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Obstructive sleep apnea in pregnancy: performance of a rapid screening tool

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Abstract

Purpose The Sleep Apnea Symptom Score (SASS) has been commonly used to assess obstructive sleep apnea (OSA). The aim of this study was to examine the psychometric properties of the SASS and the predictive value of SASS incorporating bedpartner-reported information in identifying OSA in pregnant women.

Methods A cohort of healthy pregnant women completed the SASS and Pittsburgh Sleep Quality Index. Participants underwent overnight laboratory polysomnography (PSG) monitoring. Reliability and validity of the SASS were evaluated. A multivariable predictive model, incorporating the SASS score along with BMI, age, and bedpartner-reported information, was developed to assess the risk for OSA (AHI ≥ 5 events/h). Receiver operating characteristic curves for OSA were constructed to evaluate the sensitivity and specificity of the predictive model.

Results A total of 126 and 105 participants completed the PSG during the first and third trimester, respectively. The SASS demonstrated adequate validity and acceptable reliability (Cronbach's $\alpha = 0.72$ during the third trimester). When the combined model consisting of SASS, age, BMI, and bedpartner-reported information was used, the area under the curve for AHI ≥ 5 for the first and third trimester was 0.781 (95%CI 0.648, 0.914) and 0.842 (95%CI 0.732, 0.952), respectively; the sensitivity/specificity was 76.9%/72.4% and 82.4%/78.0%, respectively.

Conclusions The SASS alone has acceptable reliability and validity, but limited predictive values. A new tool, combining the SASS and other patient characteristics (i.e., age, BMI, and bedpartner-reported snoring and breathing pauses), demonstrated improved sensitivity and specificity, and thus may have greater utility in clinical practice for predicting OSA in pregnant women.

Keywords Pregnancy · Screening · Sensitivity · Sleep apnea · Specificity

Introduction

Obstructive sleep apnea (OSA) is characterized by repeated episodes of partial or complete upper airway obstruction during sleep. Loud snoring, snorting, gasping, and/or witnessed apnea have been regarded as major symptoms and signs of sleep apnea [1]. OSA is uncommon among women of reproductive age, with a prevalence of 3% [2]. However, the prevalence of OSA ranges from 8 to 20% among pregnant women [3, 4] due to pregnancy-related changes. Due to an increase in awareness, detection, and reporting of OSA as well as higher rates of obesity, the prevalence of OSA among pregnant women has increased at an alarming rate. Its prevalence increased from 0.7 in 1998 to 7.3 in 2009 per 10,000 population, with an annual increase of 24.4% [5].

Accumulating evidence suggests that pregnant women with OSA are at increased risk for adverse maternal and neonatal outcomes independent of obesity [4, 5]. Early detection and treatment of pregnancy-associated OSA may possibly protect against adverse perinatal outcomes and improve the development of the fetus during pregnancy [6, 7]. Therefore, validated tools are needed to help healthcare providers to

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better identify OSA in pregnant women. Although polysomnography (PSG) is the gold standard for the diagnosis of OSA, it is labor-intensive, time-consuming, and expensive [8]. Thus, tools that can be easily and quickly administered during short clinical visits are crucial. Several instruments to assess the risk for OSA are widely used in clinical practice. These questionnaires include the Epworth Sleepiness Scale (ESS), the Berlin Questionnaire (BQ), and STOP-BANG Questionnaire. However, studies have found poor predictive values for the ESS [9–12], BQ [3, 9–11], and STOP-BANG [11] in pregnant women. A recent meta-analysis also found that the BQ and ESS performed poorly in predicting OSA during pregnancy, and recommended developing a new tool [13].

