SCIENTIFIC INVESTIGATIONS

A population-based estimate of the health care burden of obstructive sleep apnea using a STOP-BAG questionnaire in South Carolina

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Study Objectives: Population based estimates of obstructive sleep apnea (OSA) frequency and health impact are incomplete. The aim of this study was to determine the prevalence of risk factors for physician and sleep study diagnosed OSA among individuals in a state-based surveillance program

Methods: Using questions inserted into the 2016 (n = 5,564) and 2017 (n = 10,884) South Carolina Behavioral Risk Factor Surveillance System of the Centers for Disease Control and Prevention, we analyzed the prevalence of physician diagnosed OSA and associated comorbidities. The validated STOP-BANG questionnaire without neck circumference (STOP-BAG) defined populations at moderate risk (score 3–4) and high risk (score 5–7). Statistical analysis using weighted prevalence and means and their 95% confidence intervals (CI) thus reflect population estimates of disease burden.

Results: The population-based prevalence of physician diagnosed OSA in South Carolina was 9.7% (95% CI: 9.0–10.4). However, the populations with moderate risk (18.5%, 95% CI: 17.3–19.8) and high risk (25.5%, 95% CI: 23.9–27.1) for OSA, as determined by the STOP-BAG questionnaire, were much higher. Compared to those at low risk for OSA, those at high risk were more often diagnosed with coronary heart disease, stroke, asthma, skin cancer, other cancers, chronic obstructive pulmonary disease, arthritis, depression, kidney disease, and diabetes (all $P < .001$).

Conclusions: OSA is common and strongly associated with major comorbidities. As such, this public health crisis warrants more diagnostic and therapeutic attention. The STOP-BAG questionnaire provides a public health platform to monitor this disease.

Keywords: OSA; sleep apnea; STOP-BAG; obstructive sleep apnea

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Obstructive sleep apnea is commonly underdiagnosed. However, to date, there are few public health tools to estimate the population burden of the condition and common comorbidities.

Study Impact: With the Behavioral Risk Factor Surveillance System of the Center for Disease Control and Prevention, a STOP-BAG questionnaire was able to estimate obstructive sleep apnea prevalence. The burden of undiagnosed obstructive sleep apnea and common comorbidities associated with obstructive sleep apnea is large and can be assessed longitudinally with this state-based tool.

INTRODUCTION

Obstructive sleep apnea (OSA) is a very common disorder. Associated with aging and body mass index (BMI), the exact prevalence depends on the populations studied. Older studies show an estimated prevalence of 9–25% in the general adult population,[1,2] and newer estimates show a prevalence of greater than 50% of adults aged 30–69 years in some countries in the world.[3] The repetitive closing and opening of the upper airway with the accompanying intermittent episodic hypoxemia and sleep fragmentation seen in OSA has been associated with significant adverse health consequences, such as cardiovascular disease,[4] cognitive impairment,[5] and motor vehicle crash.[6]

Since the respiratory events in OSA occur during sleep, many patients with OSA may not be aware that they have this condition. Hence, the number of undiagnosed individuals remains unknown.[7] OSA can be diagnosed by an overnight in-laboratory polysomnography or by a home sleep apnea test in carefully selected individuals; however, these tests are expensive, have limited availability in some geographic areas, and the precise diagnostic criteria remain somewhat controversial, especially for mild to moderate disease.[8]

For these reasons, screening tools have been developed to help identify patients at high risk for undiagnosed OSA. Two commonly used questionnaires, STOP[9] and STOP-BANG,[10] were developed as reliable, concise, and easy-to-use screening tools and have been validated in a variety of surgical and medical populations.[11–14] Importantly, the 8-question STOP-BANG has a higher sensitivity and specificity than the 4-question STOP tool, since the validation strategy was to add questions identified

Table 1—STOP, STOP-BANG, and modified STOP-BAG (without neck circumference) questionnaires.

	STOP	STOP-BANG	STOP-BAG
Loud snoring	×	×	×
Tiredness	×	×	×
Observed apnea	×	×	×
High blood pressure	×	×	×
Body mass index > 35 kg/m^2	–	×	×
Age > 50 years	–	×	×
Neck circumference > 40 cm	–	×	–
Gender male	–	×	×
Total score	4	8	7

in univariate analysis of OSA populations. This makes the STOP-BANG questionnaire clinically very useful in screening populations at risk for OSA. Meta-analysis estimates of the sensitivity of STOP-BANG for mild, moderate, and severe OSA are generally 88–93% with specificities of 35–42% for the different OSA populations.[15]

