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Identification of Patients with Sleep Disordered Breathing: Comparing the Four-Variable Screening Tool, STOP, STOP-Bang, and Epworth Sleepiness Scales

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Study Objective: The Epworth Sleepiness Scale (ESS) has been used to detect patients with potential sleep disordered breathing (SDB). Recently, a 4-Variable screening tool was proposed to identify patients with SDB, in addition to the STOP and STOP-Bang questionnaires. This study evaluated the abilities of the 4-Variable screening tool, STOP, STOP-Bang, and ESS questionnaires in identifying subjects at risk for SDB.

Methods: A total of 4,770 participants who completed polysomnograms in the baseline evaluation of the Sleep Heart Health Study (SHHS) were included. Subjects with RDIs ≥ 15 and ≥ 30 were considered to have moderate-to-severe or severe SDB, respectively. Variables were constructed to approximate those in the questionnaires. The risk of SDB was calculated by the 4-Variable screening tool according to Takegami et al. The STOP and STOP-Bang questionnaires were evaluated including variables for snoring, tiredness/sleepiness, observed apnea, blood pressure, body mass index, age, neck circumference, and gender. Sleepiness was evaluated using the ESS questionnaire and scores were dichotomized into < 11 and ≥ 11.

Results: The STOP-Bang questionnaire had higher sensitivity to predict moderate-to-severe (87.0%) and severe (70.4%) SDB, while the 4-Variable screening tool had higher specificity to predict moderate-to-severe and severe SDB (93.2% for both).

Conclusions: In community populations such as the SHHS, high specificities may be more useful in excluding low-risk patients, while avoiding false positives. However, sleep clinicians may prefer to use screening tools with high sensitivities, like the STOP-Bang, in order to avoid missing cases that may lead to adverse health consequences and increased healthcare costs.

Keywords: STOP questionnaire, STOP-Bang questionnaire, Epworth Sleepiness Scale, 4-Variable screening tool, sleep disordered breathing, prediction

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SCIENTIFIC INVESTIGATIONS

Primary care providers frequently decide whether or not patients are referred for obstructive sleep apnea evaluations. Due to financial constraints, this decision must be made quickly and accurately during short patient visits. Accurate screening for sleep disordered breathing (SDB) is necessary to properly identify at-risk patients. Several tools have been proposed to rapidly identify these patients. Anecdotally, the Epworth Sleepiness Scale (ESS) has been used by primary care providers to identify patients with potential sleep disorders. However, the ESS was developed to measure propensity for sleep onset rather than the likelihood of SDB.[1,2] Takegami et al.[3] proposed a 4-Variable screening tool with high sensitivity (0.93) and high specificity (0.66) for determining SDB severity. This scale utilizes gender, blood pressure (BP), body mass index (BMI), and snoring. In addition, the STOP and STOP-Bang questionnaires,[4,5] two simple 4- and 8-item tools, also have been used to screen for SDB. However, these tools have been validated in different populations and clinical settings with differing results, leaving the clinician to wonder which tool best screens for SDB. We aimed to investigate this question by comparing the results of these 4 tools, utilizing the Sleep Heart Health Study population (SHHS) data. Thus, this study evaluated the ability of the 4-Variable screening tool, the STOP, STOP-Bang, and ESS to estimate the incidence of SDB as measured by the respiratory disturbance index (RDI) using data from the baseline SHHS examination, a low-risk community population. These

BRIEF SUMMARY

Current Knowledge/Study Rationale: Several screening tools for obstructive sleep apnea have been proposed. However, their validation studies were conducted on different populations, which limit comparisons on the predictive capabilities of these tools.

Study Impact: In this study of the STOP, STOP-Bang, the 4 variable tool, and the Epworth Sleepiness Scale, the STOP-Bang had the highest sensitivity in identifying persons with moderate-to-severe and severe OSA, whereas the 4-Variable tool excelled at ruling out moderate-to-severe and severe OSA. When choosing a screening tool, clinicians must decide whether they wish to identify persons at high risk for moderate-to-severe OSA or rule out these risks in their respective patient populations before choosing a screening tool.

tools were chosen, because answers to the tools' items were available in the SHHS database and may be useful in clinical practice. Variables for each tool were constructed to approximate as close as possible those variables used in each of the original screening tools.

