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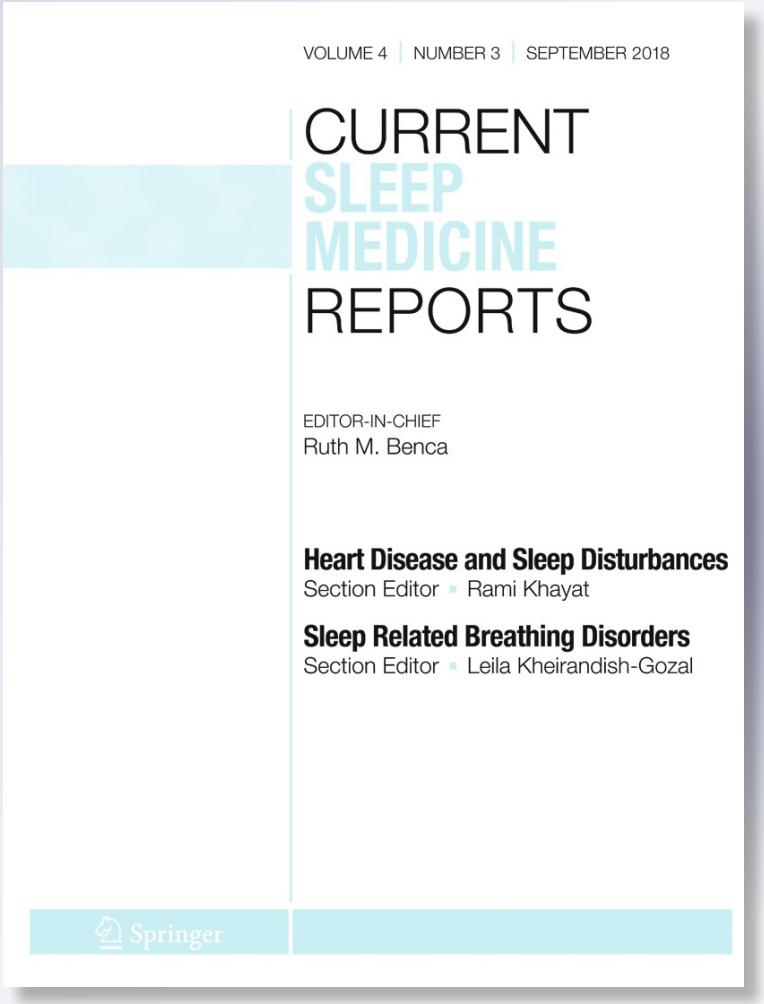

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SLEEP RELATED BREATHING DISORDERS (L KHEIRANDISH-GOZAL, SECTION EDITOR)

Screening for Sleep Apnea: When and How?

Ricardo Luiz de Menezes Duarte[1,2] · Flavio José Magalhães-da-Silveira[1] · David Gozal[3]

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Abstract

Purpose of Review Several models aimed at screening for obstructive sleep apnea (OSA) have been published, and most of these are based on questions containing clinical, demographic, and anthropometric features previously identified as OSA risk factors. Here, our main objective was to review the usefulness of some of these screening tools and delineate their performance when attempting to identify subjects at risk for OSA.

Recent Findings We evaluated some of the most cited screening tools including Sleep Apnea Clinical Score, Berlin and STOP-Bang questionnaires, Four-Variable Screening Tool, NoSAS score, and the Epworth Sleepiness Scale. Analysis of the predictive performance of the different tools is influenced by the sleep test used, the type of population studied, and the threshold of the apnea/hypopnea index used for OSA diagnosis.

Summary Nowadays, it would appear that the most employed screening instrument is the STOP-Bang questionnaire. It is a mnemonic method with eight questions dichotomized into yes-or-no responses and exhibits high sensitivity at all levels of OSA severity while also having been widely validated in several different populations.