In this study, the STOP-BANG instrument and question regarding self-report of provider-diagnosed OSA was applied to an adult population-based cohort derived through the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System (BRFSS). Our goal was to identify individuals at high-risk for OSA using available information. To this purpose, 4 questions were incorporated into the BRFSS sleep module in addition to the existing BRFSS data (age, hypertension, BMI, and sex) that were designed to capture all the elements of the STOP-BANG screening questionnaire with the exception of neck circumference. The STOP-BANG instrument is validated for a score ≥ 3,[9,10] indicating moderate to high risk of OSA. However, neck circumference is not easily captured on a questionnaire. Therefore, we analyzed BRFSS data with a STOP-BANG questionnaire that did not include the neck circumference data, which we called the STOP-BAG questionnaire (**Table 1**). The STOP-BAG has been used in other patient populations to screen for OSA and has been found to have a high sensitivity and reasonable specificity.[16,17]

The principal goal of this research project was to use the BRFSS health survey data to define the epidemiology of diagnosed and undiagnosed populations with OSA in the state of South Carolina between January 1, 2016 and December 31, 2017. Furthermore, we sought to define the impact of OSA on other health outcomes.

METHODS

In 2016, the South Carolina (SC) BRFSS included 4 sleep disorder-related questions as an optional module, which were asked to adults for the last 6 months of the year. These questions were as follows (responses detailed in **Table S1** in the supplemental material): "Over the last 2 weeks, how many days have you had trouble falling asleep or staying asleep or sleeping too much?"; "Over the last 2 weeks, how many days did you

unintentionally fall asleep during the day?"; "Have you ever been told that you snore loudly?"; and "Has anyone ever observed that you stop breathing during your sleep?"

In 2017, another state-added question was incorporated into the SC BRFSS to obtain the prevalence of diagnosed OSA ("Has a doctor ever diagnosed you with a condition called obstructive sleep apnea (also known as OSA) based on a sleep study?"; **Table S1**). The 2016 SC BRFSS data were obtained (n = 11,236), and sample exclusions were applied to remove those with incomplete or missing data that limited obtaining a complete STOP-BAG score (final n = 5,557; **Figure 1**).

Participants in the 2017 SC BRFSS (n = 11,311) were excluded if they responded, "don't know/not sure" or "refused" or dropped out of the survey before being asked if they were diagnosed with OSA by a physician (final n = 10,884, **Figure 1**). Details of the BRFSS and its characteristics are described elsewhere.[18]

We divided the 2016 cohort into those at low risk for OSA (STOP-BAG < 3), those at moderate risk (STOP-BAG 3–4), and those at high risk for OSA (STOP-BAG ≥ 5) for comparison.

The comorbidity rates of individuals at high risk for OSA (2016) and with diagnosed OSA (2017) were compared to the rates of individuals at low or moderate risk of OSA (2016) and without diagnosed OSA (2017). Comorbidity data included self-report of a physician diagnosis of coronary heart disease, stroke, asthma, skin cancer, any other cancer, COPD, arthritis, depressive disorder, kidney disease, and diabetes.

We compared the impact of at risk OSA and diagnosed OSA on general health (excellent, very good, good, fair, poor), mental health, and physical health.

Statistics

Survey analysis procedures were utilized in SAS 9.4 (SAS Inc., Cary, NC) to account for the complex weighting and sampling of BRFSS. To compare the demographic and health behavior distributions between the levels of STOP-BAG scores, weighted prevalence and mean estimates, along with their 95% confidence intervals (CIs) and chi-square tests for categorical variables, were obtained. The iterative proportional fitting or raking of the data collected allows for multivariate adjustment of outcomes by age, sex, categories of ethnicity, geographic regions within the state, marital status, education level, home ownership, and type of phone ownership. The comparison of STOP-BAG scores and self-reported OSA diagnosis to symptoms and health outcomes used the same variables in modeling. Raw data are also presented in the supplemental material without population weighting to allow an understanding of the general population sampled. ANOVA or chi-square tests with Bonferroni corrections for repeated measures was used in these analyses where referenced. *P* values < .05 were considered significant.

RESULTS

The 2016 SC BRFSS STOP-BAG estimated a low risk of OSA (STOP-BAG < 3) of 56.0% (95% CI: 54.2–57.9), moderate risk of OSA (STOP-BAG 3–4) of 18.5% (17.3–19.8) and high risk (STOP-BAG ≥ 5) of 25.5% (95% CI: 23.9–27.1) from the population of South Carolina (**Table 2**). Compared to those at