METHODS

The SHHS is a prospective multicenter cohort study designed to investigate the relationship between SDB and cardiovascular diseases in the United States. Details of the study design have been published elsewhere.[6] Briefly, initial baseline recruitment began in 1995, enrolling 6,441 subjects over 40 years of age from several ongoing geographically distinct cardiovascular and respiratory disease cohorts, who were initially assembled between 1976 and 1995. These cohorts included the Offspring Cohort and the Omni Cohort of the Framingham Heart Study in Massachusetts; the Hagerstown, MD and Minneapolis, MN sites of the Atherosclerosis Risk in Communities Study; the Hagerstown, MD, Pittsburgh, PA, and Sacramento, CA sites of the Cardiovascular Health Study; 3 hypertension cohorts (Clinic, Worksite, and Menopause) in New York City; the Tucson Epidemiologic Study of Airways Obstructive Diseases and the Health and Environment Study; and the Strong Heart Study of American Indians in Oklahoma, Arizona, North Dakota, and South Dakota. The SHHS was approved by the institutional review board for human studies, and informed written consent was obtained from all subjects at the time of their enrollment into the study. Data from 4,770 subjects with successful polysomnograms (PSGs) on whom we were able to construct the questionnaires' variables and who participated in the baseline SHHS examination were included in this analysis.

Briefly, after a home visit was scheduled, the Sleep Health Questionnaires (SHQs) generally were mailed 1 to 2 weeks prior to the in-home polysomnography appointment. Each participant was asked to complete the questionnaire prior to the home visit, at which time the SHQ was collected and verified for completeness.[7] The SHQ contained questions regarding sleep habits, as well as cardiovascular disease and respiratory problems.

SHHS participants underwent overnight in-home polysomnograms using the Compumedics Portable PS-2 System (Abbottsville, Victoria, Australia) administered by trained technicians.[8] The home visits were performed by 2-person mixed-sex teams in visits that lasted 1.5 to 2 h. There was emphasis on making the night of the polysomnographic assessment as representative as possible of a usual night of sleep. Participants were asked to schedule the visit so that it would occur approximately 2 h prior to their usual bedtime. The SHHS PSG recording montage consisted of electroencephalogram; right and left electrooculogram; a bipolar submental electromyogram; thoracic and abdominal excursions (inductive plethysmography bands); airflow, oximetry, ECG, and heart rate; body position; and ambient light. Sensors were placed and equipment was calibrated during an evening home visit by a certified technician. Comprehensive descriptions of PSG, scoring, and quality assurance procedures have been previously published.[8] In brief, sleep was scored according to guidelines developed by Rechtschaffen and Kales.[9] Apneas were defined as a complete or almost complete cessation of airflow, as measured by the amplitude of the thermocouple signal, lasting ≥ 10 sec. Hypopneas were identified if the amplitude of a measure of flow or volume (detected by the thermocouple or thorax or abdominal inductance band signals) was reduced discernibly (≥ 25% lower than baseline breathing) for ≥ 10 sec, but did not meet the criteria for apnea. For this study, only apneas or hypopneas associated with ≥ 4% oxyhemoglobin desaturation per hour of total sleep time were considered in determining the RDI, the "gold standard" for polysomnogram endpoints. Subjects with RDIs of ≥ 15 – < 30 and ≥ 30 were considered to have moderate-to-severe SDB or severe SDB, respectively. Neck circumference was obtained, and height and weight were measured directly to determine body mass index (BMI, kg/m^2).