The Multivariable Apnea Prediction (MAP) Index is another widely used screening tool for OSA that has been used in pregnancy studies [12, 14]. One of the subscales of the MAP Index is the Sleep Apnea Symptom Score (SASS). When the SASS is used along with body mass index (BMI), age, and gender in a specific formula developed for the non-pregnant population, it can estimate the probability risk for sleep apnea [15]. Although the SASS has been used to assess OSA symptoms in pregnancy studies, the psychometric evaluations of the instrument and its predictive ability have not been formally conducted. Thus, examining whether the SASS in the pregnant population performs similarly to what has been seen in non-pregnant population is necessary. This assessment also provides further conjecture on why the SASS in the pregnant population may differ.

Screening for OSA relying solely on self-reported information from pregnant women can be problematic. Symptoms of OSA, such as multiple awakenings, excessive daytime sleepiness, and fatigue, are common during pregnancy due to hormonal and physiological changes [16]. Pregnant women might consider these symptoms normal during pregnancy and thus under-report them. It is also possible that some women with OSA are unaware of nocturnal symptoms such as snoring because women can experience symptoms and signs of OSA for the first time in their lives. It is common that partners of patients with OSA complain of disturbance to their sleep due to symptoms of OSA [17, 18]. Therefore, including bedpartners' reports may possibly improve the accuracy of screening for gestational OSA and increase its predictive ability [19]. Additionally, it has been reported that the predictive value of the screening tool likely depends on the trimester of pregnancy [20], which was rarely taken into account in previous studies. There is a clear need to examine the predictive value of the SASS at different trimesters. Wilson and colleagues [12] tested the predictive values of MAP Index among 43 pregnant women. The researchers reported that the MAP Index demonstrated acceptable predictive values. However, participants included in this study were chosen at either end of the OSA risk spectrum. There is a need to replicate previous findings in a larger sample of pregnant women who are more heterogeneous in trimesters and OSA risk.

In this sub-study, we used data from a previous prospective, observational study evaluated risk factors for OSA in pregnant women [16]. The aim of this study was twofold: (1) to assess the reliability and validity of the SASS for assessing OSA risk among pregnant women, and (2) to develop a new screening tool including SASS, bedpartner-reported snoring and breathing pauses, and to determine its predictive ability to identify the diagnosis of gestational OSA during the first and third trimesters. We hypothesized that including bedpartner-reported snoring and breathing pauses will improve the ability of a screening tool to predict clinical OSA diagnosis in the pregnant population.

Methods

Participants

Data were examined from a completed cohort study of OSA in pregnancy. All women scheduled for initial obstetrics evaluation at the Hospital of the University of Pennsylvania were invited to participate. Interested women were screened for eligibility. This study was approved by the Penn Institutional Review Board. All participants, including bedpartners/roommates, provided written informed consent. Women whose pregnancy was ≤ 14 weeks of gestation were eligible. Exclusion criteria were communication/cognitive/behavioral impairments interfering with informed participation; no telephone; self-reported illicit drug use or alcoholism; serious pre-existing medical conditions; sedative/hypnotic use ≥ 3×/week; or current OSA treatment. To enrich the sample for subjects likely to develop OSA, recruitment was stratified by BMI (kg/m^2) to increase the proportion of obese women: normal (< 25.0), overweight (25.0–< 30.0), class I obesity (30.0–< 35.0), class II–III obesity (≥ 35.0) [16]. The recruitment goal for the original study was 25 subjects/category; subjects who withdrew were replaced until the goal was reached. In total, 722 interested women were screened for inclusion into the cohort, of whom 352 women met eligibility criteria. The most common reason for exclusion was pregnancy past 14 weeks of gestation ($n = 325$). Others were excluded due to not being pregnant/pregnancy loss/planned termination ($n = 17$), chronic medical conditions ($n = 4$), prenatal care at other institutions ($n = 9$), or lack of English fluency ($n = 1$). Many otherwise eligible women were not enrolled due to stratified recruitment by BMI ($n = 172$) or because they were unable to attend first-trimester polysomnography (PSG) prior to 14 weeks of gestation ($n = 54$).

Instruments

Participants completed the demographic questionnaire, SASS [15], and Pittsburgh Sleep Quality Index (PSQI) [21].

Identification of women with sleep apnea was accomplished with overnight laboratory PSG.