Figure 1—Consort diagram for populations analyzed in the 2016 and 2017 BRFSS data.
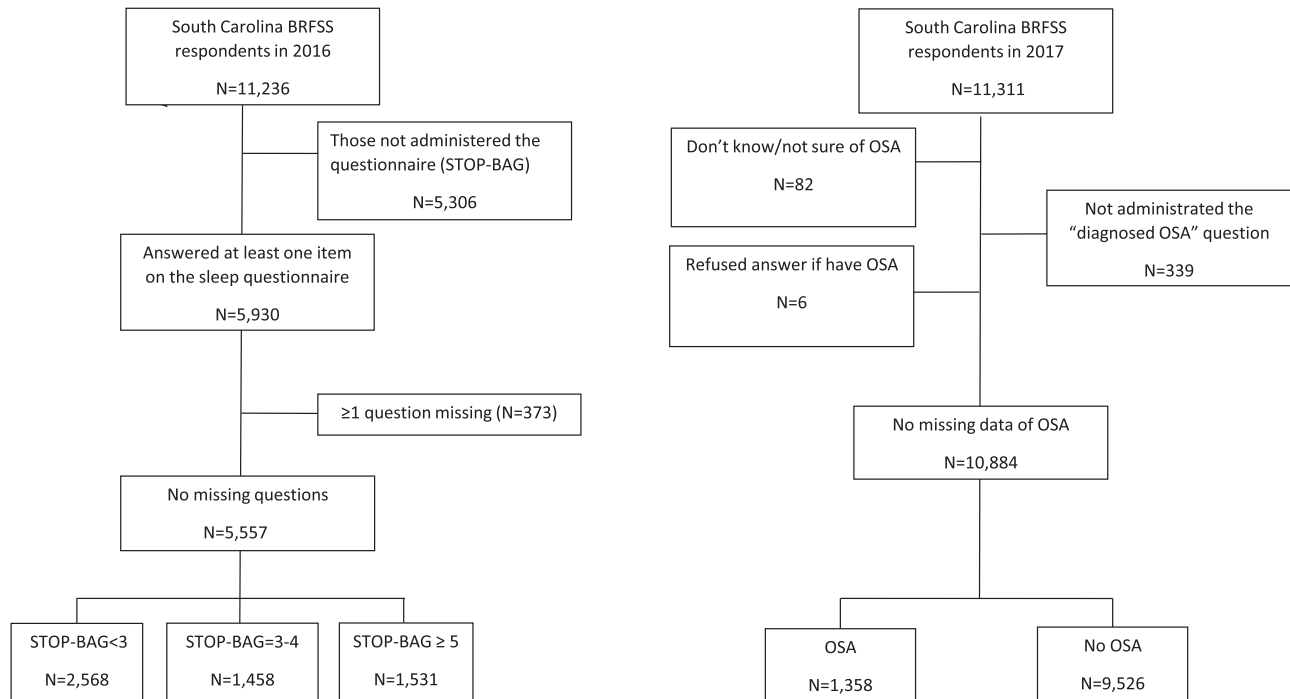
BRFSS = Behavioral Risk Factor Surveillance Survey, OSA = obstructive sleep apnea.

low risk for OSA, those at high risk included a significantly higher proportion of men with hypertension and a higher BMI. However, this is not surprising since these characteristics are components of the STOP-BAG questionnaire. Similarly, those at high risk for OSA had a higher proportion of loud snorers, witnessed apneas, and reported more trouble falling asleep and unintentionally falling asleep during the day in the past 2 weeks compared to those at low risk (**Table 3**). All of these characteristics suggest that the STOP-BAG is measuring important variables related to OSA, although further validation of this questionnaire will require more rigorous studies.

Independent of STOP-BAG questions, those at moderate and high risk for OSA more commonly had an annual household income < \$15,000, were more commonly married, and were smokers compared to the those in the low-risk group.

Multiple important health outcomes were associated with the STOP-BAG categorical score. Compared to those at low risk for OSA, those at high risk were more often diagnosed with coronary heart disease, stroke, asthma, skin cancer, other cancers, COPD, arthritis, depression, kidney disease, and diabetes (**Table S2**). Furthermore, compared to those at low risk for OSA, those at high risk had worse general health, physical health, and mental health and a higher mean number of days in which their physical and mental health was "not good" in the past month. The high-risk group also reported more difficulty concentrating or re-membering and more difficulty walking or climbing stairs. Although statistically different, the number of reported sleep hours was not meaningfully different between groups.

The 2017 SC BRFSS included the question of whether OSA had been previously diagnosed by a doctor. From this question,

the population-based prevalence of diagnosed OSA was 9.7% (95% CI: 9.0–10.4) (**Table 3**). In this population were a higher proportion of men and former smokers; BMI and age also were higher. Diagnosed individuals were more commonly diagnosed with hypertension, coronary heart disease, stroke, asthma, skin cancer, other cancers, COPD, arthritis, depression, kidney disease, and diabetes (**Table 4**). In this cohort of those diagnosed with OSA, there was reported more difficulty concentrating or remembering, more difficulty walking or climbing stairs, more individuals receiving a flu shot in the past year, and more individuals receiving a pneumonia shot ever. The OSA cohort reported more fair-poor general health and more days in the past month in which their physical or mental health was "not good." The number of days in which their physical or mental health kept them from their normal activities were higher compared to those without OSA. Among those with physician-diagnosed OSA in South Carolina, there was a significantly lower proportion of Hispanics; those identifying as never married, never smokers, heavy alcohol consumers; and those reporting excellent–very good general health compared to those without OSA.