Keywords Obstructive sleep apnea · Polysomnography · Diagnostic test · Screening

Introduction

Obstructive sleep apnea (OSA) is a very prevalent disease [1–3], especially among patients referred to a sleep laboratory, or in specific patient populations such as people undergoing preoperative assessments for bariatric surgery [4, 5], and those suffering from resistant hypertension [6, 7] or stroke [8]. The prevalence of OSA has been revisited over the last several decades and has shown increasing temporal trends, possibly due to the obesity epidemic [9] and the aging of the population [10]. The current estimated prevalence of moderate to severe OSA is around 13% among men and 6% among women [1], and that of OSA at any severity level ranging from 49.7% in men to 23.4% in women [2]. In addition, a Brazilian study with 1042 volunteers recruited from the general population and conducted in the city of Sao Paulo found an OSA prevalence of 32.8% [3]. OSA is characterized by recurrent upper airway obstructive episodes, resulting in intermittent hypoxemia, sleep fragmentation, and has been repeatedly associated with a large array of morbid consequences primarily involving the cardiovascular and metabolic systems and shown to promote increased overall mortality [11–13].

Sleep laboratories around the world have large numbers of patients with suspected OSA waiting to be tested [14–16]. To date, the gold standard for diagnosis of OSA is overnight polysomnography (PSG) in the laboratory; however, the prevalence of OSA is far higher than the volume of patients that can be handled by the available sleep laboratories around the world [16]. Due to the high prevalence of OSA, there are significant costs associated with the evaluation of all patients suspected of having OSA with PSG, especially in areas constrained by limited resources [16]. Therefore, home-based sleep apnea tests have rapidly emerged as an alternative method to diagnose OSA in adults [16]. In general, the sever-

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ity of OSA is categorized based on the apnea/hypopnea index (AHI), with an AHI from 5.0 to 14.9/h being considered as mild OSA, from 15.0 to 29.9/h being considered as moderate OSA, and ≥ 30.0/h being considered as severe OSA.

To better address the utilization of scarce PSG resources and detect those patients more likely to benefit from such onerous diagnostic test, several instruments, whether using clinical questionnaires or score-based systems, have been developed and published in the literature. In general, these instruments are based on questions containing clinical, demographic, and anthropometric risk factors associated with OSA [17••, 18••]. The comparison among the several screening tools is challenging, since their performance may vary according to several factors involved in their evaluation: (i) different tests used for diagnosis and classification of OSA severity (PSG types I-IV), (ii) the type of population recruited (general population, sleep laboratory patients, surgical patients, or those suffering from a well-defined co-morbidity or disease), and (iii) differences in the AHI threshold used to diagnose OSA and to assess its severity. The main advantages of using screening instruments in the identification of patients at high-risk for OSA can be summarized as follows: (i) to provide faster sleep testing access for very symptomatic patients; (ii) to offer portable diagnostic methods to high-risk patients, especially in areas with limited resources, reducing the long waiting times for in-lab PSG [19]; and (iii) to offer PSG to surgical patients with high risk for OSA, therefore allowing for preoperative implementation of treatment with continuous positive airway pressure (CPAP) and thereby reducing postoperative complications [20, 21•, 22, 23]. Interestingly, the US Preventive Services Task Force found insufficient evidence to the use of screening for or treatment of OSA in asymptomatic adults or adults with unrecognized symptoms [24•].

OSA Predictors

Among the several recognized OSA risk factors, the most widely used in screening instruments include gender, age, body mass index (BMI), neck circumference (NC), snoring, observed apnea, abrupt awakenings accompanied by gasping/choking, tiredness, hypertension, and excessive daytime somnolence. Obesity is possibly the most important OSA predictor being extremely common in patients diagnosed with OSA [3–5, 25]. The pathophysiology of OSA in obese adult subjects remains poorly understood, but it is believed that this process is multifactorial, whereby the principal mechanism seems to involve the deposition and infiltration of excessive adipose tissue within the neck structures leading to a reduction of the lumen of the upper airway, thereby increasing its propensity for collapse [25–28]. Other factors involved in the increased risk of OSA in obesity involve changes in lung volumes influencing the upper airway size and its resistance, as well as potential increases in airway inflammation that increase airway collapsibility [27, 28]. Increased body weight accelerates the progression of OSA, and conversely, weight loss either through bariatric surgery or via dietary intervention is accompanied by reductions in the severity of OSA [29–32]. In addition, obesity is commonly associated with a larger NC [33, 34]. The NC is a strong predictor of OSA, and increased values are associated with a higher risk of OSA [34]. Moreover, NC was associated with OSA severity, regardless of visceral obesity, especially in non-obese individuals [35].