Sleep Apnea Symptom Score The SASS, a subscale of the MAP Index [15], evaluates the presence and frequency of the following sleep symptoms (loud snoring, snorting, gasping, and witnessed apneas). In non-pregnant adults, the SASS has a high test-retest reliability and internal consistency [15].

Pittsburgh Sleep Quality Index The PSQI consists of 19 self-rated questions and 5 questions rated by a bedpartner/roommate. Nineteen self-reported items that assess sleep quality and severity of specific sleep-related complaints [21]. The PSQI has seven subscales, including sleep quality, sleep latency, sleep duration, sleep efficiency, nighttime disturbances, daytime dysfunction, and sleep medications. Sum of scores from seven components yields one Global Score. The PSQI demonstrated good internal consistency, convergent, and divergent reliability among pregnant women [22, 23].

Bedpartner reported snoring and breathing pauses The bedpartner/roommate-reported data was obtained from two questions of the PSQI [21]. These questions are "Ask roommate or bed partner how often in the past month you have had (a) loud snoring and (b) long pauses between breaths while asleep." Available answers are "Not during the past month, Less than once a week, Once or twice a week, Three or more times a week." Data were included in this sub-study from participants if they had a bedpartner/roommate who slept in the same room/bed.

Polysomnography PSG recording and scoring were described in previous studies [16, 24]. In brief, two overnight laboratory PSGs were scheduled between 8- and 14-week gestation and 33–34-week gestation. The Apnea-Hypopnea Index (AHI) was obtained. Based on the AHI, the severity of OSA was categorized into no OSA (AHI < 5), mild (AHI ≥ 5 but < 15), moderate (AHI ≥ 15 but <30), and severe OSA (AHI ≥ 30) [8].

Statistical analysis

Statistical analyses were performed using Stata IC version 12 (StataCorp, Texas, USA). Statistical significance was set at a p value < 0.05 (two-tailed). Paired t test was used to compare participant characteristics during the first and third trimester including gestational age, BMI, AHI, and SASS. Chi-square test was used to compare OSA prevalence. Internal consistency of the SASS was examined, using a threshold for acceptable internal consistency of Cronbach's $\alpha \geq 0.7$ [25]. Convergent validity was evaluated by correlating the SASS with the PSQI. Spearman correlation analysis was used due to the nonparametric nature of these scaled scores. The predictive validity of the SASS was evaluated by correlating the SASS with AHI for those with AHI < 5 events/h in the first trimester but AHI ≥ 5 events/h during the third trimester.

Predictive models incorporating SASS score along with other indicators (e.g., age, BMI, and bedpartner-reported information) were developed using multivariable logistic regression to assess OSA risk. Receiver operating characteristic (ROC) curves for AHI ≥ 5 events/h were constructed to assess the sensitivity and specificity of each model. The optimal cutoff point that minimizes total errors was used in this study, and it was located where the slope of the line tangent to the curve is equal to this ratio [15].

Results

In this study, 126 women had PSGs in the first trimester and 105 of them completed PSGs in the third trimester. Participant characteristics are presented in Table 1. The mean gestational age at the time of the first-trimester and third-trimester sleep study was 12.1 (SD 1.9) and 33.6 (SD 2.5) weeks, respectively. In the first trimester, 16 (12.7%) participants had an AHI ≥ 5, among which one had moderate OSA and one had severe OSA. By the third trimester, 28 participants (26.7%) had an AHI ≥ 5, among which four had moderate OSA and one had severe OSA.

