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Predictors of sleep disordered breathing in obese adults who are chronic short sleepers

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Abstract

Background—Sleep disordered breathing (SDB) is more common in obese adults, but not all obese adults have SDB. The aim of these analyses was to determine what predicted SDB in a sample of obese adults.

Methods—We conducted cross-sectional analysis of 139 obese men and women aged 18–50 years who are chronic short sleepers. Habitual sleep duration and sleep efficiency were estimated using 2 weeks of wrist actigraphy. Respiratory Disturbance Index (RDI) was assessed by a portable screening device. SDB was defined as RDI≥15 events/hour. Subjective sleep quality, sleepiness, and sociodemographic characteristics were evaluated by questionnaires.

Results—Increased sleep duration from actigraphy was associated with reduced odds of SDB (OR 0.44 per hour, p=.043). Neither subjective sleep quality nor sleepiness was associated with SDB. Male sex, older age, and increased waist circumference were associated with increased odds of SDB.

Conclusions—In this sample of obese adults, subjective measures of sleep quality and sleepiness were not indicators of SDB. These results suggest that in obese patients, physicians should not rely on subjective measures to determine who should be referred for a clinical sleep study. A wider use of portable apnea screening devices should be considered in non symptomatic, Non-Hispanic white males.

Keywords

sleep-disordered breathing; obese; actigraphy; subjective sleep quality; sleepiness; apnea

INTRODUCTION

Obesity rates have been increasing rapidly world-wide [1–2]. Obesity is also a major risk factor for the development of sleep disordered breathing (SDB) and therefore the prevalence

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of SDB has likely been increasing along with the obesity epidemic. The potential rise in SDB has important health implications since it has been linked to augmented risk of diabetes, heart disease and age-adjusted mortality [3–7]. Despite the associated risks of this disorder, it is estimated that as many as 93% of women and 82% of men with moderate to severe SDB are undiagnosed [8]. As such, it is critical that we identify predictors of SDB so we can properly diagnose and treat affected individuals.

Obesity is a well-established risk factor for diabetes, cardiovascular disease and hypertension. Therefore, considering the potential consequences of SDB in obese subjects, it is important to identify the determinants of SDB in these individuals. Indeed, although obesity is a risk factor for SDB, not all obese adults have SDB. Estimates of the prevalence of SDB (defined as an apnea-hypopnea index ≥15) in obese adults aged 30 to 69 years ranged from 4 to 24% in women and 13 to 55% in men [9]. Thus, a substantial number of obese adults will not have SDB.

We examined SDB in a cohort of obese men and premenopausal women aged 18–50 years who report being chronic short sleepers and were thus screened for a randomized, prospective trial of non-pharmacological sleep extension. Previous research has examined predictors of SDB in samples that included lean, overweight and obese individuals. This study focused only on obese individuals, who are particularly vulnerable to SDB. Our goal was to determine which factors were associated with SDB. In particular, we were interested in 4 determining if estimates of sleep that are more easily obtained (e.g. self-reported or actigraphy) could help determine who should be referred for a clinical sleep study.

METHODS

Study Cohort

Participants who were screened for the Sleep Extension Study between September 11, 2006 and November 3, 2009 were included in these analyses. The Sleep Extension Study is an ongoing, randomized, prospective, intervention trial of obese (BMI 30–55 kg/m^2) men and premenopausal women aged 18 to 50 years old who report sleeping less than 6.5 hours per night on average [10]. This study is conducted at the NIH Clinical Center under the NIDDK protocol 06-DK-0036 and is listed in ClinicalTrials.gov (identifier: NCT00261898). This study was approved by the Institutional Review Board at the National Institute of Diabetes, Digestive, and Kidney Diseases (NIDDK) and signed informed consent was obtained from all participants. Participants were recruited using advertisements that asked for obese (BMI 30–55 kg/m^2) volunteers who slept an average of less than 6.5 hours per night. In addition, self-reported body weight must have remained stable (within 5%) over the last 6 months to be eligible. Interested persons called a study recruitment telephone number and an initial telephone screening excluded individuals who were <18 years or >50 years old, who reported not being overweight, reported uncontrolled hypertension or diabetes, or reported sleeping more than 6.5 hours. Subjects who had been on stable regimen of thyroid hormone for the last 6 months or longer were eligible. If the volunteers were not excluded after this telephone screening, they underwent a semi-structured telephone interview. After the second telephone interview, eligible participants were invited into the clinic for a screening examination, at which time the full study was explained and informed consent was obtained. This visit included a medical history and physical examination, electrocardiogram, clinical blood work and screening for depression and anxiety using the Hamilton Depression and Anxiety scales [11]. Anthropometric measures such as height, weight, neck circumference and waist circumference were obtained and validated sleep questionnaires were administered [10]. Finally, participants were provided with a wrist actigraphy monitor (described below) to assess habitual sleep duration for two weeks. The analyses presented here examine these screening data only.