Regarding gender, OSA is more common in men than in women, and among women, the prevalence is higher in the postmenopausal phase indicating a major role for hormonal regulation of upper airway reflexes and collapsibility [36, 37]. In addition, when postmenopausal women undergo hormone replacement therapy, they seem to have a lower risk of OSA [37]. The pharyngeal airway length is substantially longer in men compared with women, and the increased length is obviously a facilitator of upper airway collapsibility [38]. There is also an increased cross-sectional area of the soft palate and an increased airway volume in men compared with women [38]. These findings show that the male airway is substantially more collapsible than the female airway [38]. Other factors that may explain the difference between genders are deleterious effects of male sex hormones and/or protective effects of female sex hormones [36]. Progression through menopause is associated with greater sleep-disordered breathing (SDB) severity, and this association is independent of aging and of changes in body weight [39]. According to clinical complaints, men with OSA more frequently present with typical symptoms, such as snoring and observed apnea; in contrast, women with OSA often have atypical symptoms, such as insomnia, morning headaches, and daytime fatigue [40–45]. In general, women with OSA are older, more obese, and with increased prevalence of co-morbidities (hypertension and diabetes) than men with OSA [43]. Conversely, NC tends to be greater in men than in women [46]. Based on polysomnographic findings, women present a lower OSA prevalence and evidence of poor sleep quality compared to men [41–46]. In addition, women have decreased total sleep time and sleep efficiency when compared to men [43].

The prevalence of OSA increases with age, with studies reporting an increase in its prevalence in elderly individuals [47, 48]. The proposed mechanisms for increasing the prevalence of OSA in the elderly include increased fat deposition around the pharynx, stretching of the soft palate, and decreased respiratory chemoreceptor and overall reflex responsiveness [49]. Elderly individuals may show an exceedingly high prevalence of OSA and are often not diagnosed, because of the misperception that the symptoms in this population are due to aging rather than to OSA.

The presence of hypertension in a patient with symptoms suggestive of OSA increases the likelihood of OSA, especially

in individuals with resistant hypertension [29, 50]. Furthermore, long-term use of CPAP promotes better blood pressure control in patients with OSA and resistant hypertension, as reflected by significant reductions in mean arterial pressure and the ability to reduce the number of antihypertensive drugs [51]. Similarly, in patients with OSA and resistant hypertension, CPAP treatment for 12 weeks resulted in a decrease in 24-h mean and diastolic blood pressures and significant improvements in nocturnal blood pressure patterns [52].

A previously published systematic review [53•] evaluated how well clinical examination findings were capable of identifying patients with OSA: the most useful item was "nocturnal choking or gasping" (summary likelihood ratio [LR] 3.3; 95% confidence interval [CI] 2.1–4.6) when the diagnostic criterion was set at AHI ≥ 10.0/h). Snoring is very common in patients with OSA, but this symptom was not useful for establishing the diagnosis (summary LR 1.1; 95% CI 1.0–1.1) [53•]. Other symptoms frequently associated with OSA include morning headache, observed apnea, fatigue, and excessive daytime sleepiness but were not as discriminative [53•]. Moreover, among patients referred for sleep evaluation, those with OSA weighed more (summary BMI 31.4; 95% CI 30.5–32.2) than those without OSA (summary BMI 28.3; 95% CI 27.6–29.0; $p < 0.001$ for the comparison), but BMI was not sufficient to increase the performance of a constellation of symptoms or physical examination signs in the screening for OSA [53•].