DISCUSSION

The prevalence of diagnosed and undiagnosed OSA in the United States has been the subject of controversy for many years. Using a question of self-report of provider and sleep study-diagnosed OSA inserted into the BRFSS, this study was able to estimate the prevalence of OSA diagnosed by a health

Table 2—Population demographics associated with individuals who have low, moderate, or high risk for OSA.

Variable	Overall Sample	Low Risk For OSA	Moderate Risk For OSA	High Risk For OSA	P Value (chi-square)
Prevalence (%)	100.0	56.0 (54.2–57.9)	18.5 (17.3–19.8)	25.5 (23.9–27.1)	
Age (mean years)	48.3 (47.6–48.9)	**40.8** (40.0–41.7)	61.8 (60.9–62.8)	54.7 (53.7–55.8)	< .0001*
Sex (% male)	47.8 (45.8–49.7)	**35.8** (33.0–38.7)	40.6 (37.1–44.2)	79.2 (76.6–81.8)	< .0001
Race (%)					< .0001
White	69.3 (67.5–71.1)	69.6 (66.9–72.3)	70.1 (66.8–73.3)	68.1 (64.9–71.2)	
Black	25.8 (24.1–27.4)	23.9 (21.5–26.4)	27.2 (24.0–30.4)	28.7 (25.6–31.8)	
Other	3.7 (2.7–4.7)	**5.2** (3.5–6.8)	1.7 (0.9–2.5)	2.0 (1.2–2.8)	
Multiracial	1.2 (0.9–1.5)	1.3 (0.8–1.8)	1.0 (0.5–1.6)	1.2 (0.8–1.7)	< .0001
Hispanic (Yes %)	4.5 (3.3–5.6)	**6.8** (4.9–8.8)	1.2 (0.5–2.0)	1.5 (0.4–2.6)	< .0001
Income (%)					.0040
< $15,000	11.4 (10.1–12.8)	**9.3** (7.4–11.2)	13.4 (10.9–16.0)	14.3 (11.6–17.0)	
$15,000–25,000	19.2 (17.5–20.9)	18.6 (16.1–21.0)	20.4 (17.4–23.5)	19.6 (16.5–22.6)	
$25,000–35,000	11.0 (9.7–12.2)	10.4 (8.7–12.1)	11.8 (9.0–14.7)	11.5 (9.1–14.0)	
$35,000–50,000	15.6 (14.1–17.2)	16.2 (13.8–18.5)	17.0 (14.0–20.1)	13.6 (11.1–16.1)	
≥ $50,000	42.8 (40.8–44.8)	45.6 (42.6–48.6)	37.3 (33.5–41.0)	41.0 (37.5–44.5)	
Marital Status (%)					< .0001
Married	51.6 (49.7–53.5)	**47.2** (44.4–50.0)	54.5 (51.0–58.1)	59.0 (55.6–62.5)	
Divorced	11.3 (10.1–12.5)	9.5 (7.9–11.0)	15.3 (12.5–18.1)	12.4 (10.1–14.8)	
Widowed	7.4 (6.6–8.1)	5.4 (4.5–6.2)	14.8 (12.6–17.0)	6.3 (4.8–7.8)	
Separated	3.4 (2.7–4.1)	3.4 (2.3–4.5)	3.0 (1.8–4.2)	3.5 (2.4–4.7)	
Never married	22.8 (21.0–24.6)	**29.9** (27.1–32.6)	10.6 (8.2–13.1)	16.2 (13.3–19.0)	
A member of an unmarried couple	3.5 (2.6–4.5)	4.6 (3.1–6.1)	1.7 (0.3–3.2)	2.5 (1.4–3.7)	