Sleep Measures

Actigraphy—Habitual sleep was estimated objectively using wrist actigraphy monitors (Actiwatch-64, Mini Mitter/Respironics/Philips, Bend OR), which are non-invasive devices similar in size to a wristwatch. Participants were asked to wear the wrist actigraphy monitor continuously for two weeks while continuing their usual daily activities (median 14 days, range 5–15 days). These monitors record a digitally integrated measure of gross motor activity using a highly sensitive piezoelectric accelerometer with a sensitivity of 0.05 g. The sampling frequency is 32 Hz and filters are set to 3–11 Hz. One-minute epochs were used in this study. Actiwatch data were analyzed by Actiware-Sleep version 3.4 software. Sleep start time was calculated as the first 10 min period in which no more than 1 epoch is scored as mobile and sleep end time was calculated as the last 10 minute period that no more than 1 epoch was scored as mobile. Bed time and wake up time were set by the investigator according to the sleep diaries of the participants. Actiwatches have been validated against polysomnography, with correlations for sleep duration ranging from .82 in insomniacs to .97 in healthy subjects [12]. Two measures from the actigraphy data were included in these analyses: ***sleep duration*** (amount of actual sleep obtained during the 24-hour period) and ***sleep efficiency*** (percentage of time in bed spent sleeping). The mean sleep duration and sleep efficiency from all available days of actigraphy were calculated for each participant.

Sleep disordered breathing was assessed over one night in either the clinic or the participant's home based on participant preference using a portable screening device (Apnea Risk Evaluation System, Advanced Brain Monitoring, Inc, Carlsbad, CA). This device has the following components: nasal cannula, adjustable head strap, forehead reflectance pulse oximeter, an accelerometer to measure head movement, and a calibrated acoustic microphone. Bedtimes were at the participant's discretion. Data were automatically scored and then reviewed by a technician. The ARES software applies automated algorithms to identify changes in pulse oximetry, pulse rate, head movement, and snoring level that are due to abnormal breathing during sleep. The device provides an estimate of the ***respiratory disturbance index*** (RDI), which is the number of abnormal respiratory events per hour of sleep. Apnea was defined as cessation of airflow for 10 seconds. Hypopneas included events identified as an airflow <50% with a 3.5 or greater percentage desaturation and 1% resaturation. Hypopneas were also determined as a minimum 1% desaturation and resaturation plus at least 1 surrogate arousal indicator (head movement, changes in snoring, or changes in pulse rate) [13]. This device has been validated against full-polysomnography and has demonstrated high sensitivity and specificity [14]. The device also provided the following information: RDI in the supine position, RDI in the non-supine position, percentage of time snoring >30 dB, mean blood oxygen saturation (SpO_2) and percentatge of time that Sp02 <90%. SDB was primarily defined as having an RDI ≥15 events per hour, however, in additional analyses we used a lower threshold for SDB of RDI>5.

Subjective Sleep—Participants completed the ***Pittsburgh Sleep Quality Index*** (PSQI), a validated 21-item questionnaire that quantifies subjective sleep quality over the past month [15]. PSQI scores range from 0 to 21 and higher scores indicate worse sleep quality. This score was also dichotomized at ≤5 or >5, which is considered the threshold for poor sleep quality. We also used the PSQI to create the variables "frequent snorer", which was defined as reporting "cough or snore loudly" ≥3 x/week and "frequent subjective apneas", which was defined as reporting "cannot breathe comfortably" ≥3 x/week. Daytime sleepiness was assessed by the ***Epworth Sleepiness Scale (ESS)***, which is a validated 8-item questionnaire [16–17]. ESS scores range from 0 to 24 and higher scores represent greater daytime sleepiness. A score greater than 10 indicates excessive daytime sleepiness and scores were also dichotomized at ≤10 or >10 [16].