Evaluation of Screening Instrument Performance

The performance of prediction models can be assessed using a variety of different methods: (i) predictors parameters obtained by 2 × 2 contingency tables (Tables 1 and 2), (ii) discriminatory ability, (iii) calibration, and (iv) overall performance assessed by Nagelkerke R^2 and Brier scores [54•]. Discrimination, i.e., the ability of a model to distinguish between patients with and without specific conditions, is estimated from the area under the curve (AUC) [54•]. The AUC may theoretically range from 0.5 (discrimination equivalent to that of pure random chance) to 1.0 (perfect discrimination) [54•]. For a binary outcome, the area under the receiver operating characteristic (ROC) curve is generally used, which plots the true positive rate against false-positive rate for consecutive cut-off points for the probability of a defined condition being present or absent [54•]. In addition, it is possible to compare the AUCs obtained by different screening approaches using previously described algorithms [55, 56].

Calibration is related to goodness-of-fit and refers to the agreement between observed outcomes and predictions, being that it is assessed by Hosmer-Lemeshow chi-square test (a p value < 0.05 indicates poor calibration) [54•]. Overall performance (how well the model predicts the likelihood of an outcome in an individual patient) can be assessed using the Nagelkerke R^2, which ranges from 0 to 1 [54•]. Using the 2 × 2 contingency tables, the following parameters can be calculated: sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, LR, and odds ratio (OR) [53•]. In general, a high sensitivity is a basic requirement for any screening instrument and will enable a quick prediction of OSA risk, particularly in areas of high OSA prevalence [17••, 18••]. Both sensitivity and specificity are not influenced by the prevalence of the disease; however, predictive values are largely dependent on disease prevalence in the examined population. Positive LR is the best indicator for ruling-in diagnosis, while negative LR is a good indicator for ruling-out the diagnosis [53•].

Screening Instruments

Several screening instruments for OSA in adults have been described in the literature and include the Sleep Apnea Clinical Score (SACS) [57], Berlin questionnaire [58], STOP and STOP-Bang questionnaires [59], Four-variable screening tool [60], and NoSAS score [61]. Interestingly, the performance of an OSA screening tool may exhibit considerable variability, which is usually related to the patient population and AHI thresholds employed [17••, 18••]. For example, the Berlin questionnaire has a better performance in primary care settings than in patients evaluated in sleep clinics or sleep laboratory settings [62, 63]. The sensitivity and specificity of a screening tool are usually inversely related, and therefore high sensitivity often comes at the cost to specificity. Therefore, in terms of OSA screening, it is more important that a screening test will exhibit a high sensitivity, and therefore does not miss many patients with this disorder, rather than a high specificity [64]. A previous systematic review [17••] recommended the use of STOP and STOP-Bang as screening tools for OSA in the surgical population because of their higher methodological quality and ease-of-use features compared with other instruments. However, a previous meta-analysis [18••] reported that among screening tools, the Berlin questionnaire had the highest diagnostic OR. In a previous study [65], when compared with the Berlin questionnaire, STOP, and Epworth Sleepiness Scale (ESS), the STOP-Bang showed improved accuracy for detecting mild, moderate, and severe OSA. Therefore, the authors suggested the use of the STOP-Bang questionnaire mainly in areas with limited resources [65].

Epworth Sleepiness Score

The Epworth Sleepiness Score (ESS) [66] is an eight-item questionnaire that assesses the subjective likelihood of falling asleep in various settings. Each item is scored from zero

Table 1 Evaluation of a screening model by 2 × 2 contingency table

Screening model	Subjects with the disease	Subjects without the disease	Total
Positive	a (TP)	b (FP)	a + b (TP + FP)
Negative	c (FN)	d (TN)	c + d (FN + TN)
Total	a + c (TP + FN)	b + d (FP + TN)	a + b + c + d (TP + TN + FP + FN)