Table 1 Characteristics of the study sample

Variable		First trimester $N = 126$	Third trimester $N = 105$
Age		27.20 ± 7.20	27.20 ± 7.20
*Gestational age***		12.03 ± 1.89	33.56 ± 2.53
Race/ethnicity	White/Other	(32) 25.40%	(26) 24.76%
	African American	(94) 74.60%	(79) 75.24%
Parity	Multiparous	(64) 50.79%	(56) 53.33%
	Nulliparous	(62) 49.21%	(49) 46.67%
Married		(48) 38.10%	(40) 38.10%
At least 4 years of college		(33) 26.19%	(26) 24.76%
Napping *	Yes	(105) 83.3%	(94) 92.2%
	No	(21) 16.7%	(8) 7.8%
*BMI (kg/m^2)***		30.00 ± 7.14	33.40 ± 6.40
*AHI**		2.07 ± 3.01	3.74 ± 5.97
AHI category**	AHI < 5	(110) 87.30%	(77) 73.33%
	AHI ≥ 5	(16) 12.70%	(28) 26.67%
SASS		4.25 ± 7.19	5.06 ± 7.84

Data were presented as mean ± standard deviation or (n)%. Variables in italics: paired t tests were used for available pairs ($n = 105$)

BMI body mass index, *AHI* apnea-hypopnea index, *SASS* Sleep Apnea Symptom Score

*$p < 0.05$, **$p < 0.01$, $n = 102$ for the third trimester

Internal consistency reliability

When completed during the first trimester, Cronbach's α for the SASS was 0.45. Removal of specific items did not substantially increase the internal consistency. The SASS had better internal consistency when completed in the third trimester, with Cronbach's α of 0.72.

Validity

Convergent validity Based on Table 2, SASS showed moderate correlation with the PSQI sleep disturbance subscale in the first and third trimester ($r = 0.36$ and $r = 0.34$, respectively, $p < 0.001$). SASS also demonstrated significant correlation with the PSQI total score ($r = 0.20$, $p < 0.05$) in the third trimester.

Predictive validity Analysis of predictive validity was based on data obtained from women who did not meet criteria for OSA in the first trimester of pregnancy. Among the 94 participants with no OSA in the first trimester, 77 (81.9%) still did not have OSA in the third trimester, and 17 had incident OSA in the third trimester, operationalized as AHI ≥ 5 events/h. Mean SASS obtained in the first trimester was higher among those who developed new OSA (0.798, SD 1.064), compared to those who did not (0.293, SD 0.559). These group differences were significantly different ($p = 0.021$).

Evaluation of SASS alone and combined with other measures as a diagnostic screening tool

Data from participants with a bedpartner were used to test the predictive values of the SASS ($n = 89$ during the first trimester and $n = 67$ during the third trimester). The predictive ability of the SASS to identify women with OSA (AHI ≥ 5) was higher when the combined models were used compared to using the SASS alone. When the combined model (model 1) consisting of SASS, BMI, and age was used, the area under the curve (AUC) for AHI ≥ 5 for the first and third trimesters was 0.776 (95%CI 0.639, 0.914) and 0.826 (95%CI 0.708, 0.943), respectively. When we added bedpartner-reported information (i.e., loud snoring and apnea) into the combined model (model 2), the AUC changed to 0.781 (95%CI 0.648, 0.914) and 0.842 (95%CI 0.732, 0.952) for the first and third trimesters, respectively (Table 3).

Table 4 shows the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) values for the two combined models. Overall, both combined models performed better during the third trimester than during the first trimester. When used during the first trimester, both combined models produced similar values. When used during the third trimester, model 2 yielded a higher estimation of sensitivity and NPV.

Discussion

Using data from a prospective cohort study, we assessed the psychometric properties of SASS and the predictive value of SASS alone, as well as in combination with other predictors, for identifying OSA in a pregnant population. Overall, the SASS demonstrated acceptable validity and reliability. A model combining SASS with age, BMI, and bedpartner-reported information demonstrated better predictive value in detecting OSA compared to SASS alone. The combined model had moderate sensitivity and specificity, suggesting its ability to predict OSA in healthy pregnant women.

