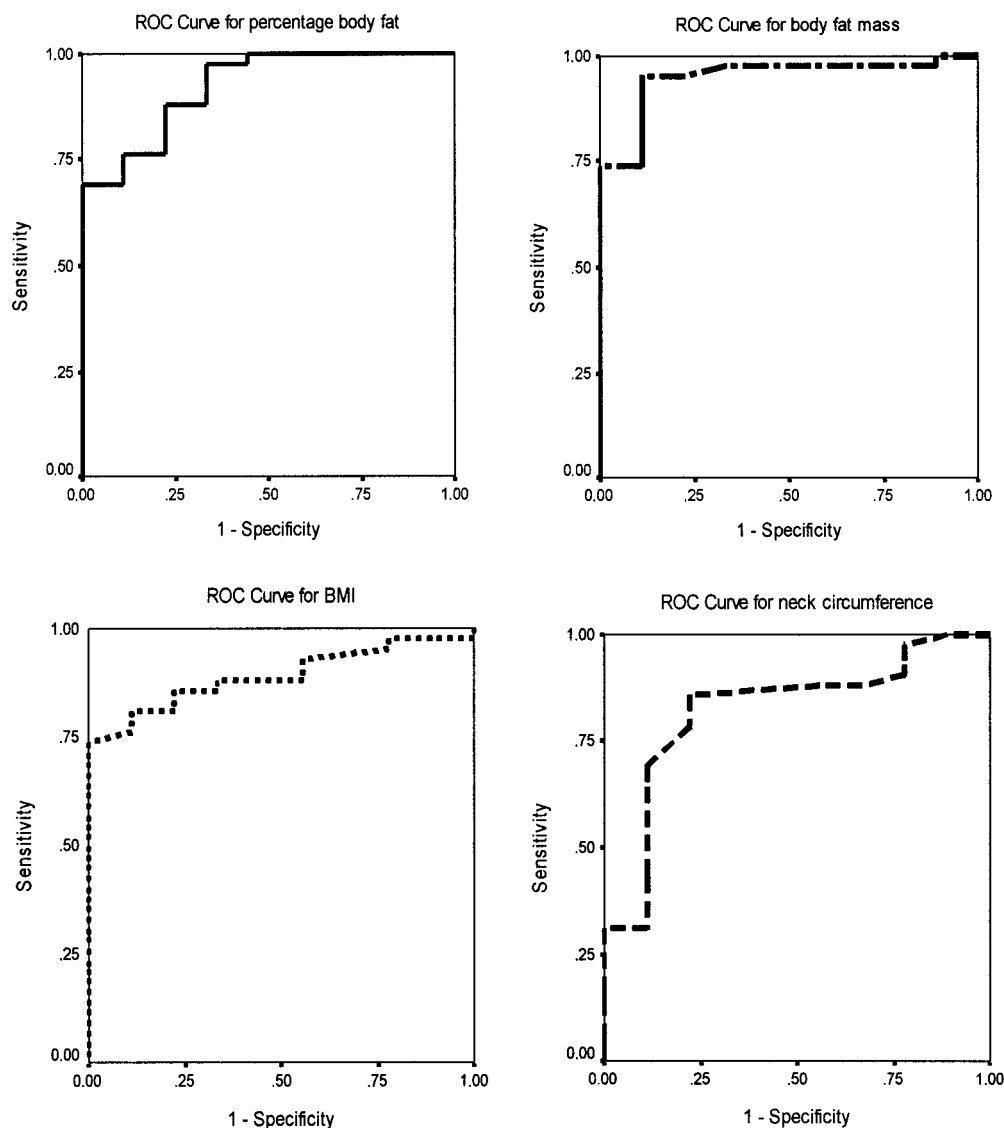


Fig. 1. ROC curves of the percentage of body fat, body fat mass, BMI, and neck circumference. X-axis represents 1- specificity (false positives) while Y-axis represents sensitivity.

one of the most popular variables used in equations for prediction of AHI.¹²

In our study group, BMI and body fat mass, followed by percentage of body fat, had the most significant correlations with AHI. Percentage of body fat, measured by BIA, revealed 100% specificity and 69% sensitivity in predicting the presence of OSAHS. False-negativity of 31% represented the nonobese OSAHS patients. Sensitivity of 95% was achieved by combining the percentage of body fat with another parameter measured by BIA, the body fat mass. In addition to body fat mass, combining BMI with percentage of body fat also increased the sensitivity from 69% to 74%.

Dixon et al.⁷ considered the neck circumference as the best single measure for predicting AHI ($r^2 = 0.43$). Similarly Katz et al.⁹ measured the external neck circumference in 123 snoring patients and found that the patients with OSAHS had thicker necks than those who did not have OSAHS. They also identified BMI, age, internal circumference of the pharynx, and neck circumference as

significant predictors of OSAHS, explaining 39% of the total variation in AHI in their study group by these parameters. Furthermore, they identified neck circumference as the most important predictor of OSAHS of all the parameters they studied. In contrast with these studies, in ours, neck circumference had weaker correlation coefficients than BMI and percentage of body fat. The smaller area under the ROC curve of neck circumference indicated the high number of false-negative and false-positive results in predicting OSAHS.