TP true positive, *FP* false positive, *FN* false negative, *TN* true negative

(would never doze) to three (high chance of dozing), totaling a score of 0–24 points. A score ≥ 11 points is commonly used as being indicative of excessive daytime sleepiness. Although ESS is not a tool that was developed for screening of OSA but rather for excessive daytime sleepiness, it has been widely used in OSA-related studies. Unfortunately, some studies show a poor utility of ESS as a screening instrument for OSA [67–69]. A possible explanation for the poor ESS performance in screening OSA is that it is based on the level of excessive daytime sleepiness, which is not always present in individuals with OSA. In addition, the ESS is poorly correlated with the severity of OSA [70], even if subjects diagnosed with OSA and excessive daytime sleepiness reported shorter sleep latency, increased sleep efficiency, and worse nocturnal oxygenation than those without excessive daytime sleepiness [70].

Sleep Apnea Clinical Score

This screening tool includes four parameters: NC, hypertension, habitual snoring, and reports of nocturnal gasping/choking, with a final score ranging from 0 to 110 points [57]. Subjects with the highest clinical score had an LR and post-test probability of OSA of 5.17 and 81%, respectively. In contrast, subjects with the lowest clinical score had an LR of 0.25 and a post-test probability of OSA of 17% [57]. The SACS score was validated in postsurgical patients to identify patients who desaturated in the postoperative period [71]. Using SACS, a large follow-up prospective study reported that a higher risk of OSA was associated with a much higher likelihood of postoperative desaturations [72]. In addition, postoperative respiratory events were also associated with a high SACS (OR 3.5, $p < 0.001$) [72]. An earlier study evaluated the performance of nine available instruments for assessing the likelihood of OSA, with the SACS showing the highest positive LR (5.6) and PPV (95.2%) [73].

Berlin Questionnaire

The Berlin questionnaire is a useful tool for screening OSA risk in the general population. Its properties in the primary care setting were initially assessed on 744 subjects who were undergoing portable sleep monitoring [58]. This model has three sections: (i) snoring-related behaviors, (ii) daytime fatigue and sleepiness during daily activities, and (iii) obesity and hypertension. The questionnaire requires that two of the three categories will test as being positive before the results can be considered as indicative of a high probability of OSA being present. The Berlin questionnaire [58] identified, in a primary care population, 37.5% of patients as being at high-

Table 2 Predictive parameters obtained by 2 × 2 contingency table

	Definition
Sensitivity	Proportion of people with a positive test result among those with the disease (TP/TP + FN)
Specificity	Proportion of people with a negative test result among those without the disease (TN/TN + FP)
PPV	Probability of having the disease in a subject with a positive test result (TP/TP + FP)
NPV	Probability of not having a disease in a subject with a negative test result (TN/ FN + TN)
Accuracy	Proportion of those individuals with disease who had a positive test plus those without disease who had a negative test result (TP + TN/TP + FP + FN + TN)
LR+	The likelihood ratio for a positive result (LR+) shows how much the odds of the disease increases when a test is positive, being calculated as sensitivity/(1 − specificity)
LR−	The likelihood ratio for a negative result (LR−) shows how much the odds of disease decreases when a test is negative, being calculated as (1 − sensitivity)/specificity
Odds ratio	It is the positive likelihood ratio divided by the negative likelihood ratio [(LR+)/(LR−)]
Youden's Index	It can be calculated as (sensitivity + specificity) − 1. It ranges from 0 for a poor diagnostic yield and to a "perfect" value of 1.0 for a perfect diagnostic test

PPV positive predictive value, *NPV* negative predictive value, *LR+* positive likelihood ratio, *LR−* negative likelihood ratio, *TP* true positive, *FP* false positive, *FN* false negative, *TN* true negative

risk to have an AHI > 5, with sensitivity and specificity of 86 and 77%, respectively.