Education (%)					.0022
Did not graduate HS	15.0 (13.4–16.6)	13.8 (11.3–16.2)	16.3 (13.4–19.1)	16.8 (13.9–19.7)	
Graduated HS	29.8 (28.0–31.5)	27.8 (25.3–30.3)	31.9 (28.5–35.2)	32.5 (29.3–35.7)	
Attended college or technical school	32.5 (30.7–34.4)	**33.1** (30.5–35.8)	31.8 (28.5–35.2)	31.7 (28.4–34.9)	
Graduated from college or technical school	22.7 (21.3–24.1)	25.3 (23.1–27.4)	20.0 (17.7–22.4)	19.0 (16.7–21.3)	
Rural (%)	16.4 (15.3–17.6)	15.1 (13.3–16.9)	19.3 (16.9–21.7)	17.2 (15.1–19.4)	.0218
Smoker (%)					< .0001
Every day smoker	12.9 (11.5–14.3)	11.9 (10.1–13.8)	13.0 (10.4–15.7)	14.9 (12.2–17.7)	
Some days smoker	7.3 (6.1–8.4)	7.4 (5.7–9.2)	7.8 (5.7–10.0)	6.4 (4.6–8.2)	
Former smoker	27.0 (25.4–28.6)	**19.9** (17.8–22.0)	32.3 (29.1–35.6)	38.8 (35.5–42.1)	
Never smoker	52.8 (50.9–54.7)	**60.7** (57.9–63.5)	46.8 (43.3–50.3)	39.9 (36.5–43.2)	
BMI (mean kg/m^2)	28.3 (28.0–28.5)	**26.2** (25.9–26.5)	29.0 (28.5–29.5)	32.1 (31.6–32.7)	< .0001*
Heavy alcohol consumption (Yes %)	7.3 (6.2–8.3)	6.8 (5.4–8.2)	7.6 (5.3–10.0)	8.1 (5.9–10.3)	.5498
Difficulty concentrating or remembering (Yes %)	13.7 (12.3–15.0)	**11.7** (9.8–13.6)	15.1 (12.5–17.7)	16.8 (14.1–19.6)	.0020
Difficulty walking or climbing stairs (Yes %)	16.8 (15.5–18.1)	**8.0** (6.7–9.3)	26.0 (23.0–29.1)	29.4 (26.3–32.5)	< .0001
Shingles vaccine (Yes %)	21.3 (19.7–22.9)	21.2 (18.6–23.9)	21.7 (18.9–24.4)	20.9 (18.0–23.8)	.9314
Adult flu shot/spray past 12 months (Yes %)	36.6 (34.8–38.3)	**31.7** (29.2–34.2)	46.1 (42.7–49.6)	40.3 (37.0–43.6)	< .0001
Pneumonia shot ever (Yes %)	35.8 (34.0–37.7)	**27.8** (25.2–30.3)	46.7 (43.1–50.2)	44.4 (40.9–47.9)	< .0001
Days had trouble with sleep (mean days)	4.2 (4.0–4.4)	**3.8** (3.5–4.1)	4.3 (3.9–4.7)	4.9 (4.5–5.3)	< .0001
Sleep days during the day (mean days)	1.3 (1.1–1.4)	**0.5** (0.4–0.6)	1.6 (1.4–1.9)	2.7 (2.4–3.0)	< .0001
Snore loudly (Yes %)	49.7 (47.8–51.6)	**27.6** (25.1–30.2)	64.7 (61.4–68.1)	87.4 (85.2–89.6)	< .0001
Observed stop breathing (Yes %)	15.8 (14.5–17.1)	**2.1** (1.4–2.9)	16.3 (13.6–19.0)	45.6 (42.1–49.0)	< .0001