Sociodemographic and Anthropometric Variables

The following sociodemographic and anthropometric variables are included in these analyses: age (years), sex (0=male), race, education, marital status, neck circumference and waist circumference. The categories of race included in these analyses were Non-Hispanic Whites, Non-Hispanic Black and Other Race. The Other Race category included Native American, Asian, Asian/Pacific Islander, Hispanic/Latino and unknown. Because there were few people in each of these categories we combined them into a single category. Education level was grouped into the following two categories: (1) <4 year college degree; (2) 4-year college degree or higher. Marital status was grouped into the following three categories: married; single; and divorced, separated or widowed. To measure neck circumference, the subject stood with the head in the Frankfort Horizontal Plane, a plane used in craniometry. The tape was placed perpendicular to the long axis of the neck, at the minimal circumference. To measure waist circumference, the measuring tape was placed in a horizontal plane around the abdomen above the uppermost lateral border of the right iliac crest. The measurement was made at the end of a normal expiration. If this site could not be determined, the measurement was taken at the maximum circumference at or near the level of the umbilicus.

Statistical Analysis

The statistical analysis comprised two steps. First, descriptive statistics for each sleep and demographic variable were calculated for the cohort as a whole and separately by SDB group. Statistical tests used to compare SDB groups included: *t* test for difference in means, Wilcoxon rank test for means of skewed variables, Fisher's exact test or Pearson Chi-square test for difference in frequency. Second, logistic regression models were used to predict SDB (RDI≥15). Separate regressions were performed for each of the four sleep variables: (1) actigraphy sleep duration (hours), (2) actigraphy sleep efficiency (%), (3) PSQI Score, and (4) Epworth Sleepiness Score. Covariates included in all four models were sex, race, education, marital status, age, neck circumference, and waist circumference. Finally, interaction terms between sex and each of the sleep variables were added to the regression models to test whether the associations between the sleep measures and SDB varied by sex. All analyses were performed using SAS (version 9.1.3, SAS Institute Inc., Cary, NC, USA) and JMP (version 8.0, SAS Institute Inc., Cary, NC, USA).

RESULTS

Table 1 presents the sociodemographic characteristics of the study population for the full sample combined and separately by SDB group. Over two-thirds of the sample (70%) were women and over half were non-Hispanic black. Ages ranged from 21–50 years and BMI ranged from 29.6–53.7 kg/m^2. Approximately 29% of the sample had SDB (RDI>15), while 66% had an RDI>5. In unadjusted comparisons, persons with SDB had a significantly higher mean BMI, larger neck circumference and larger waist circumference than those without SDB. There were also significantly more men in the SDB group. Table 2 describes the sleep variables in the full sample and separately by SDB group. Based on actigraphy, persons with SDB slept approximately 36 minutes less on average and had an average sleep efficiency that was approximately 8% lower than those without SDB. Self-reported sleep duration, PSQI score and ESS score did not differ significantly between SDB groups.

Table 3 presents the results from the logistic regression models predicting SDB. Separate models were estimated for each of the four sleep measures: actigraphic sleep duration, actigraphic sleep efficiency, subjective sleep quality (PSQI score) and subjective sleepiness (ESS score). Women had substantially lower odds of SDB than men in all models. Larger waist circumference and increasing age were associated with increased odds of prevalent

SDB in all models. Non-Hispanic Blacks had reduced odds of SDB when adjusting for either of the actigraphy measures, but not when adjusting for the subjective measures. Longer habitual sleep duration was significantly associated with reduced odds of prevalent SDB ($p<.05$) and there was a trend for an association between higher sleep efficiency and reduced odds of prevalent SDB ($p=.08$). Neither of the subjective sleep measures, PSQI score or ESS, was associated with SDB. If we used the dichotomous versions of these subjective measures the results were the same. None of the other covariates, including education, marital status, or neck circumference, were significantly associated with prevalent SDB in the multivariate analyses. When we defined SDB using a lower threshold (RDI>5), actigraphic sleep duration and efficiency were not significantly associated with SDB and ESS and PSQI remained non-significant (all $p>.30$).

