HHS Public Access

Author manuscript

*J Clin Hypertens (Greenwich)*. Author manuscript; available in PMC 2014 August 01.

Published in final edited form as:

*J Clin Hypertens (Greenwich)*. 2013 August ; 15(8): 593–599. doi:10.1111/jch.12144.

# The Association between Obstructive Sleep Apnea and Hypertension by Race/Ethnicity in a Nationally Representative Sample

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## Abstract

**Background—**The association between OSA and hypertension by race/ethnicity has not been well characterized in a national sample.

**Subjects—**Adult participants in the 2007–2008 National Health and Nutrition Examination Survey.

**Methods—**We reviewed self-reports of sleep apnea diagnosis, snorting, gasping or stopping breathing during sleep and snoring to derive whether OSA was probable (pOSA). Multivariable logistic regression determined whether pOSA predicted hypertension in the cohort, and BMI and ethno-racial strata.

**Results—**pOSA predicted hypertension in several groups: 1) Within BMI strata, there was a significant association among overweight individuals [OR (95% CI) =1.82 (1.26–2.62)]; 2) In race/ethnicity subgroups, the association was significant among Hispanic/Latinos [OR (95% CI) =1.69 (1.13, 2.53)] and whites [OR (95% CI) =1.40 (1.07, 1.84)]; 3) In models stratified by both race/ethnicity and weight, pOSA predicted hypertension among overweight Black/African Americans [OR (95% CI) =4.74 (1.86–12.03)], overweight whites [OR (95% CI) =1.65 (1.06, 2.57)], and obese Hispanic/Latino participants [OR (95% CI) =2.01 (1.16, 3.49)].

**Conclusions—**A simple, self-report tool for OSA was strongly associated with hypertension, and may serve as a potential future opportunity for OSA diagnosis.

### Keywords

Hypertension; sleep problems and hypertension; race/ethnicity; risk assessment; OSA

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**Statement of Financial Disclosures:** The authors report no specific funding in relation to this research and no conflicts of interest to disclose.

## Introduction

Obstructive Sleep Apnea (OSA) is common,[1,2] and characterized by intermittent collapse of the upper airway during sleep.[3] Diagnosis of OSA relies on polysomnography (PSG), which counts the number of apneas (flow cessations) or hypopneas (flow reductions) per hour of sleep to compute the apnea-hypopnea index (AHI).[4] OSA has been linked to hypertension in cross-sectional[5] and longitudinal[6,7] studies. A recent meta-analysis of randomized controlled trials as well recent findings from a RCT in nonsleepy individuals concluded that treating OSA with positive airway pressure (PAP) lowers blood pressure.[8,9] While the pooled estimate of the effect of PAP was modest, the reduction was more prominent in groups with more severe apnea and higher compliance with PAP therapy. Accordingly, the American Heart Association listed OSA among treatable causes of hypertension.[10] These data provide a compelling case for widespread identification and treatment of OSA among those with hypertension.

The diagnostic gold standard for OSA remains PSG. However, PSG relies on a sleep laboratory, requires technical expertise, is expensive, and is often inaccessible.[11] These characteristics make PSG unsuitable for population-wide case finding. While portable, limited-channel testing is gaining attention, the need persists for a quick, easy, and inexpensive strategy to assess risk on a population-wide level, so that diagnostic testing can be targeted to select groups at highest risk.

Body mass index (BMI) has been used as a proxy variable for measuring obesity, which is a powerful risk factor for OSA,[12] and identifies apnea with reasonable accuracy.[13–15] Among non-obese referrals to sleep centers, however, certain self-reported symptoms may add value in risk assessment.[13] While choking, gasping and apneas witnessed during sleep by others are common symptoms of apnea, self-reported snoring is not only a sensitive symptom of OSA,[16–19] but has also been associated with hypertension in OSA.[20,21] This relationship between OSA symptoms and hypertension may be mediated by race and ethnicity,[22,23] but large sample data in groups such as Hispanic/Latinos are not available. Additionally, typical symptom-experience, such as witnessed apneas or morning headaches have been purported to be less useful among women.[24,25]