Our findings suggest that the SASS is a valid and reliable tool in pregnancy for screening for pregnancy-associated OSA. The Sleep Disturbance subscale of the PSQI covers common symptoms of OSA (e.g., cannot breathe comfortably and cough/ snoring loudly) [21]. Theoretically, the SASS and the Sleep Disturbance subscale should correlate with each other. Indeed, the correlation between SASS and this subscale was moderate in this sample ($r = 0.34$–0.36), supporting the convergent validity of the SASS. In contrast, low correlations were found between SASS and PSQI global score. These findings are not surprising, as the PSQI do not directly measure apneic symptoms. While sleep apnea can lead to poor sleep quality [26], pregnancy-related hormonal and physical

Table 2 Convergent validity of SASS with PSQI, represented using Spearman correlation coefficients

Variable	First trimester SASS	Third trimester SASS
PSQI Sleep Quality Subscale	0.030	0.063
PSQI Sleep Latency Subscale	− 0.085	0.129
PSQI Sleep Duration Subscale	− 0.077	0.101
PSQI Sleep Efficiency Subscale	0.019	− 0.044
PSQI Sleep Disturbance Subscale	0.328**	0.337**
PSQI Daytime Dysfunction Subscale	− 0.003	0.197*
PSQI Global Score	0.027	0.196*

PSQI Pittsburgh Sleep Quality Index, *SASS* Sleep Apnea Symptom Score

*$p < 0.05$; **$p < 0.01$

Table 3 Receiver operating characteristic (95%CI) for different models

Model	First trimester $N = 89$ (13OSA)	Third trimester $N = 67$ (17OSA)
BMI + age	0.772 (0.635, 0.909)	0.831 (0.714, 0.947)
SASS	0.676 (0.529, 0.823)	0.579 (0.417, 0.742)
Model 1	0.776 (0.639, 0.914)	0.826 (0.708, 0.943)
Model 2	0.781 (0.648, 0.914)	0.842 (0.732, 0.952)

Model 1: SASS + BMI + Age, Model 2: SASS + BMI + Age + Bedpartner-reported information

SASS Sleep Apnea Symptom Score, *BMI* body mass index

changes, as well as sleep fragmentation associated with physical discomfort, could also result in poor sleep quality [27]. Therefore, during pregnancy, the presence of poor sleep quality may not be specific to sleep apnea.

The SASS showed good internal consistency reliability when used during the third trimester, indicating that the items measure the same symptoms and produce similar scores. However, the SASS did not demonstrate adequate internal consistency when used during the first trimester (Cronbach's $\alpha = 0.45$). This finding is not surprising as the prevalence of OSA in the first trimester is relatively low. Therefore, the items either measured different sleep-related symptoms rather than OSA or there was simply nothing (or little) to measure [28].

When used alone, SASS demonstrated poor predictive values in detecting OSA during pregnancy. This finding is consistent with work performed by Wilson et al. [12]. Specifically, when the SASS was used alone, these investigators found that the AUC was 0.70, which was slightly higher than the AUC found in the current study (0.586–0.676). When they used a cut-off point of 0.5, the SASS had a sensitivity of 80% and a specificity of 71%. When a cut-off point of 0.84 was used, it had a high specificity (89%), but low sensitivity (53%). Similarly, other commonly used screening tools also demonstrated limited predictive values. Antony and colleagues [10] found that the BQ and ESS did not accurately predict OSA among pregnant women. Olivarez and colleagues [3] also reported that the BQ had a poor sensitivity and specificity of 35% and 63.8%, respectively. ESS and BQ did not adequately predict OSA among women with high-risk pregnancy (e.g., gestational hypertension), with an AUC of below 0.60 [9]. Likewise, Tantrakul et al. [20] evaluated the BQ and STOP-Bang in detecting OSA in women with high-risk pregnancies. Both questionnaires demonstrated limited predictive capacities during the first trimester, although the predictive values improved in the second and third trimester. Lockhart et al. [11] evaluated the predictive value of commonly used screening tools (i.e., BQ, ESS, and STOP-Bang) in identifying OSA during pregnancy. The AUC ranged from 0.63 to 0.69. However, none of the tools accurately detected OSA during the third trimester, with sensitivities between 14.6 and 33.3%. Wilson and colleagues [12] also found that the BQ had limited predictive abilities, with a sensitivity and specificity of 0.87 and 0.32, respectively. Based on the above evidence, currently available tools may not be optimal in screening for OSA during pregnancy.