4-Variable Screening Tool

The risk for SDB was calculated according to Takegami et al.[3] Sex was assigned a value of 1 for males and 0 for females; BMI kg/m^2 categories (< 21.0, 21.0–22.9, 23.0–24.9, 25.0–26.9, 27.0–29.9, ≥ 30) were assigned a value between 1 and 6; BP mm Hg (systolic BP [SBP] < 140 or diastolic BP [DBP] < 90, SBP 140–159 or DBP 90–99, SBP 160–179 or DBP 100–109, SBP ≥ 180 or DBP ≥ 110) was assigned a value between 1 and 4; and snoring was assigned 1 for a response of snoring *almost every day* or *often*, and 0 for snoring *sometimes*, *almost never*, or *unknown*. The overall risks for participants were calculated by assigning their screening values for BMI and BP to the associated equation variables. Sex and snoring were factored by values of 4. The following equation[3] was used: SDB = (sex*4) + (BMI category value) + (BP category value) + (snoring*4). The cut point of 14 was used for the 4-Variable screening tool, according to the recommendation of Takegami et al.[3]

STOP and STOP-Bang Questionnaires

Questionnaire responses similar to those used in the STOP questionnaire[4] were used to construct the STOP score. **S**nore was considered affirmative if the participant reported snoring loudly (louder than talking or loud enough to be heard through closed doors). **T**iredness/sleepy during the day was affirmative if the participant reported yes to feeling unrested during the day no matter how many hours of sleep he/she had (*often* and *almost always* = yes; *never*, *rarely*, and *sometimes* = no) and reported feeling tired (*all of the time*, *most of the time*, *a good bit of the time* = yes, and *some of the time*, *a little bit of the time*, and *none of the time* = no). **O**bserved stop breathing was defined as yes if participant answered affirmative to the question "based on what you have noticed or household members have told you, are there times when you stop breathing during your sleep?" Blood **P**ressure was defined as positive if the participant answered *yes* to being treated with medication for high blood pressure. High risk of SDB was defined as answering affirmative to ≥ 2 questions. Low risk of SDB was defined as answering affirmative < 2 questions on the STOP.

The Bang portion was evaluated by assessing body mass index (**B**MI > 35 kg/m^2), **A**ge (over 50 years old), **N**eck circumference (neck circumference > 40 cm), and **G**ender (male). One point was assigned for each affirmative answer; 0 for no answers. High risk for SDB was defined as ≥ 3 affirmative an-

swers to the 8 STOP-Bang items. Low risk was defined as ≤ 2 affirmative answers.

Epworth Sleepiness Scale (ESS)

The Epworth Sleepiness Scale (ESS) was completed by the SHHS participants. The ESS is a validated 8-item questionnaire that measures subjective sleepiness.[1] Subjects are asked to rate how likely they are to fall asleep in different situations. Every question is answered on a scale of 0 to 3. ESS values range from zero (unlikely to fall asleep in any situation) to 24 (high chance of falling sleep in all 8 situations). The ESS final score was dichotomized into < 11 (low risk for sleepiness) and ≥ 11 (high risk).

Statistics

Each tool was compared on the following parameters: sensitivity, specificity, the likelihood ratio for a positive result (LR+), and the likelihood ratio for a negative test result (LR−). Separate bivariate logistic regression models for each tool were used to determine the odds ratio (OR) in predicting SDB. Models including scores for the different tools were constructed to assess the areas under the receiver operating characteristic (ROC) curves for SDB. Statistical analyses were conducted using Intercooled Stata version 9.0 statistical software (Stata Corp, College Station, TX).

RESULTS

Descriptive characteristics for the study population are presented on **Table 1**. The overall mean age was 62.4 (± 10.3 SD) years, 51.5% were males, 44.1% snored, and 12.1% had a BMI ≥ 35 kg/m^2. A total of 12.6% were classified as having moderate-to-severe SDB, and 7.2% as having severe SDB. Of those with moderate-to-severe SDB, 65.2% were males and 55.9% snored. Of those with severe SDB, 70.7% were males and 69.6% snored. BMI ≥ 35 kg/m^2 was present in 21.7% of those with moderate-to-severe SDB and 31.3% of those with severe SDB. The mean scores for the 4-Variable screening tool were 9.3 (± 3.5 SD, range from 2–18) for all subjects, 10.8 (± 3.2 SD) for those with moderate-to-severe SDB, and 12.0 (± 3.1 SD) for those with severe SDB. ESS scores of ≥ 11 were present in 28% the overall subjects, in 32% of those with moderate-to-severe SDB, and in 40% of those with severe SDB with the mean ESS scores being 8.7 (± 4.6 SD) for those with moderate-to-severe SDB and 9.7 (± 4.9 SD) for those with severe SDB. The proportion of subjects with ≥ 2 positive answers in the STOP questionnaire was 59.9% for those with moderate-to-severe SDB and 73% for those with severe SDB. The proportions of subjects with ≥ 3 positive answers for the STOP-Bang questionnaire were 88.6% for those with moderate-to-severe SDB and 92.5% for those with severe SDB.