The predictive performance of the Berlin questionnaire for OSA, however, may vary in different patient populations: this tool showed a sensitivity of 0.62 and a specificity of 0.43 when the respiratory disturbance index threshold was set > 10/h [63]. Due to the low sensitivity and specificity, as well as the large number of false negatives and positives, the Berlin questionnaire is deemed as not being an appropriate instrument for identifying patients with OSA in a sleep clinic population [63]. In a previous study that evaluated the performance of Berlin questionnaire in the elderly with the aim to screen moderate to severe OSA, a sensitivity of 77% and a specificity of 39% were reported [74]. Thus, due to the low specificity, the Berlin questionnaire alone is not an accurate instrument for identifying elderly subjects with OSA in a general healthy population [74]. Similarly, in a cohort of 422 resistant hypertensive patients, the Berlin questionnaire had a low accuracy when identifying patients with OSA (55.6%) and should not be used as a screening method for selecting which patients with resistant hypertension should be referred for a PSG evaluation [75]. In a recent systematic review and meta-analysis, the Berlin questionnaire exhibited modest-high sensitivity and low specificity to detect clinically relevant OSA in sleep clinic patients [64]. At all levels of OSA severity (from AHI ≥ 5.0/h to AHI ≥ 30.0/h), surgical patients screened with Berlin questionnaire showed a sensitivity ranging from 68.9 to 87.2% and specificity ranging from 56.4 to 46.4%, respectively [76]. Regarding AUC, the discriminatory ability using Berlin questionnaire was of 0.690 (for any OSA), 0.672 (for moderate/severe OSA), and 0.668 (for severe OSA) [76].

STOP and STOP-Bang Questionnaires

Both instruments [59] are self-administered, easy-to-use, and consist of four or eight dichotomized (1 point for each positive answer) questions: the STOP questionnaire consists of four questions that inquire about loud snoring, tiredness, observed apnea, and hypertension (total score from 0 to 4 points), while the STOP-Bang questionnaire uses STOP parameters plus BMI > 35 kg/m^2, age > 50 years, NC > 40 cm, and male gender (total score from 0 to 8 points) [59]. The STOP and STOP-Bang questionnaires use a score ≥ 2 points and ≥ 3 points to identify subjects at risk for presence of OSA, respectively [59]. In addition, it is also possible to categorize patients according to the STOP-Bang questionnaire into three categories: low risk (from 0 to 2 points), moderate risk (3 and 4 points), and high risk (from 5 to 8 points) [77]. This mnemonic model was initially developed and validated in pre-surgical patients [59], where it showed the following sensitivities: 83.6% (for any OSA), 92.9% (for moderate/severe OSA), and 100% (for severe OSA) [59].

The STOP-Bang questionnaire has been widely validated in various and markedly different populations: sleep clinic patients [62, 78–81], surgical patients [82–84], general population [85, 86], bus drivers [87], and obese patients [88]. Although a STOP-Bang score ≥ 3 points is very sensitive (sensitivity from 91 to 100%) to detect OSA in obese and morbidly obese patients, the specificity is low (from 7 to 28%), yielding high false-positive rates [88]. Therefore, a STOP-Bang score ≥ 4 points provides a better balance between sensitivity and specificity in the obese population: in morbidly obese patients, a STOP-Bang score ≥ 4 points showed high sensitivity at all levels of OSA severity (for example, 90% for identifying severe OSA) [88].

The yield of the STOP-Bang in screening patients for OSA and its relationship with OSA probability among different populations was corroborated in a recent meta-analysis [89••]: in the sleep clinic population, aiming to detect any OSA, moderate/severe OSA, and severe OSA, the sensitivity ranged from 90 to 96%, NPV ranged from 46 to 90%, and specificity ranged from 49 to 25%; respectively. In addition, AUC was consistently > 0.72 for all OSA severities [89••]. In the surgical population, the corresponding sensitivities obtained by the STOP-Bang emerged when screening for any OSA, moderate/severe OSA, and severe OSA 84, 91, and 96%, respectively; in addition, the NPVs were 56, 84, and 97%, respectively [89••]. The specificity for any OSA, moderate/severe OSA, and severe OSA was 43, 32, and 29%, respectively, and the PPVs were 76, 46, and 24%, respectively. The AUC was consistently > 0.6 for all OSA severities [89••]. Another finding related to the STOP-Bang is that with increasing scores, the probability of having any OSA, moderate/severe OSA, and severe OSA also increases [78, 83, 88]. The specific combination of a subset of predictive factors in the STOP-Bang questionnaire may improve its specificity: for example, a STOP score ≥ 2 points, male gender, a BMI > 35 kg/m^2, and an NC > 40 cm were more predictive of OSA than age [77]. Moreover, the specificity obtained by the STOP-Bang questionnaire may be improved by the addition of serum bicarbonate levels [90].