DISCUSSION

In this sample of obese men and premenopausal women who are chronic short sleepers, actigraphic sleep duration and actigraphic sleep efficiency demonstrated a modest association with prevalence of SDB, which confirmed that those identified as having SDB (RDI>15) in our sample did indeed sleep less and had worse sleep quality most likely due to the arousals and disturbances caused by SDB. When we used a lower cutoff for SDB (RDI>5) these actigraphic estimates were no longer associated with SDB, which indicates that less severe SDB does not affect actigraphically-assessed sleep duration and quality. Importantly, commonly-used subjective instruments to assess sleep, such the Pittsburgh Sleep Quality Index and the Epworth Sleepiness Scale, were not associated with SDB in this sample of obese adults. In the models adjusting for the actigraphic sleep measures, Non-Hispanic black race was associated with reduced odds of SDB, which means that for a given level of sleep duration or sleep efficiency, blacks were less likely to have SDB than whites. This is probably due to the fact that in general blacks obtain shorter sleep and have worse sleep quality than whites for reasons other than SDB [18–20]. Finally, men were also much more likely to have SDB and increasing age was also associated with higher odds of SDB, both associations that are well-established [21–22]. The sociodemographic variables, education and marital status, and the anthropometric measure, neck circumference, were not associated with SDB.

Contrary to our findings, three large epidemiologic studies report a significant association between SDB and increased subjective sleepiness. The Wisconsin Sleep Cohort Study, which included 602 state employees aged 30–60 years, reported that subjective sleepiness was significantly greater in those with SDB (AHI≥5) [22]. The Sleep Heart Health Study, which conducted in-home polysomnography recordings in over 5,000 adults (mean age of 64 years), reported that scores on the ESS increased with increasing severity of SDB [23]. Finally, the MrOs study, which enrolled men aged 65 years and older, observed a significantly higher mean ESS score in men with SDB (RDI≥15) than men without SDB [24]. All three of these studies included a wide range of body mass indices, while our study included only obese. A potential reason for a lack of association in our sample could be related to the finding that obese individuals without OSA have reported greater sleepiness than non-obese [25]. Indeed, over one-third of our sample were classified as having excessive daytime sleepiness. It may be that obesity, itself, can lead to excessive daytime sleepiness, obscuring any effect of SDB on subjective sleepiness. Furthermore, because insufficient sleep itself is a primary cause of sleepiness, the effect of SDB on sleepiness in this sample of chronic short sleepers may not be detectable.

The current finding that there was no apparent relationship between the degree of sleep disordered breathing and subjective assessment of sleep quality and sleepiness has important clinical implications. It indicates that obese individuals may not reliably report difficulty sleeping and therefore, physicians should not wait for a complaint from their obese patients before referring them for a clinical sleep study. Obesity is a major risk factor for obstructive sleep apnea (OSA), particularly in men [21]. In this study, 50% of the men and 20% of women had an RDI>15, which is the clinical cutoff for sleep disordered breathing. Given the serious health consequences of untreated OSA, particularly increased risk of cardiovascular disease [26], early diagnosis of this disorder is highly desirable.

There are some important limitations of this study to consider. First, this is a volunteer sample of obese men and premenopausal women recruited in the Washington, DC area. Therefore, it is not clear to what extent our findings may be generalizable to obese adults throughout the US. In addition, our recruitment targeted obese individuals who average less than 6.5 hours of sleep, so longer sleepers may likely not have responded to this advertisement. The CARDIA study, which also had an average age of 40 years, reported an average sleep duration of 6.1 hours and only 8 people (1% of the sample) slept 8 or more hours per night [18]. Furthermore, this study reported that higher BMI was associated with shorter sleep durations [27]. Taken together, this suggests that there are not very many obese long sleepers and our sampling method would not have excluded many people. Another limitation is that full polysomnography, which is considered the gold standard to assess sleep, was not included and a more accurate assessment of sleep disordered breathing was not available. Nonetheless, the RDI derived from the portable monitor correlates strongly with SDB assessed by PSG [13–14].

