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REVIEW

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The role of screening questionnaires in the assessment of risk and severity of obstructive sleep apnea — polysomnography versus polygraphy

Abstract

Obstructive sleep apnea (OSA) is a disease of significant importance, which may lead to numerous severe clinical consequences. The gold standard in the diagnosis of this sleep-related breathing disorder (SRBD) is polysomnography (PSG). However, due to the need for high expertise of staff who perform this procedure, its complexity, and relatively low availability, some simpler substitutes have been developed; among them is polygraphy (PG), which is most widely used.

Also, there is a variety of questionnaires suitable to assess the pre-test probability and severity of OSA. The most frequently used ones are the STOP-BANG questionnaire (SBQ), NoSAS questionnaire, and Berlin questionnaire (BQ). However, they have different sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) when being used in various populations.

The aim of this study is to provide a concise and clinically-oriented review of the most frequently used questionnaires, with special attention to its strengths and limitations. Moreover, we discuss whether PSG or PG would be more preferred for confirming OSA diagnosis with the highest likelihood.

Key words: obstructive sleep apnea, polysomnography, polygraphy, STOP-BANG, NoSAS, Berlin questionnaire

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Introduction

Obstructive sleep apnea (OSA) is a disease of significant importance, characterized by repetitive pauses in breathing during sleep, caused by upper respiratory tract collapses [1]. Considering the prevalence of OSA and its physiologic consequences, in certain patients, the time to establish correct diagnosis in polysomnography (PSG) is of great clinical importance. According to some previous estimates, OSA affects 3 to 7% of adult men and 2 to 5% of adult women in the general population [2]. There is also an association between the risk of OSA development and age, accounting for even higher disproportions among genders (78% in women to 90% in men) [3, 4].

OSA is characterized by the recurrent cessation of breathing (apneas) or partial upper airway obstruction (hypopneas) during sleep. Apnea-hypopnea index (AHI) is a widely used measurement for indicating the severity of OSA [1, 5]. Depending on the numbers of apneas and hypopneas per hour, OSAS can be classified as mild (AHI ≥ 5, to < 15), moderate (AHI ≥ 15 to < 30) or severe (AHI ≥ 30) [6].

Several risk factors for OSA development have been identified, including obesity, older age, male sex, and neck circumference [7, 8]. Various

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studies also showed the association of OSA and hypertension, highlighting that elevated morning diastolic blood pressure may be one of the symptoms related to OSA [8, 9]. Other symptoms reported by patients which indicate OSA include snoring, breathing pauses noticed by a bed partner, morning headaches, and daytime sleepiness [8]. These measurable and reported features are used in some questionnaires for assessing OSA probability.

OSA leads to severe clinical consequences. Several population-based studies have reported that OSA escalates the risk of hypertension, cardiovascular events, metabolic and endocrine disorders, underscoring the need for a timely diagnosis and treatment [10–13]. Also, a variety of studies show a considerable indirect effect of OSA on traffic accidents, accidents during work and loss of productivity [14–17]. Consequently, patients with a high pre-test probability of OSA should be prioritized to sleep examinations.

According to the American Academy of Sleep Medicine Clinical Practice Guideline, sleep studies have been categorized as Type I, Type II, Type III and Type IV [18]. Type I is in-laboratory full polysomnography (PSG). It includes electroencephalogram (EEG), electrooculogram (EOG), chin electromyogram (EOM), electrocardiography (ECG), respiratory airflow, respiratory movements, leg movements, oxygen saturation and notification of body position [19]. Type II studies use the same monitoring sensors as Type I, but are unattended and can be performed outside of the sleep laboratory [18]. Type III studies use devices that measure limited cardiopulmonary parameters at a minimum of four channels (airflow, respiratory effort, pulse rate and oxygen saturation) [19]. They are divided into cardiorespiratory polygraphy (PG) and portable home monitors. Type IV studies are limited channel devices, which further include oxygen saturation, pulse rate, single respiratory effort signal or airflow. All the above-mentioned studies are collected in Table 1.