Conversely, despite being widely validated [89••, 91], the STOP-Bang alone was insufficient to confirm significant OSA in military veterans undergoing unattended sleep studies, in whom a score of 3 points showed a high sensitivity (99.1%) but also a very low specificity (4.9%) [92]. A previous study [93] with 502 patients (465 males and 37 females) who underwent portable sleep studies showed that a STOP-Bang score ≥ 3 points predicted AHI ≥ 5/h with an AUC of 0.72 (95% CI 0.69–0.78). Sensitivity and specificity were calculated separately for males and females but yielded similar results for the two genders (sensitivity 98.8 vs. 100.0% and specificity 4.0 vs. 0.0%; respectively) [93]. However, this study had some limitations, namely that (i) few females

were included in the study, (ii) all subjects were evaluated with unattended sleep study instead of full in-lab PSG, and (iii) no comparisons between AUCs obtained in males vs. females were calculated. In another study [78] that included 1426 subjects who underwent full PSG, snoring and observed apneas were reported more frequently by males, while the responses to tiredness and hypertension were similar among the two genders. BMI and age were similar among genders as well, but males had greater NC (42.8 ± 4.2 vs. 38.0 ± 4.1 cm) [78].

Four-Variable Screening Tool

The four-variable screening tool [60] is a scoring system consisting of four variables: gender, blood pressure levels, BMI, and self-reported snoring. These four parameters are categorized as follows: (i) sex: 1 point for males; (ii) BMI (< 21.0, 21.0–22.9, 23.0–24.9, 25.0–26.9, 27.0–29.9, ≥ 30) is assigned a value between 1 and 6; (iii) blood pressure (systolic blood pressure [SBP] < 140 mmHg or diastolic blood pressure [DBP] < 90 mmHg, SBP 140–159 or DBP 90–99, SBP 160–179, or DBP 100–109, SBP ≥ 180 or DBP ≥ 110 mmHg) is assigned a value between 1 and 4; and (iv) snoring was assigned 1 for a response of snoring almost every day or often and 0 for snoring sometimes, almost never, or unknown [60]. Overall risk for each participant is calculated by adding the component scores for each variable, ranging from 2 to 18 points [60]. In the derivation dataset ($n = 307$; 33.9% females), using a cut-off point of 11, this model exhibited an AUC of 0.90, and the discriminatory ability of the model was maintained in the validation dataset ($n = 308$; 1% females) [60]. In addition, the discriminatory power of the four-variable screening tool was not significantly different from that of Multivariable Apnea Risk Index (MAP) or SACS [60].

Previously, four models (four-variable screening tool, STOP, STOP-Bang, and ESS) were evaluated based on their ability for identifying OSA: for predicting moderate/severe OSA, the STOP-Bang had the highest sensitivity (87.0%) with an AUC of 0.64, while the four-variable screening tool had the highest specificity (93.2%) and accuracy (79.4%) [85]. For predicting severe OSA, STOP-Bang showed the highest sensitivity (70.4%), while the four-variable screening tool had the highest specificity (93.2%) and accuracy (86.7%) with an AUC of 0.67 [85]. Similar findings were previously reported [94] comparing five different models (STOP, STOP-Bang, Berlin, ESS, and four-variable screening tool): the STOP-Bang had the highest sensitivity (97.6%) and the largest AUC (0.73) but the lowest specificity (12.7%) for moderate/severe OSA. On the other hand, the four-variable screening tool had the highest specificity (74.4%) followed by ESS (67.0%).