Data are expressed as prevalence or mean with 95% confidence intervals. Low, moderate, and high risk for OSA determined with STOP-BAG questionnaire scores of 1–2, 3–4, and ≥ 5, respectively (SC BRFSS 2016). Bold numbers are significantly different from the high risk group. *Analysis by ANOVA for continuous variables. BMI = body mass index, HS = high school, OSA = obstructive sleep apnea.

Table 3—Weighted bivariate comparisons of those with OSA and without OSA from the 2017 SC BRFSS comparing demographics and health behaviors of the cohort.

Variable	Overall Population (n=10,884)	With OSA (n=1,358)	Without OSA (n=9,526)	P Value (chi-square)
Prevalence (%)	100.0 (–)	9.7 (9.0– 10.4)	90.3 (89.6– 91.0)	
Age (mean years)	48.6 (48.1–49.1)	**57.9** (56.8– 59.1)	47.6 (47.1–48.2)	< .0001*
Sex (% male)	47.7 (46.4–49.1)	**56.6** (53.1– 60.1)	46.8 (45.3–48.2)	< .0001
Race (%)				.0716
White	68.1 (66.8–69.3)	72.0 (68.9–75.2)	67.6 (66.2–69.0)	
Black	27.3 (26.1–28.6)	24.6 (21.5– 27.6)	27.6 (26.3–29.0)	
Other	3.1 (2.6–3.6)	2.2 (0.9– 3.4)	3.2 (2.7–3.8)	
Multiracial	1.5 (1.2–1.8)	1.2 (0.7–1.7)	1.5 (1.2–1.9)	
Hispanic (Yes %)	4.8 (4.1–5.5)	**1.8** (0.7–2.9)	5.1 (4.3–5.9)	.0005
Income (%)				.0456
< $15,000	11.7 (10.8–12.7)	11.8 (9.3–14.2)	11.7 (10.7–12.8)	
$15,000–25,000	19.8 (18.7–21.0)	**24.3** (20.7–27.9)	19.3 (18.1–20.6)	
$25,000–35,000	10.5 (9.6–11.5)	9.9 (7.6–12.1)	10.6 (9.6–11.6)	
$35,000–50,000	15.0 (13.9–16.0)	12.8 (10.4–15.2)	15.2 (14.0–16.4)	
≥ $50,000	42.9 (41.5–44.4)	41.2 (37.4–45.1)	43.1 (41.5–44.7)	
Marital Status (%)				< .0001
Married	49.9 (48.5–51.2)	**56.6** (53.0–60.2)	49.2 (47.7–50.6)	
Divorced	10.6 (9.8–11.4)	**14.9** (12.4–17.5)	10.1 (9.3–10.9)	
Widowed	8.2 (7.7–8.80)	**11.6** (9.5–13.7)	7.9 (7.3–8.5)	
Separated	3.7 (3.1–4.2)	5.0 (3.5–6.6)	3.5 (3.0–4.1)	
Never married	24.0 (22.7–25.4)	**9.6** (7.1–12.1)	25.5 (24.1–27.0)	
A member of an unmarried couple	3.6 (3.0–4.2)	2.2 (0.7–3.7)	3.7 (3.1–4.4)	
Education (%)				.8106
Did not graduate HS	14.5 (13.4–15.5	14.8 (11.9– 17.6)	14.4 (13.3–15.6)	
Graduated HS	30.3 (29.0–31.5)	29.9 (26.5–33.3)	30.3 (29.0–31.6)	
Attended college or technical school	31.7 (30.4–33.0)	30.5 (27.1–33.8)	31.8 (30.4–33.2)	
Graduated from college or technical school	23.6 (22.6–24.6)	24.9 (22.0–27.7)	23.4 (22.4–24.5)	
Rural (%)	16.0 (15.2–16.8)	16.8 (14.5–19.2)	15.9 (15.0–16.8)	0.4623
Smoker (%)				< .0001
Every day smoker	12.8 (11.9–13.8)	11.2 (8.5–14.0)	13.0 (12.0–14.1)	
Some days smoker	6.3 (5.6–7.0)	5.3 (3.4–7.2)	6.4 (5.6–7.1)	
Former smoker	26.7 (25.5–27.9)	**38.6** (35.1–42.1)	25.4 (24.2–26.6)	
Never smoker	54.2 (52.8–55.5)	**44.9** (41.3–48.4)	55.2 (53.7–56.7)	
BMI (mean kg/m^2)	28.7 (28.5–28.8)	**33.3** (32.8–33.9)	28.1 (27.9–28.3)	< .0001*
Heavy alcohol consumption (Yes %)	6.6 (5.8–7.3)	**3.6** (2.2–5.0)	6.9 (6.1–7.7)	.0012
Difficulty concentrating or remembering (Yes %)	12.6 (11.7–13.5)	**24.7** (21.4–27.9)	11.3 (10.3–12.2)	< .0001
Difficulty walking or climbing stairs (Yes %)	16.9 (16.0–17.8)	**41.3** (37.8–44.9)	14.2 (13.3–15.1)	< .0001
Shingles vaccine (Yes %)	25.4 (24.2–26.7)	29.2 (25.9–32.5)	24.8 (23.4–26.1)	.0127
Adult flu shot/spray past 12 months (Yes %)	40.3 (39.0–41.6)	**55.2** (51.5–59.0)	38.7 (37.2–40.1)	< .0001
Pneumonia shot ever (Yes %)	39.0 (37.6–40.3)	**56.4** (52.5–60.2)	36.9 (35.5–38.4)	< .0001

Data are expressed as prevalence or mean with 95% confidence intervals comparing those with and without OSA. Bold numbers are significantly different from the not diagnosed group. *Analysis by ANOVA for continuous variables. BMI = body mass index, HS = high school, OSA = obstructive sleep apnea.

care practitioner as 9.7% (95% CI: 9.0–10.4) of the state population. The typical respondent in South Carolina with diagnosed OSA is male, has an annual income > $50,000, and a diagnosis of hypertension. Using a weighting format to over-represent populations who are difficult to reach by telephone survey, this state-based survey conducted by the Centers for

Table 4—Weighted bivariate comparisons of those with OSA and not diagnosed with OSA showing health behaviors/outcomes from the 2017 SC BRFSS.