Predictive parameters comparing the 4 questionnaires for moderate-to-severe SDB showed the STOP-Bang questionnaire had the highest sensitivity (87.0%) and area under the ROC curve (0.64) and that the 4-Variable screening tool had the highest specificity (93.2%) and number of correctly classified (79.4%; **Table 2**). Predictive parameters for severe SDB showed that the STOP-Bang questionnaire had the highest sensitivity (70.4%) and that the 4-Variable screening tool had the highest specificity (93.2%), number of correctly classified (86.7%), and area under the ROC curve (0.67; **Table 3**). The 4-Variable screening tool, however, had the lowest sensitivity in predicting moderate-to-severe SDB (24.7%) and severe SDB (41.5%) compared to the other tools, while the ESS had the lowest area under the ROC curve for both moderate-to-severe SDB (0.53) and severe SDB (0.58).

DISCUSSION

Based on our ability to reconstruct the questionnaire and tool variables with the SHHS population data, we found that in terms of sensitivity, the STOP-Bang tool identified more subjects with moderate-to-severe SDB and severe SDB. The STOP-Bang performed better than the STOP. Identifying persons with significant SDB is paramount in high risk pre-operative and sleep clinic populations and promotes early treatment that may mitigate associated comorbidities and their sequelae. However, the 4-Variable screening tool excelled in specificity, classifying fewer normal persons as high-risk for moderate-to-severe-SDB and severe SDB. This tool could perform favorably in low-risk populations in primary care when patients have no sleep complaints and are not obese or diagnosed with cardiovascular disease, diabetes, and other associated comorbidities. The 4-Variable screening tool, nonetheless, had the lowest sensitivity to predict moderate-to-severe SDB and severe SDB, which could lead to missed cases that if untreated could lead to adverse health outcomes, increasing healthcare costs. Furthermore, the STOP-Bang questionnaire, which showed similar predictive abilities to the 4-Variable screening tool for severe SDB, may be more easily scored in clinic environments without access to computer-scoring programs. As expected, the ESS did not predict moderate-to-severe SDB or severe SDB as well as the STOP, STOP-Bang, and 4-Variable screening tool due to its focus on sleep propensity rather than SDB.

Our findings also show that the tools' predictive parameters in the SHHS community population differ from those found on their derivation and validation studies. This may be due to differences in populations used, where preselected clinical populations were used for the derivation parameters, or to our variable derivations. Previously published validation parameters[4] report higher sensitivities for the STOP tool in predicting moderate-to-severe (74.3%) and severe (79.5%) SDB than the values obtained in our study. Similarly, sensitivities for the STOP-Bang tool were higher in previously validation studies in predicting moderate-to-severe (92.9%) and severe (100%) SDB. Specificities, however, were lower in previously reported validation parameters for the STOP tool (53.3% for moderate-to-severe SDB and 48.6% for severe SDB) and for the STOP-Bang tool (43.0% for moderate-to-severe SDB and 37.0% for severe SDB) than the specificities obtained in our study. Previously reported sensitivities[3] for the 4-Variable screening tool were higher for moderate-to-severe (33%) and severe (57.1%) SDB than the sensitivities reported in our study. Specificities for the 4-Variable screening tool, however, were comparable to those obtained in our study for moderate-to-severe (94.1%) and severe (91.3%) SDB.