To date, limited evidence exists regarding the association between OSA and hypertension by race/ethnicity group in a national, ethnically diverse sample. Accordingly, using data from the National Health and Nutrition Examination Survey (NHANES) (2007–2008) cohort, we aimed to: 1) determine if self-reported probable sleep apnea, based on snoring, snorting or previous diagnosis, is significantly associated with hypertension, and 2) determine if differences persist in this association when stratifying by race/ethnicity and obesity categories.

## Methods

### Study Sample

NHANES (2007–2008) is a nationally representative sample of non-institutionalized individuals and recruitment of participants, survey design and sampling methodology have

been explained elsewhere.[2627] The overall response rates for the 2007–2008 survey was N=10,149 (78.4%) for the health interview and N=9,762 (75.4%) for the physical examination. Because a primary aim was to evaluate associations by race, we first excluded participants in the "other race" category (N=465); we next excluded participants <18 years (N=3,715); and subsequently anyone with missing covariate data of interest (N=1,551). Our final analysis sample (N=4,418) included participants with complete data for the primary exposure (sleep apnea symptoms) and outcome (hypertension). All study participants gave informed consent before participation in the examination and study protocol.

### Probable Obstructive Sleep Apnea (pOSA)

The primary outcome was the Probable Obstructive Sleep Apnea (pOSA) score, which utilized three different questions from the survey items to identify likely sleep apnea. These included self-reported 1) previous sleep apnea diagnosis, 2) snorting, gasping or stopping breathing during sleep, and 3) snoring during sleep. Participants were asked "In the past 12 months, how often did you [a. snore] or [b. snort, gasp, stop breathing] while you were sleeping?" and possible questionnaire responses were: 1) "never"; 2) "1–2 nights/week"; 3) "3–4 nights/week"; 4) "5 or more nights/week." Participants responding to either snoring ≥3–4 times per week or snorting ≥3–4 times per week, or who reported previous sleep apnea diagnosis were identified as having pOSA.[28]

### Hypertension

Participants were identified as having hypertension or not if they had a systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or if they were taking blood pressure lowering medications.

### Sleep Characteristics

Additional survey items on sleep that were assessed evaluated non-restorative sleep and daytime sleepiness. For non-restorative sleep, participants were asked "Over the past month, how often do you feel unrested during the day, no matter how many hours of sleep you have had?" Daytime sleepiness was measured using the following question: "In the past month, how often do you feel excessively or overly sleepy during the day?" Response options for both questions included: 1) Never; 2) Rarely (1 time/month); 3) Sometimes (2–4 times/month); 4) Often (5–15 times/month); 5) Almost Always (16–30 times/month).

### Covariates

A number of covariates were considered in regression models, including socioeconomic (SES) and health characteristics (Table 2). SES characteristics were measured via self-report from the in-person interview and were considered for the analysis given that they are associated with sleep complaints and hypertension. Objectively-measured anthropometrics were obtained according to NHANES protocols, including height (m) and weight (kg) in order to calculate BMI ($kg/m^2$), and waist circumference (cm).[28] Health behaviors were evaluated based on interview questions. Participants were asked "Over the past month how often did you …?" Depression status was measured using the nine item symptom depression scale based on the Patient Health Questionnaire (PHQ-9).[29]