Variable	Overall Population (n=10,884)	With OSA (n=1,358)	Without OSA (n=9,526)	P Value (chi-square)
General health (%)				< .0001
Excellent	18.7 (17.6–19.9)	**5.7*** (3.8–7.6)	20.1 (18.9–21.4)	
Very good	30.8 (29.6–32.1)	**21.6*** (18.6–24.5)	31.8 (30.5–33.2)	
Good	30.9 (29.7–32.1)	33.9 (30.5–37.3)	30.6 (29.3–31.9)	
Fair	13.4 (12.6–14.3)	**22.1*** (19.1–25.1)	12.5 (11.6–13.4)	
Poor	6.1 (5.5–6.7)	**16.8*** (14.1–19.4)	5.0 (4.3–5.6)	
Hypertension (Yes %)	38.8 (37.5–40.0)	**68.4*** (64.9–71.9)	35.6 (34.3–36.9)	< .0001
Ever diagnosed with CHD (Yes %)	5.0 (4.5–5.5)	**16.6*** (13.8–19.3)	3.8 (3.3–4.2)	< .0001
Ever diagnosed with stroke (Yes %)	4.0 (3.5–4.4)	**10.2*** (8.0–12.4)	3.3 (2.9–3.7)	< .0001
Ever diagnosed with asthma (Yes %)	14.0 (13.1–15.0)	**24.2*** (21.1–27.3)	13.0 (11.9–14.0)	< .0001
Currently have asthma (Yes %)	9.2 (8.4–10.0)	**19.5*** (16.6–22.3)	8.1 (7.2–8.9)	< .0001
Ever diagnosed with skin cancer (Yes %)	7.4 (6.9–8.0)	**12.1*** (10.0–14.2)	7.0 (6.4–7.5)	< .0001
Ever diagnosed with other cancer (Yes %)	7.6 (7.0–8.2)	**12.3*** (10.3–14.4)	7.1 (6.5–7.7)	< .0001
Ever diagnosed with COPD (Yes %)	7.9 (7.3–8.6)	**21.5*** (18.6–24.4)	6.5 (5.9–7.2)	< .0001
Ever diagnosed with arthritis (Yes %)	28.8 (27.7–29.9)	**55.9*** (52.2–59.5)	25.9 (24.8–27.0)	< .0001
Ever diagnosed with depressive disorder (Yes %)	20.4 (19.3–21.4)	**34.7*** (31.3–38.1)	18.8 (17.7–20.0)	< .0001
Ever diagnosed with kidney disease (Yes %)	3.3 (2.8–3.7)	**9.2*** (7.0–11.4)	2.6 (2.2–3.0)	< .0001
Ever diagnosed with diabetes (Yes %)	13.8 (13.0–14.6)	**36.6*** (33.2–40.0)	11.3 (10.6–12.1)	< .0001
Physical health not good (mean days)	4.2 (4.0–4.4)	**9.0*** (8.1–9.9)	3.7 (3.5–3.9)	< .0001*
Mental health not good (mean days)	4.4 (4.1–4.6)	**6.4*** (5.6–7.2)	4.2 (3.9–4.4)	< .0001*
Poor physical or mental health (mean days)	5.4 (5.0–5.7)	**9.7*** (8.6–10.7)	4.8 (4.5–5.2)	< .0001*

Data are expressed as prevalence or mean with 95% confidence intervals. Bold numbers are significantly different from the not diagnosed group. *Analysis by ANOVA for continuous variables. CHD = coronary heart disease, COPD = chronic obstructive pulmonary disease, OSA = obstructive sleep apnea.

Disease Control and Prevention[18] collects self-reported information about chronic conditions and health risk behaviors throughout the year and can provide confidence intervals to inform the true state prevalence.[19] This is the first report that describes the use of the BRFSS, the largest ongoing, annual health survey in the United States, to determine the prevalence of OSA and could serve a model to better target this disease using a population-based approach.

However, the prevalence of the population who remains undiagnosed is much harder to define. By using the STOP-BAG instrument, the study found a prevalence of moderate risk as defined by STOP-BAG scores of 3–4 was 18.5%, (95% CI: 17.3–19.8) and high risk as defined by STOP-BAG scores ≥ 5 was 25.5%, (95% CI: 23.9–27.1) of the population. If it is true that 44% of the population has OSA, then this would be a public health emergency of epidemic proportions, since approximately 10% are currently diagnosed with the condition. Much more likely is the possibility that a higher point score on STOP-BAG portends higher risk and more comorbidities. This would suggest that the high-risk STOP-BAG scores ≥ 5 are populations who may derive the most benefit from therapy. However, this estimate of 23.9–27.1% of the entire state population is a public health crisis.

We do not believe that South Carolina is much different from other states in the rise of obesity and thus prevalence of OSA. An analysis of National Health and Nutrition Examination Survey

(NHANES) data revealed that the age-adjusted US prevalence of obesity in 2013–2014 was 35.0% in men and 40.4% in women.[20] The prevalence of obesity showed significant linear trends for increase between 2005 and 2014 for women; however, there were no significant trends for men. Obesity is linked to several adverse health outcomes, such as cardiovascular disease, diabetes, and also OSA; thus, an increasingly high prevalence of obesity indicates an unhealthy population and a burgeoning national health crisis.[21] Moreover the prevalence of obesity has racial differences, with Hispanic and Black populations being disproportionately affected compared to non-Hispanic Whites and Asian adults.[22] The baseline examination of the Hispanic Community Health Study/Study of Latinos, a population-based cohort of US Hispanics/Latinos conducted between 2008 and 2011,[23] estimated that 37% of men and 43% of women were obese, with a BMI ≥ 30 kg/m². Since the prevalence of OSA is linear with the prevalence of obesity, one challenge in this study was to define correlates of OSA that were independent of BMI.