The gold standard for OSA diagnosis is PSG. Moreover, the clinical application of this method goes beyond OSA. PSG is recommended not only for the detection of sleep-related breathing disorders (SRBD) like OSA, central sleep apnea syndrome, Cheyne-Stokes respiration and alveolar hypoventilation syndrome, but also for narcolepsy, parasomnias, sleep-related seizure disorders, restless legs syndrome and periodic limb movement sleep disorder [20]. However, PSG is a relatively expensive and not widely available procedure, which requires well-trained personnel. Furthermore, in the time of decreased availability of health service, like during the pandemic of SARS-CoV-2, PSG would be even more unobtainable. Polygraphy (PG) is one of the examples of type 3 devices, and has been proposed to be a substitute for PSG for assessing patients with a high pre-test probability of OSA [21]. These devices do not detect arousals during sleep, and the AHI obtained from them is usually lower than the result achieved from PSG [20]. Therefore, the patients still have to undergo PSG and the time for proper diagnosis extends. The main advantage of using PG, however, is cost-effectiveness and feasibility of use [22].

Review of the literature of the field shows that there is a variety of questionnaires suitable for assessing the pre-test probability and severity of OSA (Table 2). The questionnaires are easy-to-use and low-cost tools used by sleep specialists all over the world, however, they have different sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) when being used in various populations.

Table 1. Categories of sleep studies

Type 1	Type 2	Type 3	Type 4
Stand in-laboratory technician-attended PSG	Full unattended, ambulatory overnight PSG	Cardiorespiratory PG or portable home monitors	Limited channel devices
Consists of: EEG, EOG, EMG, ECG, respiratory airflow, respiratory movements, leg movements, oxygen saturation and notification of body position	Consists of basic channels named in type 1	Minimum four channels: airflow, respiratory effort, pulse rate and oxygen saturation	Consists of: oxygen saturation, pulse rate, single respiratory effort signal and/or airflow
Optional parameters: more EEG channels, leg EMG, body position channel, snoring detection	Optional channels may differ between available technologies	Optional channels: body position, one electrophysiological channel (e.g. ECG or leg EMG), actigraphy	Optional channels: body position, snoring sensor and/or photoplethysmographic pulse wave

Table 2. Questionnaires used to assess pre-test probability and severity of OSA

Questionnaire name	Scoring	Cut-off value	Advantages	Disadvantages
STOP-Bang	From 0 to 8 points	3 points	Helpful as a screening tool for detection of OSA in sleep clinic and surgical population. The greater the score, the greater probability of severe OSA	Composed of subjective and objective responses.
NoSAS	From 0 to 17 points	7 points	Easy to use because of consisting only 5 items. Nearly all of the items can be easily measured and are objective. It can be applied in demanding populations. (e.g. major depression)	
Berlin questionnaire	**High risk:** if there are 2 or more categories where the score is positive. **Low risk:** if there is only 1 or no categories where the score is positive.	—		Nearly all of questions can be subjectively understood.

Therefore, the aim of our study is to provide a brief and clinically-oriented review of the most frequently used questionnaires for OSA examination, with special attention to its strengths and limitations. Moreover, we discuss whether PSG or PG should be used to confirm the diagnosis of OSA with the highest likelihood.

STOP-Bang questionnaire

The STOP questionnaire was developed due to a need for creating a user-friendly, quick and concise questionnaire for OSA screening in surgical patients at preoperative clinics [23, 24]. It includes four „yes/no" questions referring to snoring, tiredness, observed apnea and pressure (STOP). The STOP-BANG was developed to further improve the sensitivity of this questionnaire and to detect patients, especially with moderate and severe OSA [23]. It consists of subjective perception as well as clinical characteristics, with a total of 8 items. The acronym BANG stems from the first letters of the following features: body mass index, age, neck circumference (in male ≥ 43, in female ≥ 41), gender (BANG), which are assessed while completing this questionnaire. These features are also described by „yes/no" answers which make the scale quick and simple to fill out. For each question, answering "yes" scores 1 and "no" response scores 0. Score 1 is obtained for age > 50 years old, neck circumference in male ≥ 43 cm and in female ≥ 41 cm and BMI > 35 kg/m^2. The total score ranges from 0 to 8 points (Table 3).