Adipose tissue quantification of the abdominal and neck regions by MRI and CT has been used to observe OSAHS patients. With use of MRI, it was observed that patients with OSAHS had a larger cross-sectional area of adipose tissue adjacent to the airway than control subjects.¹³ In another study performed with MRI, it was determined that the volume of the adipose tissue adjacent to the upper airway was associated with the AHI.¹⁴ In contrast with these studies, Schafer et al.⁸ reported a correlation between AHI and intraabdominal fat but not be-

Variables	Diagnosis = OSAHS if Greater Than or Equal to	Sensitivity	1 - Specificity
Cross-sectional area of	98.25	1.000	.167
abdominal visceral	*106.20	*1.000	*.000
fat (cm ²)	110.60	.963	.000
	116.00	.926	.000
BMI	22.00	1.000	1.000
	25.95	.897	.222
	26.95	.810	.111
	*27.95	*.738	*.000
	28.30	.714	.000
	30.15	.452	.000
Percentage of body fat	16.20	1.000	1.000
(%) measured by BIA	22.40	.881	.222
	25.30	.762	.111
	*25.95	*.690	.000
	26.05	.667	.000
	26.75	.571	.000
Body fat mass (kg)	12.1	1.000	.889
measured by BIA	15.1	.952	.111
	16.0	.905	.111
	21.0	.738	.000
	21.4	.714	.000
	21.9	.690	.000

Sensitivity and specificity of some of the different cut-off points of variables including body mass index (BMI), percentage of body fat, body fat mass, and cross-sectional area of abdominal visceral fat. *Best combinations of sensitivity and specificity.

BIA = bioelectrical impedance assay; OSAHS = obstructive sleep apnea-hypopnea syndrome.

tween AHI and parapharyngeal fat or AHI and neck subcutaneous fat. Visceral fat accumulation rather than subcutaneous fat was stressed by Shinohara et al.⁶ as an important risk factor for OSAHS in obese subjects. The mass load of visceral fat may cause an increase in the activities of the inspiratory muscles by restricting the motion of the diaphragm. This, in turn, results in increased inspiratory negative airway pressure leading to

Variables	Area under the Curve	Asymptotic Significance (P)
BMI	0.890	<.001
Neck circumference	0.824	.02
Body fat mass	0.948	<.001
Percentage body fat	0.923	<.001
Cross-sectional abdominal visceral adipose tissue area	1.000	<.001

Concordance of the variables increases when the area becomes closer to 1.000.

BMI = body mass index.

collapse in the upper airway. In the early stages of diet therapy and exercise training, a reduction in visceral fat, but not in the subcutaneous fat, was demonstrated.¹⁵ Even a small weight reduction was found to be associated with a significant improvement in OSAHS.¹⁶ These data prove the correlation between the OSAHS and the visceral or abdominal fat.

In agreement with the previously cited studies, cross-sectional area of abdominal visceral fat had significant correlation with AHI in our study. This variable had weaker correlations with AHI than BMI and parameters measured by BIA, but for the differential diagnosis between simple snoring and OSAHS, it was more useful. One hundred percent sensitivity and specificity indicated that the cross-sectional area of abdominal visceral fat was the most significant determinant of the presence of OSAHS. A cut-off point of 106.2 cm² area of cross-sectional abdominal visceral fat provided the exact differential diagnosis (100% sensitivity and specificity) between simple snorers and OSAHS patients in our study group. Shinohara et al.⁶ reported in their study that all of the patients with an abdominal visceral fat area of more than 220 cm² manifested OSAHS syndrome, whereas no patients with an abdominal visceral fat area of less than 120 cm² were classified as OSAHS. Shinohara et al. diagnosed sleep apnea according to apnea index (AI ≥ 5), cut-off points to predict OSAHS were higher in comparison with the present study.

Prediction equations and questionnaires have been widely used as nonsleep tests for screening OSAHS. The Epworth Sleepiness Scale, the best-known questionnaire, is reported to have limited sensitivity and specificity (42% and 64%, respectively) for diagnosis.¹² There are many variables such as BMI, neck circumference, cephalometric data, and biochemical or radiologic parameters that have been used in the prediction equations to diagnose OSAHS or to predict AHI. To the best of our knowledge, from the literature we collected, estimated sensitivity and specificity of these prediction equations are 66.5% and 88.7%, respectively.¹² In the present study, percentage of body fat and body fat mass (both measured by BIA) were suggested as significant predictors of OSAHS. The significance and specificity of diagnosis of OSAHS was found to be 100% and 69%, respectively, if percentage of body fat was equal or greater than 25.95%. In our study, it was indicated that these variables might be combined with other commonly used variables to create new equations, and BIA could be used as an alternative test before PSG for classifying patients.

BMI has been commonly used to determine obesity. It is calculated without concern for the components of weight (lean body mass, fat mass, etc.). The role of body fat composition, especially abdominal visceral fat, in OSAHS patients was proven. BIA has the advantage of determining fat composition of the body. Because of this ability, BIA is superior to BMI. Determination of body fat could be also performed with more expensive and time consuming techniques such as CT and MRI. By being easy, safe, and inexpensive, BIA should be preferred over CT and MRI.

CONCLUSION

The differentiation of severe OSAHS patients, who have priorities for PSG and treatment, from patients with

mild disease or simple snoring may increase the efficient use of sleep laboratories' resources. For this differential diagnosis, reliable predictive tests with a high diagnostic value are necessary. An ideal diagnostic test in a general population should have a relatively high specificity to minimize false-positives, yet it should also have sufficient sensitivity. Furthermore, the test should be minimally intrusive and relatively inexpensive. BIA, having sufficient sensitivity and specificity in addition to its low cost and facility, can be used as an alternative test before PSG for classifying patients, or it can be used as a screening test.

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