### Statistical Analysis

We summarized demographics, clinical characteristics, and sleep measures among race/ethnicity groups using proportions for categorical variables and means (±SD) for continuous variables. Comparisons among race/ethnicity groups (Table 1 and Supplemental Table 1) were assessed using analysis of variance (ANOVA) for continuous characteristics and chi-square tests for categorical covariates; a $p<0.05$ means that at least one of the 3 groups is different. We then compared the sleep characteristics, race/ethnicity and anthropometrics across hypertension status using t-tests or chi-square tests for continuous or categorical covariates, respectively (Table 2). To evaluate the adjusted association between sleep apnea risk and hypertension, we subsequently performed multivariable logistic regression analysis. In the multivariable models we added covariates (described above) that were theoretically important based on previous literature. Multivariate logistic regression models were also stratified by race/ethnicity group and obesity category (Table 3a, 3b). Interactions between pOSA and BMI categories (<25, 25–30, ≥30kg/m$^2$) and race/ethnicity were also evaluated. The sample weights provided with the NHANES data, which reflect the unequal selection probabilities and other adjustments, were used in all analyses to assure proper and unbiased estimates and standard errors. All analyses were conducted using SAS Software, Version 9.3 (SAS Institute Inc., Cary, NC) or Stata, Version 12 (StataCorp, College Station, TX).

## Results

The mean (±SD) age of the cohort was 46.5 (±16.4) years. Over half of the participants were female (51.9%) and married (56.6%), and 25.4% were college graduates. Thirty-five percent of participants in the cohort met the criteria for high blood pressure and were identified as having hypertension, and 33.3% were identified as having pOSA (Table 1). When stratifying by race/ethnicity, Hispanic/Latino participants had the lowest prevalence of hypertension (20.2%) and Black/African Americans had the highest prevalence (40.5%) ($p<0.001$). While only 13.2% of non-Hispanic Whites were uninsured, 24.2% of Black/African Americans and 45.2% of Hispanic/Latinos reported not having health insurance ($p<0.001$). Individuals with hypertension had a greater BMI (30.5 kg/m$^2$±7.8 vs. 27.7 kg/m$^2$±5.8, $p<0.001$) and waist circumference (104.7 cm ±17.6 vs. 95.2 cm± 14.5, $p<0.001$) than non-hypertensives (Table 2). When comparing sleep characteristics by hypertension status, hypertensive individuals were more likely to have apnea symptoms ($p<0.001$), including previous physician diagnosis of sleep apnea ($P<0.001$), frequent snoring ($p<0.001$), and non-restorative sleep ($p<0.001$); however, there were no differences between hypertensive and non-hypertensive participants for daytime sleepiness ($p=0.197$), which was consistent with previous reports (Table 2).[13]

We evaluated whether pOSA predicted hypertension first in the entire cohort, then within BMI and race/ethnicity strata. Among the entire cohort, pOSA was a significant predictor of hypertension in unadjusted models [OR (95% CI) =1.86 (1.58, 2.18)] and in models adjusted for age, gender, race, marital status, education, income to poverty ratio, health status, access to insurance, alcohol intake, current and past smoking, and depression [OR (95% CI) =1.40 (1.13, 1.75)] (Tables 3a, 3b). In obesity subgroups, the strongest significant association was observed among overweight individuals [OR (95% CI) =1.82 (1.26, 2.62)], and this was not significant among normal (BMI <25 kg/m$^2$) or obese (BMI ≥30 kg/m$^2$) groups in fully

adjusted models (Table 3a). When stratifying by race/ethnicity, pOSA was the strongest predictor of hypertension among Hispanic/Latinos in unadjusted models [OR (95% CI) =2.88 (2.18, 3.80)], and this association remained significant in fully-adjusted models [OR (95% CI) =1.69 (1.13, 2.53)] (Table 3b). Among Black/African Americans, pOSA was not a significant predictor of hypertension in fully adjusted models (Table 3b), but effect modification by BMI group was evident (p-value for interaction=0.009). In multivariate models stratified by race/ethnicity and BMI, pOSA was associated with greater than a four-fold odds of hypertension among overweight Black/African Americans [OR (95% CI) =4.74 (1.86, 12.03)] (Figure 1, Supplementary Table 2). This association was also significant among overweight Non-Hispanic Whites [OR (95% CI) =1.65 (1.06, 2.57)] in fully adjusted models. A significant association between pOSA and hypertension demonstrated a two-folds increased odds in fully-adjusted models among obese Hispanic/Latino participants [OR (95% CI) =2.01 (1.16, 3.49)], but not among overweight Hispanic/Latinos [OR (95% CI) =1.59 (0.71, 3.55)]. (Figure 1, Supplementary Table 2).