Numerous studies indicated the widespread use of SBQ [25–28]. For example, SBQ has been used for detecting OSA in pregnant women (second trimester), in highway bus drivers, in obese and surgical patients [25–29]. Additionally, SBQ is thought to be an excellent tool for screening moderate to severe OSA in adults with Down Syndrome [30]. Despite validation in multiple various populations, SBQ appears to be less useful in patients with chronic kidney disease and end-stage renal disease [31]. On the contrary, a study conducted on patients with atrial fibrillation reported high sensitivity (89%) at the cost of low specificity (36%) [32]. The PPV was 89%, and the NPV was 36%.

SBQ is also commonly used in the sleep clinic, where the prevalence of OSA is high. In the study conducted by Reis *et al.*, score ≥ 3 had a sensitivity and PPV for all OSA of 93.4% and 86.6%, respectively [33]. The increase in the SBQ score accompanies the rise in the probability of OSA, to 95% with a score of 6. Moreover, with higher SBQ score, the greater the probability of severe sleep apnea would be. Reis *et al.* also showed that an SBQ score of 3 and 2 had an NPV for moderate or severe OSA of 85.3% and 91.7%, respectively. It means that a score lower than 3 showed high discriminative power to exclude moderate to severe OSA. Similar results were obtained by Farney *et al.* because their research probability of having OSA in patients with a score of ≥ 3 was 85.1% [34]. Also, as in a previous study, with any score of > 3, the probability of detecting severe OSA continuously increases. Recently, we assessed

Table 3. STOP-Bang questionnaire

STOP	Do you SNORE loudly (louder than talking or loud enough to be heard through closed doors)?	Yes	No
	Do you often feel TIRED, fatigued, or sleepy during daytime?	Yes	No
	Has anyone OBSERVED you stop breathing during your sleep?	Yes	No
	Do you have or are you being treated for high blood PRESSURE?	Yes	No
BANG	BMI more than 35kg/m^2?	Yes	No
	AGE over 50 years old?	Yes	No
	NECK circumference >16 inches (40cm)?	Yes	No
	GENDER: Male?	Yes	No

the SBQ's accuracy in positional OSA in adults [35]. As in previous studies, we used a cut-off score of 3, and we found high sensitivity (96.9%), but the specificity was only 16.7% in our study population. For the probability of OSAS diagnosis with SBQ≥3, the PPV was 79.2% and NPV was 62.0%. In the study conducted by Boyton *et al*. using a cut-off of ≥ 3 points, for AHI levels of > 5, > 15, and > 30, respective sensitivities were 82.2, 93.2 and 96.8% and specificities were 48.0%, 40.5%, and 33.1% [36]. PPV and NPV for AHI > 5 were 79.2% and 28.3%, for AHI > 15 were 52.2% and 66.7%, for AHI > 30 were 36.4% and 96.3%, respectively.

When it comes to the general population, Tan *et al*. showed the sensitivity of a STOP-Bang score of ≥ 3 was 66.2% for detecting AHI ≥ 15, and 69.2% for detecting AHI ≥ 30. The specificities were 74.7% and 67.1%, respectively. The NPVs were 85% for moderate-to-severe OSA and 94.8% for severe OSA. The PPVs were 50.6% and 20.2%, respectively [37]. Investigations carried by Silva *et al*. [38] revealed that the sensitivity of SBQ score ≥ 3 was 87% to detect moderate-to-severe OSA and 70.4% to detect severe OSA. The specificities were 43.3% and 59.5%, respectively. However, there is an insufficient amount of data in the general population and further investigation is needed.