Table 4 Diagnostic tests (95%CI) for different models

Model	First trimester $N = 89$ (13OSA)	Third trimester $N = 67$ (17OSA)
Model 1		
Sensitivity	76.9 (54.0, 99.8)	76.5 (56.3, 96.6)
Specificity	73.7 (63.8, 83.6)	78.0 (66.5, 89.5)
PPV	33.3 (16.5, 50.2)	54.2 (34.2, 74.1)
NPV	94.9 (89.3, 1.00)	90.7 (82.0, 99.4)
Model 2		
Sensitivity	76.9 (54.0, 99.8)	82.4 (64.2, 1.00)
Specificity	72.4 (62.3, 82.4)	78.0 (66.5, 89.5)
PPV	32.3 (15.8, 48.7)	56.0 (36.5, 75.5)
NPV	94.8 (89.1, 1.00)	92.9 (85.1, 1.00)

Model 1: SASS+BMI + Age, Model 2: SASS+BMI + Age + Bedpartner-reported information

SASS Sleep Apnea Symptom Score, *BMI* body mass index, *PPV* positive predictive values, *NPV* negative predictive value

In this study, the combined model consisting of SASS, age, BMI, and bedpartner-reported information performed better than the SASS alone in predicting OSA. While our findings are similar to several studies in this area, differences in methodology and study population demonstrate how these different screening tools may be used in different populations. For instance, Facco et al. [9] found that a multivariable model incorporating frequent snoring, chronic hypertension, age, and BMI showed good predictive values when used in women with high-risk pregnancies. The model resulted in an AUC of 0.86, slightly higher than the AUC in the present study (AUC 0.781–0.854). The optimal cut-off point resulted in a sensitivity, specificity, PPV, and NVP of 85.7%, 73.6%, 55.8%, and 93.0%, respectively, slightly different from our findings. These discrepancies may be explained by the difference in OSA prevalence reported in Facco et al. study and in this study as disease prevalence affects predictive values [29]. Similarly, Lockhart et al. found that a multivariable prediction model developed from existing tools performed better than current screening tools alone in detecting OSA during pregnancy [11]. Compared to the previous two studies, we used the gold standard of in-lab PSG for the diagnosis of OSA. In contrast, an unattended portable device (Watch-PAT) was used in Facco et al. study, and a type 3 device (ResMed ApneaLink) was used in Lockhart et al. study. Additionally, participants in Facco et al. study were women with high-risk pregnancies, and data in Lockhart et al. study were collected only during the third trimester. Wilson and colleagues [12] developed an

optimized model for screening for OSA in 43 pregnant women. The model consisted of snoring volume, BMI ≥ 32 kg/cm^2, and tiredness upon awakening. It had an AUC of 0.95 and demonstrated better predictive values than ours. However, that model may not be applicable to our population. Participants in the Wilson et al. study were either with high risk or no risk for OSA. In contrast, our participants were more heterogeneous in terms of OSA risk. Additionally, in the Wilson et al. study, BMI was obtained during the second trimester and dichotomized at the threshold of 32 kg/cm^2. BMI changes dramatically with the advance of pregnancy; using this threshold may not be appropriate for women during the first and third trimesters. Wilson and colleagues only obtained one PSG recording at 37-week gestation. In comparison, we obtained two, separate PSG recordings during the first and third trimesters, which enabled us to examine the predictive values of the screening tool for each trimester independently. Overall, the screening model developed in this study may have advantages over the previous ones in that it was validated against the gold standard in a relatively large sample and can be used in healthy pregnant women.