## Discussion

These findings suggest that a pOSA score, which was based on symptoms and/or previous diagnosis, is an independent predictor of hypertension in an ethnically diverse sample. POSA was most useful in overweight individuals (BMI of 25–30 kg/m$^2$), and among Hispanic/Latinos. A strong and significant association was also demonstrated between pOSA and hypertension among obese Hispanic/Latinos, unlike the other race/ethnicity groups, where obesity may have “overshadowed” any additive risk conferred by background sleep apnea.

Convincing evidence suggested that sleep apnea symptoms are associated with hypertension among overweight individuals. Obstructive sleep apnea among obese populations has been widely studied;[30] however, our findings suggest that these self-reported symptoms are more relevant in those that are overweight but not-obese. A possible reason for this is that obesity or morbid obesity already confers significant risk for cardiovascular disease, independent of the presence of OSA. However, in overweight groups such symptom assessment is helpful in marking those with hypertension and future studies utilizing OSA screening should target this weight group.

The majority of large U.S. sleep cohorts evaluating this topic have been relatively homogeneous, consisting mostly of Non-Hispanic White participants.[31–33] The present study offers a more ethnoracially diverse sample and highlights both the increased odds of hypertension among Black/African Americans and Hispanic/Latinos with pOSA, as well as the need for further investigation and oversampling of these race groups in future studies.[32]

This recommendation is supported by the finding that the prevalence of hypertension and uncontrolled hypertension is disproportionately high among Black/African Americans compared to Non-Hispanic Whites [OR (95% CI) = 2.54 (1.90, 3.40)],[34] and prevalence of hypertension among this race group has significantly increased from 1988–1994 through 2007–2008 (p=0.04).[35,36] In addition, very little evidence exists regarding sleep health among Hispanic/Latinos, the fastest-growing minority population in the U.S.[37] The

Hispanic/Latino population has disproportionately high levels of obesity, hypertension and cardiovascular disease,[38–40] all of which are linked to sleep apnea. Our findings indicate that pOSA was associated with a 69% increased odds of hypertension among Hispanic/Latinos independent of socio-demographics and traditional cardiovascular risk factors. Although the prevalence of OSA in Hispanic/Latinos is unknown, studies suggest a greater prevalence of snoring among Hispanic/Latinos compared to their Non-Hispanic White counterparts [OR (95% CI) =2.30 (1.43, 3.69) for men; OR (95% CI) =2.25 (1.48, 3.42) for women].[41] Thus, given the observed differences in race-stratified adults, a better understanding of risk factors and treatment opportunities for sleep apnea and hypertension among Black/African Americans and Hispanic/Latinos is needed when developing novel, population-wide preventative and therapeutic strategies.

The nation-wide obesity epidemic may be contributing to rising sleep apnea rates in the United States. As previously noted, PSG assessment is costly, time-consuming and not accessible to a large proportion of the US population. Access to healthcare, a sleep specialist or even a general health provider is unavailable for many. Symptom-based screening offers an attractive alternative, given the risk of adverse cardiovascular outcomes associated with untreated OSA. According to these data, although approximately 19% of the overall population reported being uninsured, this number was disproportionately higher (45%) among Hispanic/Latino individuals. Therefore, PSG testing, case identification, initiation of treatment and potential benefits of that treatment, including potential blood pressure-lowering effects, would be inaccessible to just under half of the Hispanic/Latinos in this study. Implementing a simple tool such as pOSA, as well as exploring treatment options, is all the more critical in this ethnoracial group given the current limitations in clinical application.