In a meta-analysis of seventeen studies including a total of 9,206 patients, the accuracy of the STOP-Bang questionnaire was validated by PSG [39]. In the sleep clinic population, the pooled sensitivity of a STOP-Bang score ≥ 3 to predict any OSA, moderate-to-severe and severe OSA was 90%, 94% and 96%, respectively, whereas the pooled specificity was relatively low (49%, 34% and 25%, respectively). The PPVs for any OSA, moderate-to-severe, and severe OSA were as follows: 91%, 72% and 48%, whereas the NPVs were 46%, 75% and 90%, respectively. This review also showed relatively high sensitivity of SBQ in detecting OSA in the surgical population (91%). The specificity at the same cut-off is modest, ranging from 32% in the surgical population to 34% in the sleep clinic. In another meta-analysis, the researchers also observed that the STOP-BANG has great sensitivity for detecting OSA, but its limitation is specificity [40]. They showed that SBQ is superior for detecting mild, moderate, and severe OSA than other questionnaires, but has the significant impact on the population on which it is used. Summarizing, the discussed questionnaire is the best screening tool for the detection of OSA in the sleep clinic and surgical population.

NoSAS

The NoSAS was developed as a new screening tool for recognizing patients at risk of sleep-disordered breathing [41]. The NoSAS score consists of five items and a certain amount of points is given for each item (Table 4). Neck circumference > 40 cm is rated at 4 points, body mass index (BMI) between 25 and < 30 kg/m2 — 3 points, BMI ≥30 kg/m^2 — 5 points, 4 points for being older than 55 years, and 2 points for being male. Consequently, the total score ranges from 0 to 17 points.

In the HypnoLaus study conducted on 2,168 participants, a score of 8 was used as a threshold [41]. The score had an AUC of 0.74, a PPV — 0.47 and an NPV — 0.90. Similar results were obtained from the EPISONO cohort — the NoSAS score had an AUC of 0.81, a PPV of 0.33 and an NPV of 0.98. Additionally, in this research, the NoSAS was compared with the STOP-BANG questionnaire and Berlin questionnaire, and found to have a significantly better outcome. The same threshold was used in a different study by Peng *et al*., and the results were as

Table 4. NoSAS questionnaire

Feature	Points
Neck circumference	4
BMI 25 to < 30 kg/m^2	3
BMI ≥ 30 kg/m^2	5
Snoring	2
Age > 55 years	4
Sex (male)	2

follows: to predict AHI ≥ 5, AHI ≥ 15 and AHI > 30, the sensitivity and specificity were 0.590 and 0.707, 0.649 and 0.626, and 0.644 and 0.562, respectively [42]. When the AHI ≥ 5 was used for diagnosing sleep-disordered breathing, the NoSAS score had the largest area under the curve compared to other questionnaires in the study (the Berlin questionnaire was the second one). Another study in patients referred by primary care physicians to the sleep unit by Coutinho Costa [43] demonstrated the sensitivity and PPV were 94.3% and 87.6% for all OSA severity categories, using a cut-off value of 7 points. With the same cut-off, the NPV for all OSA was 50%. In another study conducted on a group of patients suspected of sleep-disordered breathing, the NoSAS showed 71.6% sensitivity, 68.7% specificity, PPV 89.0% and NPV 40.7% for detecting OSA [44].

The main advantage of the NoSAS questionnaire is its small number of items which can be easily and objectively measured. Additionally, due to its ease of use, it can be applied in demanding populations, for example in patients with major depression [45].

In a study conducted by Tan *et al*. [46] in a multi-ethnic Asian cohort, the sensitivity, specificity, NPV and PPV of the NoSAS score to predict severe SRBM were 69.2%, 73.1%, 95.2%, and 23.7%, respectively. Therefore, the researchers proved that NoSAS performed similarly to the STOP-Bang and Berlin questionnaires. One of the major limitations of this study, however, is that they used type 3 portable monitors.

Berlin questionnaire

The Berlin questionnaire (BQ) was initially developed in 1999 to identify patients at risk for OSA in primary care [47]. The Berlin questionnaire is divided into three categories (Table 5). The first of them is related to snoring, the second part is about sleepiness and fatigue, and the last one is about the presence of hypertension. In category 1, high risk was defined as persistent symptoms in two or more questions about their snoring. In category 2, high risk was defined as persistent waketime sleepiness, drowsy driving, or both. In category 3, high risk was defined as a history of high blood pressure. Patients at high risk in at least two categories are considered to be also at elevated risk for OSA.