Sleep disordered breathing has been consistently associated with increased morbidity, including impairments of glucose metabolism, blood pressure and cardiovascular disease [3–7]. Considering the debilitating consequences of SDB, it is important to diagnose the disease as early as possible. Our analysis suggests that in obese adults, subjective sleep measures are not good indicators of underlying SDB. A wider clinical use of portable apnea screening devices should be considered as screening tool to detect sleep apnea in obese subjects, especially in Non-Hispanic white males, regardless of whether specific complaints of daily somnolence are reported by the patient.

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Table 1

Characteristics of the study population

	All (n=139)	No SDB (n=99)	SDB (n=40)	Difference
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**P-value**
Age (years)	40.8 (6.9)	40.5 (6.7)	41.5 (7.6)	0.493*
BMI (kg/m^2)	38.2 (5.9)	37.3 (5.4)	40.3 (6.5)	0.011*
Neck circumference (cm)	39.8 (4.2)	38.5 (3.7)	42.9 (3.9)	<0.0001*
Waist circumference (cm)	116.5 (14.2)	113.0 (12.3)	125.3 (15.0)	<0.0001*
	% (n)	**% (n)**	**% (n)**	
Gender Female Male	69.8 (97) 30.2 (42)	79.8 (79) 20.2 (20)	45% (18) 55% (22)	<0.0001#
Race/ethnicity Non-Hispanic black Non-Hispanic white Other	56.1 (78) 33.1 (46) 10.8 (15)	59.6 (59) 30.3 (30) 10.1 (10)	47.5 (19) 40.0 (16) 12.5 (5)	0.427&
Education <College >=College	(n=98) 40.8 (40) 59.2 (58)	(n=74) 37.8 (28) 62.2 (46)	(n=24) 50.0 (12) 50.0 (12)	0.343#
Marital Status Married Single Divorced/Separated/Widowed	36.7 (51) 44.6 (62) 18.7 (26)	35.4 (35) 40.47 (40) 24.2 (24)	40.0 (16) 55.0 (22) 5.0 (2)	0.028&

* t-test for means

Fisher's exact test

& Pearson chi-sq test

Table 2

Sleep characteristics of the study population for the full sample combined and separately by SDB groups (SDB = RDI≥15).

	All (n=139)	No SDB (n=99)	SDB (n=40)	Comparing SDB groups
Continuous Variables	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**p value**
Actigraphy sleep duration (hour/day)	5.65 (1.07)	5.82 (0.89)	5.22 (1.36)	0.013*
Actigraphy sleep efficiency (%)	77.5 (9.8)	79.9 (6.7)	71.7 (13.5)	0.001*
Subjective sleep duration (hour/day)	5.12 (0.95)	5.12 (0.96)	5.12 (0.90)	0.999*
PSQI Score	9.0 (3.4)	8.9 (3.2)	9.2 (3.7)	0.630*
Epworth sleepiness score	8.6 (4.4)	8.4 (4.4)	8.9 (4.5)	0.593*
AHI 3%-supine	19.5 (24.9)	8.4 (9.9)	45.7 (29.9)	<0.0001^
AHI 3% non-supine	11.3 (18.3)	3.7 (5.2)	29.1 (24.9)	<0.0001^
% snore >30 dB	35.8 (17.7)	31.8 (18.6)	45.7 (9.8)	<0.0001^
Mean Sp02	95.4 (8.4)	95.6 (9.8)	94.9 (2.6)	<0.0001^
Sp02 <90	3.47 (9.85)	0.94 (3.42)	9.77 (16.06)	<0.0001^
Dichotomous Variables	**% (n)**	**% (n)**	**% (n)**	
PSQI score (n=128)				
≤5 (good sleep quality)	14.0 (18)	85.9 (79)	86.1 (31)	0.999#
>5 (poor sleep quality)	86.0 (110)	14.1 (13)	13.9 (5)	
Epworth sleepiness score (n=134)				
≤10	67.9(91)	69.2 (65)	65.0 (26)	0.688#
>10 (excessive daytime sleepiness)	32.1(43)	30.8 (29)	35.0 (14)	
Frequent Snorer (n=137)				
Yes	22.6 (31)	16.3 (16)	38.5 (15)	0.0116#
No	77.4 (106)	83.7 (82)	61.5 (24)	
Frequent Subjective Apneas				
Yes	2.9 (4)	1.0 (1)	7.5 (3)	0.0718#
No	97.1 (135)	99.0 (98)	92.5 (37)	