Other questionnaires have been proposed for screening SDB. In their meta-analysis, Ramachandran and Josephs[10] evaluated

Table 1—Descriptive characteristics of the study population for the 4-Variable screening tool, ESS, STOP, and STOP-Bang questionnaires*

	All (%)	Moderate-to-Severe SDB (%)	Severe SDB (%)
Total N (%)	4,770.0	603.0 (12.6)	345.0 (7.2)
Age (mean, SD)	62.4 (10.3)	64.4 (9.9)	63.9 (10.0)
4-Variable screening tool			
Sex			
Female	48.5	34.8	29.3
Male	51.5	65.2	70.7
Snore (often/every day)			
No	55.9	44.1	30.4
Yes	44.1	55.9	69.6
BP (systole/diastole)			
< 140/< 90	73.1	68.3	59.1
140–159/90–99	19.8	23.6	29.9
160–179/100–109	5.6	6.3	8.9
≥ 180/≥ 110	1.6	1.8	2.1
BMI			
< 21	3.3	1.3	1.2
21–22.9	6.8	3.0	2.3
23–24.9	13.3	10.1	6.1
25–29.9	41.3	35.2	27.3
30–34.9	23.1	28.7	32.8
≥ 35	12.1	21.7	31.3
4-Variable screening tool (min 2- max 18) mean (SD)	9.3 (3.5)	10.8 (3.2)	12.0 (3.1)
ESS (min 0 – max 24) mean (SD)	8.2 (4.4)	8.7 (4.6)	9.7 (4.9)
ESS%			
< 11	72.0	68.0	60.0
≥ 11	28.0	32.0	40.0
STOP and STOP-Bang			
Snore (loudly)			
No	89.8	84.3	72.8
Yes	10.2	15.7	27.2
Tired/Sleepy			
No	80.6	79.2	76.3
Yes	19.3	20.8	23.7
Witnessed stop breathing			
No	70.6	61.1	34.0
Yes	29.4	38.9	66.9
Hypertension medication			
No	60.5	54.6	44.9
Yes	39.5	45.4	55.1
BMI (kg/m^2)			
≤ 35	87.9	78.3	68.7
≥ 35	12.1	21.7	31.3
Age (years)			
< 50	12.9	8.6	8.9
≥ 50	87.1	91.4	91.1
Neck circumference (cm)			
≤ 40	67.6	49.6	36.8
> 40	32.4	50.4	63.2
Gender Male			
No	48.5	34.8	29.3
Yes	51.5	65.2	70.7
STOP % with ≥ 2 positive answers	49.7	59.9	73.0
STOP-Bang % with ≥ 3 positive answers	72.4	88.6	92.5
STOP total score (mean, SD)	2.9 (0.9)	3.0 (0.9)	3.3 (0.8)
STOP-Bang total score (mean, SD)	3.4 (1.3)	4.0 (1.3)	4.6 (1.4)

*Percent, unless otherwise indicated. BP, blood pressure; BMI, body mass index; ESS, Epworth Sleepiness Scale.

Table 2—Predictive parameters for the 4-Variable screening tool, STOP, STOP-Bang, and ESS questionnaires for moderate-to-severe SDB

	4-Variable ≥ 14	STOP	STOP-Bang	ESS ≥ 11
Sensitivity %	24.7	62.0	87.0	39.0
Specificity %	93.2	56.3	43.3	71.4
Correctly Classified %	79.4	57.5	51.0	64.8
LR+	3.7	1.4	1.5	1.4
LR−	0.80	0.67	0.30	0.85
Odds Ratio (95% CI)	4.5 (3.5–5.8)	2.1 (1.8–2.4)	5.1 (4.0–6.4)	1.6 (1.4–1.8)
Area Under the ROC (95% CI)	0.59 (0.57–0.61)	0.58 (0.56–0.61)	0.64 (0.62–0.66)	0.53 (0.52–0.56)

LR+, likelihood ratio for a positive test. LR−, likelihood ratio for a negative test. CI, confidence interval.