There are numerous studies that evaluated the Berlin questionnaire validity for OSA risk in sleep clinic populations [48–52]. Saleh *et al*. showed that the sensitivity, specificity, PPV and NPV were as follows: 97%, 90%, 96% and 93% against AHI > 5 [48]. A similar sensitivity for predicting OSA was found by El-Sayed (95%), but they noted a sensitivity of only 23%. The PPV and NPV in the latter study were 92% and 33%, respectively [51]. The researcher also assessed these parameters at AHI > 15 and AHI > 30 cut-offs. The BQ had high sensitivity for detecting moderate-to-severe (95%) and severe OSA (97%), but very low specificity for detecting moderate-to-severe (7%) and severe OSA (10%). In a study by Amra *et al*., the sensitivity, specificity, PPV and NPV of the BQ for OSA diagnosis with AHI > 5 were found to be 84%, 62%, 96%, 25%, respectively [50]. In contrast, the values at AHI ≥ 15 were 87.9%, 36.7%, 75.3%, 58.0% and at AHI ≥ 30 were 87.8%, 26.5%, 51.5%, 70.9%. The study conducted by Ng et al. showed that the BQ was unreliable in patients in predicting OSAS by PSG-AHI [53]. A different study demonstrated that the BQ has a high sensitivity (87.2%), but low specificity (11.8%) with PPV 73.2% and an NPV 25.0% [54].

There was also a study carried out on the general population [55], which concluded that the high-risk group based on the BQ predicted an AHI ≥ 5 with a sensitivity of 69% and specificity of 83%. On the other hand, a study in a generally healthy elderly population revealed that the BQ is not a satisfactory tool to predict OSA [56]. The BQ is also considered to be a poor predictor of OSA in a random group of patients undergoing pulmonary rehabilitation [57].

It is also worth highlighting that OSA was also found to be associated with idiopathic intracranial hypertension (IIH) [58]. The sensitivity of the BQ in IIH patients was 83.3%, the specificity was 58.3%, the PPV was 75%, and the NPV was 70%, respectively [59].

In the meta-analysis conducted by Senaratna et al. [60], the Berlin questionnaire was proven to have good sensitivity for detecting clinically rel-

Table 5. Berlin questionnaire

Category 1					
Do you snore?	Yes	No	Don't know		
Your snoring is...	Slightly louder than breathing	As loud as talking	Louder than talking	Very loud, can be heard in adjacent rooms	
How often do you snore?	Nearly every day	3–4 times a week	1–2 times a week	1–2 times a month	Never or nearly never
Has your snoring ever bothered other people?	Yes	No			
Has anyone noticed that you quit breathing during your sleep?	Nearly every day	3–4 times a week	1–2 times a week	1–2 times a month	Never or nearly never
Category 2					
How often do you feel tired or fatigued after your sleep?	Nearly every day	3–4 times a week	1–2 times a week	1–2 times a month	Never or nearly never
During your wake time, do you feel tired, fatigued, or not up to par?	Nearly every day	3–4 times a week	1–2 times a week	1–2 times a month	Never or nearly never
Have you ever nodded off or fallen asleep while driving a vehicle?	Yes	No			
If yes, how often does it occur?	Nearly every day	3–4 times a week	1–2 times a week	1–2 times a month	Never or nearly never
Category 3					
Do you have high blood pressure?	Yes	No	Don't know		

evant OSA (≥ 15 AHI) in the sleep clinic population. In the other populations, it had modest-high sensitivity for detecting clinically relevant OSA. Additionally, its specificity was low in all populations. In another meta-analysis, the BQ with the Sleep Disorders Questionnaire were the two most accurate questionnaires in preoperative use, but the researchers also observed that no single prediction tool functions as an ideal preoperative test [61].