NoSAS Score

The recently developed NoSAS score [61] allocates 4 points for having an NC > 40 cm, 3 points for having a BMI of 25 kg/m^2 to less than 30 kg/m^2 or 5 points for having a BMI ≥ 30 kg/m^2, 2 points for snoring, 4 points for age > 55 years, and 2 points for being male. A score ≥ 8 points identifies subjects at risk of clinically significant SDB. The NoSAS score performed well in a general population sample from Switzerland included in the HypnoLaus cohort with an AUC of 0.74 (95% CI 0.72–0.76). In another general population cohort from Brazil, the EPISONO cohort, the NoSAS score showed an AUC of 0.81 (95% CI 0.77–0.85). The NoSAS score performed significantly better than STOP-Bang questionnaire (AUC 0.67 [95% CI 0.65–0.69]; with $p < 0.0001$) and Berlin questionnaire (AUC 0.63 [95% CI 0.61–0.66]; with $p < 0.0001$) [61].

Conversely, in a study [95] designed to validate the NoSAS score in a multiethnic Asian cohort and compare its performance with STOP-Bang and Berlin questionnaires: both questionnaires performed similarly to the NoSAS score, with AUCs being clustered around 0.682–0.748. Also, the NoSAS was evaluated in subjects suffering from depressive disorder [96]. Using a threshold ≥ 8 points, the NoSAS performed as follows: sensitivity 0.79, specificity 0.66, NPV 0.91, and PPV 0.41. The AUC was 0.72 for NoSAS, 0.66 for STOP-Bang and 0.69 for Berlin questionnaire (not significant) [96]. In another study [97] aiming to validate the NoSAS score as a screening tool for SDB in clinical populations, 2208 participants were recruited. The NoSAS score identified individuals at risk of clinically significant SDB (defined as an AHI threshold ≥ 20 events/h), with an AUC of 0.707 [97]. The NoSAS score performed significantly better than the STOP (AUC 0.655) and STOP-Bang (AUC 0.704) questionnaires and the ESS (AUC 0.642) [97].

No-Apnea

We should be remiss if we did not mention a simplified approach that we recently developed for screening OSA among a high-risk population of patients referred for PSG evaluation: this tool, termed No-Apnea, consists of two objective items, namely, NC and age [98]. This model with a total score of 0–9 points used a cut-point ≥ 3 to classify patients at high risk of having any OSA, moderate/severe OSA, and severe OSA and exhibited, in the derivation cohort, AUCs of 0.784, 0.758, and 0.754; respectively. Subsequently, the model was validated confirming its reproducibility. In a sleep-lab population, despite its simplicity when compared to STOP-Bang questionnaire and NoSAS score, there was no statistically significant difference in discriminatory ability among them [98]. The potential value of this instrument in the general population or in elected cohorts remains to be evaluated.

Conclusions

To date, several screening tools have been described to identify subjects at risk for OSA. Interestingly, the performance of an OSA screening instrument may display considerable variability according to the patient population being evaluated, the sleep test employed for the diagnosis of OSA, and AHI thresholds used for the diagnosis of OSA. Both Berlin and STOP-Bang questionnaires are well-validated models. The Berlin questionnaire was developed primarily in primary care, and its performance is reflected by superior accuracy among primary care patients than in sleep laboratory patients. However, it includes several items needed for its completion, which hinders its widespread use. The STOP-Bang is a mnemonic method containing eight parameters with dichotomized responses of yes-or-no answers. This tool exhibits high sensitivity at all levels of OSA severity, and it reasonably maintains its screening performance in several different clinical settings, and therefore these properties have led to its current widespread utilization around the world.

Compliance with Ethical Standards

Conflict of Interest Ricardo L. M. Duarte, Flavio J. Magalhães-da-Silveira, and David Gozal each declare no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

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