*t-test for means

^chi-square test

#Fisher's exact test for frequency

Table 3

Results from logistic regression models predicting SDB from subjective and objective sleep measures and covariates.

	Model 1: Actigraphy Sleep Duration (hours)	**Model 2: Actigraphy Sleep Efficiency (%)**	**Model 3: PSQI Score**	**Model 4: Epworth Sleepiness Score**
	OR 95% CI (p value)	**OR 95% CI (p value)**	**OR 95% CI (p value)**	**OR 95% CI (p value)**
Sex				
Female	0.073 (0.006,0.878) (0.0392)	0.055 (0.005, 0.614) (0.0185)	0.041 (0.004, 0.410) (0.0066)	0.048 (0.005, 0.433) (0.0068)
Male	Ref	Ref	Ref	Ref
Race				
Non-Hispanic Black	0.205 (0.030, 1.376) (0.046)	0.241 (0.036, 1.610) (0.049)	0.385 (0.075, 1.976) (0.204)	0.426 (0.083, 2.190) (0.135)
Other	2.351 (0.240, 23.06) (0.153)	2.898 (0.303, 27.74) (0.117)	1.298 (0.118, 14.33) (0.523)	2.519 (0.274, 23.17) (0.219)
Non-Hispanic White	Ref	Ref	Ref	Ref
Education				
>=college	0.319 (0.062, 1.645) (0.172)	0.473 (0.103,2.162) (0.334)	0.611 (0.149, 2.515) (0.495)	0.688 (0.173, 2.740) (0.596)
<college	Ref	Ref	Ref	Ref
Marital Status				
Divorced/Separated	0.098 (0.007, 1.328) (0.154)	0.156 (0.014, 1.793) (0.235)	0.129 (0.012, 1.440) (0.148)	0.147 (0.014, 1.525) (0.207)
Married	0.368 (0.075, 1.806) (0.856)	0.430 (0.091, 2.035) (0.921)	0.535 (0.127, 2.256) (0.635)	0.430 (0.100, 1.851) (0.895)
Single	Ref	Ref	Ref	Ref
	Unit OR 95% CI (p value)	Unit OR 95% CI (p value)	Unit OR 95% CI (p value)	Unit OR 95% CI (p value)
Age (years)	1.148 (1.028, 1.313) (0.025)	1.156 (1.026, 1.321) (0.017)	1.110 (1.003, 1.253) (0.060)	1.130 (1.024, 1.270) (0.024)
Neck circumference (cm)	0.819 (0.566, 1.143) (0.253)	0.789 (0.554, 1.075) (0.152)	0.772 (0.547, 1.047) (0.111)	0.793 (0.572, 1.065) (0.137)
Waist circumference (cm)	1.122 (1.039, 1.236) (0.008)	1.121 (1.039, 1.231) (0.007)	1.139 (1.056, 1.250) (0.002)	1.130 (1.052, 1.236) (0.002)
Actigraphy Sleep Duration (hours)	0.436 (0.180, 0.931) (0.043)			

	Model 1: Actigraphy Sleep Duration (hours)	**Model 2: Actigraphy Sleep Efficiency (%)**	**Model 3: PSQI Score**	**Model 4: Epworth Sleepiness Score**
	OR 95% CI (p value)	**OR 95% CI (p value)**	**OR 95% CI (p value)**	**OR 95% CI (p value)**
Actigraphy Sleep Efficiency (%)		0.915 (0.825, 1.006) (0.079)		
PSQI Score			0.853 (0.676, 1.052) (0.151)	
Epworth Sleepiness Score				0.999 (0.850, 1.169) (0.9917)