Sleep Apnea Clinical Score

The Sleep Apnea Clinical Score (SACS) is a relatively new screening tool which aims to predict the presence of OSA, based on snoring, witnessed episodes of apnea, neck circumference and systemic hypertension [62]. Depending on the OSA severities indicated by AHI levels, the SACS had the sensitivity ranging from 39% to 51% and specificity ranging from 90% to 88% in primary care population [63]. In the study conducted on 91 patients with COPD, the SACS performed better than the BQ and ESS in predicting OSA [62]. However, the data regarding this questionnaire are limited and it is required to conduct more studies assessing a predicting role and utility compared with other scales.

Epworth Sleepiness Scale

The Epworth Sleepiness Scale (ESS) consist of 8 items in which patients rate their tendency to falling asleep in certain situations during daytime. Each item is rated from 0 to 3, where '0' indicates no probability of falling asleep and '3' indicates high probability [64]. The score greater than 10 is a predictor of the presence of excessive daytime sleepiness. The studies showed that this questionnaire is not a useful tool neither for OSA diagnosis nor to assess its severity [65, 66]. On the other hand, Hardinge *et al*. measured the intensity of daytime sleepiness before and after continuous positive airway pressure (CPAP) and came to conclusion that it is a great tool for monitoring the effectiveness of OSA treatment [67].

Discussion

It is worth pointing out that all of the presented questionnaires differ from each other in terms of objectivity of the answers. The STOP-BANG has 3 of 8 points which are subjective responses, the NoSAS has only 2 of 17 points which are subjective responses, whereas BQ is practically composed of questions which can be subjectively understood (despite the occurrence of hypertension). That creates a problem in understanding or subjective perception of a certain ailment.

The screening questionnaire for OSA should be accessible to perform, precise and appropriate for different populations. In our review, most of the presented studies focused on the validation of questionnaires in the sleep clinic patients, where the prevalence of OSA is high. Sleep clinics may demand questionnaires of high sensitivity, like SBQ, in order to accurately diagnose patients with OSA. Additionally, when the result of SBQ is 5 or higher, it may prompt clinicians to carry out PSG sooner, because the higher the score, the greater probability of severe OSA would be. In some populations, for example in the surgical population, time of predicting OSA is crucial. SBQ is a quick and verified tool for predicting this SRBM and thus will be clinically convenient and applicable under time-sensitive situation. On the other hand, in the general population, the high specificity of questionnaire may prevent unnecessary referral for PSG.

One of the mentioned studies [41], which was carried out on a sizable population, indicated that the NoSAS, as a new screening tool, had greater diagnostic accuracy than the SBQ or BQ. It consists of only 5 items, practically all of them are objective and it seems to be a very quick, easy and precise tool for prediction of OSA. In a different study, conduced on adult patients referred to the sleep center, the NoSAS showed a better discrimination capacity compared to the Berlin and STOP-Bang [68].

None of the presented questionnaires was sensitive and specific enough to desist further investigations. If PSG is available, it should be used as a gold standard in the diagnostic path. In case of the absence of this expensive and time-consuming examination, PG should be applied as a faster and easier option.

In one of the studies [69], the researchers provided a valuable finding that a symptomatic patient with BMI lower than 25.0 kg/m^2 has a very low chance (< 3%) of AHI ≥ 15 events/h in the lateral sleep position. Therefore, positional treatment can be an alternative applied prior to conducting PSG in that group of patients.

The ESS is a well described tool for assessing daytime sleepiness, but it is not recommended as a questionnaire for OSA diagnosis.

Summary

The SBQ seems to be a useful screening tool in the sleep clinic and surgical population. However, the current literature review shows that studies suggesting which questionnaire can be useful in the general population are sparse. Therefore, further research in this field would be of great clinical importance. The presented questionnaires may have some utility in assessing the likelihood of OSA in patient, albeit they do not give satisfactory level of certainty in the detection or exclusion of this SRBD. PSG remains a gold standard for OSA detection, and PG should constitute the first alternative only in case of its unavailability.

Conflict of interest

The authors declare no conflict of interest.

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