We note several limitations and strengths. The cross-sectional study design limits causal inference. Additionally, self-reports may have introduced misclassification. We surmise that such misclassification would be non-differential with respect to the presence of OSA, and so we expect that the utility of the pOSA score would be biased toward the null. We recognize that the prevalence of overweight and obese individuals in our sample was relatively high and that we did not have an even distribution of lower weight individuals. In efforts to address this issue, we presented all models stratified by BMI group in addition to the overall results. Residual confounding is also inherent in the observational study design; however, this robust dataset allows us to evaluate differences by race/ethnicity, an area of sleep research that remains under-explored. We used a nationally-representative sample, which has clear benefits in generalizability compared with prior studies that draw from specialized, clinic-based cohorts. Finally, the tool we developed relies on simple symptoms of OSA, which are easily obtainable and feasible on a mass scale, and which were strongly associated with increased blood pressure.

Symptom-based identification of OSA is an important area for future prevention efforts, especially given the rising rates of obesity and sleep apnea. Symptoms had the strongest association with hypertension among overweight individuals, a group that deserves attention in prospective evaluations in the future. Future studies should also attempt to validate our sleep apnea assessment tool by conducting confirmatory sleep studies in a community-based

sample. Additionally, differences persisted by race/ethnicity groups, and further exploration of this association in studies that oversample for Hispanic/Latinos and Black/African Americans is warranted. Finally, prior studies have shown that PAP therapy yields greater blood pressure reductions in some subgroups than others[8]. Whether these differences are a function of race/ethnicity deserves investigation.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgements

We would like to thank the Centers for Disease Control and Prevention for collecting these data and making them available, as well as the NHANES participants.

With regards to grant funding, Dr. Sands is supported by NIH grant T32HL07713-19; Dr. Grandner was supported by the American Heart Association (12SDG9180007), the National heart, Lung and Blood Institute (K23HL110216), the National Institute for Environmental Health Sciences (R21ES022931), and a fellowship from the Institute for Translational Medicine and Therapeutics, funded by UL1RR024134 (Penn CTSA); Dr. Gurubhagavatula is funded by RO1-OH009149.

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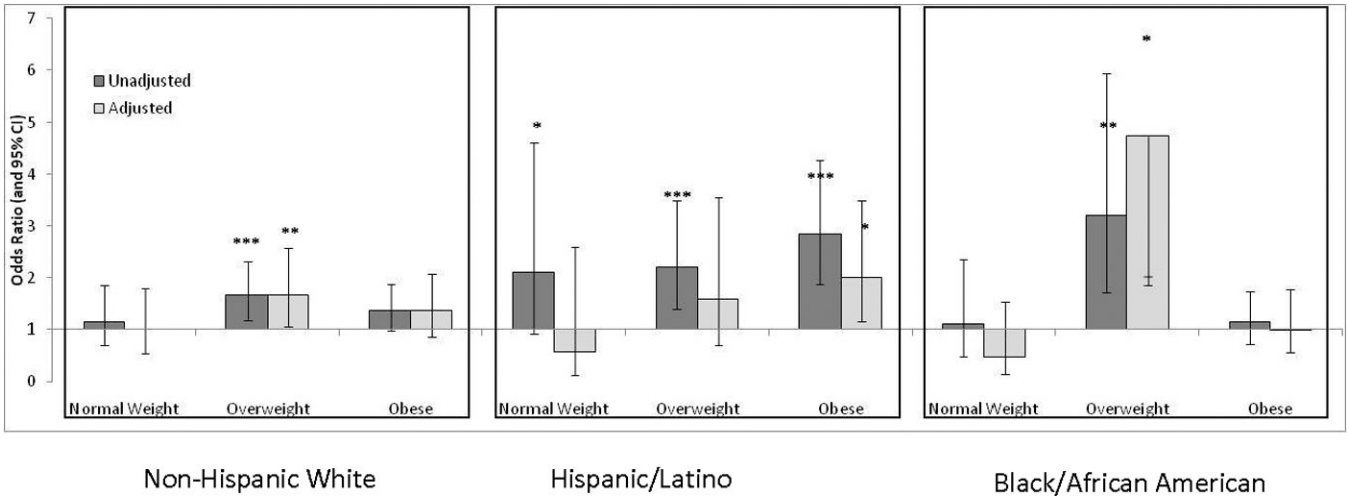