Table 3—Predictive parameters for the 4-Variable screening tool, STOP, STOP-Bang, and ESS questionnaires for severe SDB

	4-Variable ≥ 14	STOP	STOP-Bang	ESS ≥ 11
Sensitivity %	41.5	68.8	70.4	46.1
Specificity %	93.2	59.5	59.5	70.4
Correctly Classified %	86.7	59.4	60.7	68.7
LR+	6.1	1.5	1.7	1.6
LR−	0.63	0.69	0.49	0.76
Odds Ratio (95% CI)	9.8 (7.5–12.7)	2.1 (1.8–2.5)	3.5 (2.7–4.4)	2.0 (1.6–2.5)
Area Under the ROC (95% CI)	0.67 (0.65–0.70)	0.65 (0.62–0.67)	0.66 (0.64–0.67)	0.58 (0.55–0.6)

LR+, likelihood ratio for a positive test. LR−, likelihood ratio for a negative test. CI, confidence interval.

several clinical screening tests for obstructive sleep apnea, including the American Society of Anesthesiologists (ASA)[11,12] checklist, the Berlin questionnaire,[13] the Sleep Questionnaire,[14] the sleep disorders questionnaire (SDQ),[15] and the STOP and STOP-Bang questionnaires.[4,5] The authors concluded that the Berlin questionnaire and the SDQ were the most accurate questionnaires overall to screen for SDB. They also concluded that the ESS was the least accurate, and that the STOP questionnaire, although the simplest tool, was a poor predictor of SDB, as was the ASA screening tool. The authors, however, identified the STOP-Bang questionnaire as an excellent method for predicting severe SDB due to its simplicity and relatively ease of use rather than incorporating tools with more complex scoring methods into standard preoperative evaluations.

In a recent systematic review, Abrashami et al.[16] reported that the Wisconsin[17] and the Berlin questionnaires had the highest sensitivity and specificity overall (respectively). The authors state, however, that the validity of the studies was unclear due to the potential for bias. Subjects in the Berlin study were "pre-screened" for presence and frequency of snoring, wake-time sleepiness or fatigue, and history of obesity or hypertension, which may have introduced selection bias. Abrashami et al.[16] did not make a definite conclusion regarding the most accurate questionnaire to screen for SDB; however, in accordance with Ramachandrean and Josephs,[10] they recommended the STOP-Bang questionnaire due to its high-quality methodology and reasonably accurate results. Our study was performed deriving variables from pre-existing data, and therefore, we might have over- or underestimated the predictive abilities of these tools.

We acknowledge that the 4-Variable screening tool was developed and validated in Japanese subjects, using different BMI cutoff values than those recommended by the National Institutes of Health (NIH).[18] We, therefore, also evaluated our analyses using the NIH BMI cutoff values of < 18.5, 18-5-24.9, 25.0-29.9, and ≥ 30.0. Using the NIH BMI classification yielded similar results to the BMI classification by Takegami et al.,[3] with only 2 subjects moving from a final 4-Variable screening tool score < 14 to that ≥ 14. Therefore, in order to preserve comparability with the results of Takegami et al., we retained the same BMI categories used by Takegami when computing the 4-Variable scores.

Our population was composed of subjects over 40 years of age from several ongoing geographically distinct cardiovascular and respiratory disease cohorts. Although this is a community population with a normal mean sleepiness score (ESS 8.2), this population is of interest to primary care providers wishing to screen their patients who may not necessarily be overtly symptomatic for SDB.

We further acknowledge that our analyses are limited to screening for moderate-to-severe or severe SDB because of the established morbidities of SDB in these individuals. Although those with mild SDB may be symptomatic, it is yet uncertain whether there are associated cardiovascular and other comorbidities.

We, therefore, recommend that multiple screening questionnaires and tools such as the STOP, STOP-Bang, 4-Variable tool, and ESS be evaluated concomitantly in various clinic and hospital settings to allow for comparison of significant differences within the same populations. Ideally, screening tools with high sensitivities and areas under the ROC curves should be chosen to screen populations with high risk for SDB; whereas, specificities and the percentages of correctly classifying persons into low- and high-risk groups for SDB may take precedence in

low-risk populations who demonstrate no overt signs of SDB or associated comorbidities and lack easy access to polysomnography. Nonetheless, they should have sufficient sensitivity to avoid missing large number of cases. Sleep clinicians may prefer to use screening tools with high sensitivities, like the STOP-Bang, in order to avoid missing cases that may lead to adverse health consequences and increase overall healthcare costs.

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