Since most patients with OSA remain undiagnosed, it is currently difficult to define how many of the associated comorbidities such as coronary heart disease, stroke, depression, and diabetes are OSA specific and how many are due to obesity and the associated metabolic syndrome. However, these associations in our study are similar to the OSA literature, in which those who screen as high risk

for OSA[24–26] and those who are diagnosed with OSA[27,28] have incredibly high prevalence of these comorbidities. The implication that early and aggressive screening and treatment of OSA may result in overall improvement in general health and well-being of the population is a strategy that health policy makers and clinicians should embrace. Furthermore, if screening is done with newer technology that does not rely on laboratory polysomnography, this would very likely be accompanied by a decreased expenditure on health care. Indeed, aggressive screening and treatment for OSA has been demonstrated to result in health care cost savings in several populations.[29,30]

We performed this study by adding additional questions to the BRFSS as an optional module, so that the components of the STOP-BAG questionnaire could be captured. Although the 8-item STOP-BANG questionnaire has been demonstrated to have good sensitivity and modest specificity in detecting OSA in many populations,[15] the abbreviated STOP-BAG questionnaire without neck circumference could emerge as an important public health tool, since the component questions need not require the presence of a health care practitioner to collect.

We were also able to define aspects of probable health care disparities in our study. In this study, a greater proportion of Hispanics were categorized as being at low risk for OSA and had a lower OSA diagnosis rate compared to Whites. Although published data on US Hispanics is somewhat limited, there is evidence to suggest that the OSA prevalence in Hispanics is quite high. A prevalence survey of sleep-disordered breathing in San Diego adults, which monitored blood oxygen desaturations ≥ 4% with home recording instruments, usually for 3 consecutive nights, found that 16.3% of US Hispanics and racial minorities have ≥ 20 oxygen desaturation events/h of sleep compared to 4.9% of non-Hispanic Whites ages 40–64 years.[31] Obesity was the most important demographic predictor of sleep-disordered breathing in this study, followed by age, male sex, and ethnicity. In a cross-sectional analysis of 14,440 individuals from the baseline examination of the Hispanic Community Health Study/Study of Latinos,[32] the age-adjusted prevalence of minimal sleep-disordered breathing as assessed with an apnea-hypopnea index (AHI) ≥ 5 events/h, moderate sleep-disordered breathing (AHI ≥ 15), and severe sleep-disordered breathing (AHI ≥ 30) was found to be 25.8%, 9.8%, and 3.9%, respectively. However, only 1.3% of participants reported a sleep apnea diagnosis, which would imply that OSA, although common in Hispanics, was rarely given a clinical diagnosis remembered by the Hispanic BRFSS respondents.

We were perplexed by the increased use of influenza, pneumococcal, and shingles vaccination in the at-risk and diagnosed OSA populations. The best explanation is that these individuals, by way of the comorbidities, have much more contact with the health care community and with more clinic visits have more opportunities to receive these important health interventions. One of the possibilities is that the option of diagnosing OSA was equally discussed and dismissed. Dismissing the opportunity for a sleep study or empiric trial of auto-continuous positive airway pressure can come from many barriers within the medical community, including the lack of effectiveness of therapy in the eyes of many primary care physicians.

There are limitations to this study. There is no doubt that the STOP-BAG needs further validation. As a highly sensitive screening tool, the STOP-BANG parent instrument has modest specificity when measured against the AHI. Furthermore, the STOP-BANG is good at detecting the absence of severe OSA with very low scores.[33] However, there are also limitations to using AHI as the gold standard for OSA, since treatment efficacy and comorbidities are more closely aligned with symptoms and the duration of hypoxemia, which may be better captured on questionnaire instruments than by AHI alone.

The 2016 SC BRFSS data included the components of the STOP-BAG questionnaire that were not included in the 2017 data. The 2017 data included a question on diagnosed OSA, which was not included in the 2016 data. Because the BRFSS is designed with weighting to be demographically representative of the population in the entire state, we believe that the populations are similar, but not identical. Other limitations include those that are inherent to all survey-based studies, including self-reporting bias and recall bias. Sleep studies were not available to confirm/refute the diagnosis of OSA in respondents; however, to improve the reliability of self-report of provider-diagnosed OSA, we chose to include history of testing in the prevalence question. The reliability of self-reported diagnoses of chronic conditions between BRFSS and other surveys has been found to be high.[19]

CONCLUSIONS

Among the adult population of South Carolina, the prevalence of diagnosed OSA is approximately 10% of the state. However, the population at high risk using the STOP-BAG instrument is approximately 25%. This new instrument should be further studied to define the instrument validation metrics, since application to the BRFSS and other large datasets can highlight important health policy applications to better understand OSA prevalence and optimal treatment and improve public health.

ABBREVIATIONS

AHI, apnea-hypopnea index
ANOVA, analysis of variance
BMI, body mass index
BRFSS, Behavioral Risk Factor Surveillance Survey
CI, confidence interval
COPD, chronic obstructive pulmonary disease
OSA, obstructive sleep apnea

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DISCLOSURE STATEMENT