**Figure 1.**
Association between pOSA and Hypertension Stratified by Race and BMI Group

**Table 1**

Demographic Information Stratified by Race/Ethnicity

| Variable | Overall (n=4,418) | Non-Hispanic White (n=2,230) | Hispanic/Latinos (n=1,255) | Black/African American (n=933) | p* |
|---|---|---|---|---|---|
| **Hypertension** | 35.26% | 37.13% | 20.22% | 40.54% | <0.0001 |
| **Probable OSA** | 33.30% | 33.76% | 33.25% | 30.30% | 0.2160 |
| **Daytime Sleepiness (Indicating 'Almost Always' or 'Often')** | 18.66% | 20.04% | 12.29% | 17.06% | <0.0001 |
| **BMI (kg/ $m^2$)** | 28.7 ± 6.6 | 28.4 ± 5.3 | 29.3 ± 9.2 | 30.2 ± 10.5 | <0.0001 |
| **Age (years)** | 46.5 ± 16.4 | 48.0 ± 13.6 | 40.3 ± 21.0 | 44.0 ± 21.1 | <0.0001 |
| **Male** | 48.15% | 48.16% | 51.15% | 44.64% | 0.0530 |
| **Alcohol Use (Drinks/day)** | 2.03 ± 2.70 | 1.90 ± 1.85 | 3.06 ± 6.73 | 1.75 ± 2.68 | <0.0001 |
| **Current Smoker** | 23.16% | 23.23% | 19.66% | 26.83% | 0.0074 |
| **Past Smoker** | 48.23% | 50.97% | 38.36% | 41.81% | <0.0001 |

* p-value from ANOVA (for continuous variables) or chi-square test (for categorical variables) testing the global null hypothesis of equivalence across the 3 race/ethnicity groups

**Table 2**

Demographics, Sleep Characteristics, Anthropometrics by Hypertension Status

| Predictor | Subgroup | Overall n=4,418 | Hypertension | | |
|---|---|---|---|---|---|
| | | | No (n=2,220) | Yes (n=2,198) | p* |
| **Probable OSA** | No | 66.70% | 71.64% | 57.64% | <0.0001 |
| | Yes | 33.30% | 28.36% | 42.36% | |
| **Apnea** | No | 95.23% | 97.40% | 91.24% | <0.0001 |
| | Yes | 4.77% | 2.60% | 8.76% | |
| **Snore** | Never | 29.56% | 32.81% | 23.26% | <0.0001 |
| | Rarely | 18.37% | 20.05% | 15.11% | |
| | Occasionally | 19.19% | 18.85% | 19.87% | |
| | Frequently | 32.88% | 28.29% | 41.76% | |
| **Snort** | Never | 78.86% | 80.78% | 75.24% | 0.0001 |
| | Rarely | 8.41% | 8.54% | 8.16% | |
| | Occasionally | 6.57% | 5.85% | 7.94% | |
| | Frequently | 6.16% | 4.84% | 8.66% | |
| **Daytime Sleepingss** | Never | 31.36% | 30.63% | 32.70% | 0.1974 |
| | Rarely | 21.97% | 21.83% | 22.23% | |
| | Sometimes | 28.00% | 28.66% | 26.79% | |
| | Often | 12.91% | 13.62% | 11.61% | |
| | Almost Always | 5.75% | 5.25% | 6.67% | |
| **Unrestful Sleep** | Never | 26.47% | 24.24% | 30.58% | 0.0002 |
| | Rarely | 16.40% | 15.73% | 17.64% | |
| | Sometimes | 28.34% | 29.81% | 25.65% | |
| | Often | 18.03% | 19.57% | 15.19% | |
| | Almost Always | 10.76% | 10.66% | 10.95% | |
| **Race** | Non-Hispanic White | 75.16% | 73.00% | 79.14% | <0.0001 |
| | Hispanic/Latinos | 13.35% | 16.45% | 7.65% | |
| | Black/African American | 11.49% | 10.55% | 13.21% | |