We found that predictive values for the combined model consisting of SASS, age, BMI, and bedpartner-reported information were generally higher during the third trimester than in the first trimester. This finding is in line with a previous study. In women with high-risk pregnancies, Tantrakul and colleagues [20] found that the predictive values of the BQ and STOP-Bang improved in the third trimester compared to the first trimester. In addition, women with high-risk pregnancies (e.g., gestational hypertension) are more likely to have OSA than healthy women [30]. Therefore, the prevalence of OSA in healthy pregnant women and those with high-risk pregnancies may be significantly different, a circumstance that would result in different PPV and NPV. A recent meta-analysis [13] also suggests that the performance of any screening tools for OSA depends on characteristics of the pregnancy, such as trimester and whether the women are healthy or have high-risk pregnancies. Overall, the predictive model developed by Facco et al. [9] and the questionnaires used by Tantrakul et al. [20] were noted to be good screening tools for pregnant women with high-risk pregnancies. The current screening tool would be suitable for screening OSA in relatively healthy pregnant women.

This study has several strengths. First, the diagnosis of OSA was based on overnight in-laboratory PSGs, allowing the assessment of all respiratory events during sleep. Second, risk factors for gestational sleep apnea (e.g., BMI) can vary significantly from first to the third trimester. Since women were evaluated in the first and third trimester, we were able to demonstrate the utility of SASS at both time points. Third, the use of a prospective cohort attenuated a number of potential biases. Fourth, consistent with the previous study by Facco and colleagues [9], we used a multicomponent approach by incorporating the questionnaire of interest as well as several easily obtained clinical measures. This approach was superior to using the SASS alone and reflected the unique nature of sleep apnea seen in pregnancy. Finally, we added bedpartner-reported information to the model in predicting OSA during pregnancy, which has not been done.

Study findings need to be interpreted in light of the limitations. First, the definition we used for sleep apnea was based on an AHI of 5 or greater, which reflects only mild sleep apnea [8]. However, even mild sleep apnea has been shown to have adverse health effects in the non-pregnant sample [31]. In addition, an AHI ≥ 5 has been suggested an increased risk factor for maternal/fetal complications among pregnant women [4]. Second, although we have demonstrated that bedpartner-observed snoring and apnea are more reliable than self-reported symptoms, their use is limited to those with a partner who is able to make these observations. Additionally, all participants were instructed to ask their bedpartners about whether they witnessed them experiencing sleep problems. The participants then fill out the questionnaire based on the information provided by the bedpartners. However, it is possible that the participants reported what they think their bedpartners would say. This double subjectivity needs to be addressed in future studies by having the bedpartners fill out the corresponding questionnaire. Lastly, the baseline prevalence of OSA in the current population in which the SASS was tested may be of importance to its greater utility as a screening tool in the broader population. In this sample, the prevalence of OSA was 12.7%, higher than the previous report [4]. The oversampling of overweight/obese participants and African-American women may have contributed to the higher prevalence estimate in this study. Therefore, our findings may only be generalized to women of similar ethnic background and BMI category.

Despite the limitations, this study has important implications for clinical practice. In general, the combined model, consisting of SASS, age, BMI, and bedpartner-reported information, demonstrated better predictive values during the third trimester than during the first trimester. However, considering the negative maternal and fetal outcomes of OSA, clinicians are recommended to administer this screening tool as early as possible. In that case, those with a high risk of OSA can be timely identified and referred to the sleep specialist. For those who are screened negative, follow-up screening should be administered. In this study, when the combined model was used, the NPV values were much higher than the PPV, indicating that this model is good at identifying those without OSA. The PPV increases as the prevalence of a disease increases. Therefore, clinicians could target the screening test to those at high risk of developing OSA, such as pregnant women with obesity or diabetes. Additionally, bedpartners of the pregnant women are advised to participate in the screening process.

In conclusion, we found that the SASS is a reasonably reliable and valid tool for predicting OSA in a pregnant population. When combined with other patient characteristics (i.e., age, BMI, and bedpartner-reported information), the SASS has improved potential utility in clinical practice for predicting OSA in healthy pregnant population. Future research may investigate our model using different AHI cutoff points in larger pregnant populations with various conditions (e.g., gestational diabetes and hypertension).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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