*J Clin Hypertens (Greenwich)*. Author manuscript; available in PMC 2014 August 01.

| Predictor | Subgroup | Overall n=4,418 | Hypertension | | |
|---|---|---|---|---|---|
| | | | No (n=2,220) | Yes (n=2,198) | p* |
| **BMI (kg/ m$^2$)** | | 28.7 ± 6.6 | 27.7 ± 5.8 | 30.5 ± 7.8 | <0.0001 |
| **Waist Circumference (cm)** | | 98.6 ± 16.3 | 95.2 ± 14.5 | 104.7 ± 17.6 | <0.0001 |
| **BMI Group** | BMI < 25 | 30.79% | 36.23% | 20.79% | <0.0001 |
| | BMI 25–30 | 34.94% | 35.41% | 34.08% | |
| | BMI ≥ 30 | 34.27% | 28.36% | 45.12% | |
| **Gender** | Female | 51.85% | 52.34% | 50.95% | 0.4735 |
| | Male | 48.15% | 47.66% | 49.05% | |

*p-value from t-test (for continuous variables) or chi-square test (for categorical variables) comparing those with hypertension to those without hypertension

## Table 3

**a. Association between pOSA and Hypertension, Overall and by BMI Group**

| Outcome | OSA | Model† | Overall (n=4,418) | | BMI Groups | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | BMI < 25 (n=1,233) Normal | | BMI 25–30 (n=1,551) Overweight | | BMI ≥ 30 (n=1,634) Obese | |
| | | | OR (95% CI) | p | OR (95% CI) | p | OR (95% CI) | p | OR (95% CI) | p |
| Hypertension | pOSA | m1 | 1.86 (1.58, 2.18) | <.0001 | 1.18 (0.78, 1.76) | 0.4333 | 1.77 (1.34, 2.34) | 0.0001 | 1.46 (1.14, 1.88) | 0.0029 |
| | | m2 | 1.40 (1.13, 1.75) | 0.0025 | 0.91 (0.54, 1.53) | 0.7131 | 1.82 (1.26, 2.62) | 0.0014 | 1.32 (0.96, 1.81) | 0.0927 |

**b. Association between pOSA and Hypertension, Overall and by Race/Ethnicity Group**

| Outcome | OSA | Model† | Overall (n=4,418) | | Race/Ethnicity Groups | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Non-Hispanic White (n=2,230) | | Hispanic/Latino (n=1,255) | | Black/African American (n=933) | |
| | | | OR (95% CI) | p | OR (95% CI) | p | OR (95% CI) | p | OR (95% CI) | p |
| Hypertension | pOSA | m1 | 1.86 (1.58, 2.18) | <.0001 | 1.78 (1.46, 2.18) | <.0001 | 2.88 (2.18, 3.80) | <.0001 | 1.88 (1.39, 2.55) | <.0001 |
| | | m2 | 1.40 (1.13, 1.75) | 0.0025 | 1.40 (1.07, 1.84) | 0.0149 | 1.69 (1.13, 2.53) | 0.0105 | 1.34 (0.88, 2.03) | 0.1734 |

†**m1**: Unadjusted; **m2**: Adjusted for age, gender, race, marital status, education, income to poverty ratio, health status, access to insurance, alcohol intake, current smoking, past smoking, depression and BMI group (in "Overall" only); **pOSA**: Probable OSA

†**m1**: Unadjusted; **m2**: Adjusted for age, gender, BMI group, marital status, education, income to poverty ratio, health status, access to insurance, alcohol intake, current smoking, past smoking, depression and race (in "Overall" only); **pOSA**: Probable OSA