Predictors of Sleep-Disordered Breathing in Community-Dwelling Adults

The Sleep Heart Health Study

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Background: Sleep-disordered breathing (SDB) is common, but largely undiagnosed in the general population. Information on demographic patterns of SDB occurrence and its predictive factors in the general population is needed to target high-risk groups that may benefit from diagnosis.

Methods: The sample comprised 5615 community-dwelling men and women aged between 40 and 98 years who were enrolled in the Sleep Heart Health Study. Data were collected by questionnaire, clinical examinations, and in-home polysomnography. Sleep-disordered breathing status was based on the average number of apnea and hypopnea episodes per hour of sleep (apnea-hypopnea index [AHI]). We used multiple logistic regression modeling to estimate cross-sectional associations of selected participant characteristics with SDB defined by an AHI of 15 or greater.

Results: Male sex, age, body mass index, neck girth, snoring, and repeated breathing pause frequency were independent, significant correlates of an AHI of 15 or greater. People reporting habitual snoring, loud snoring, and frequent breathing pauses were 3 to 4 times more likely to have an AHI of 15 or greater vs an AHI less than 15, but there were weaker associations for other factors with an AHI of 15 or greater. The odds ratios (95% confidence interval) for an AHI of 15 or greater vs an AHI less than 15 were 1.6 and 1.5, respectively, for 1-SD increments in body mass index and neck girth. As age increased, the magnitude of associations for SDB and body habitus, snoring, and breathing pauses decreased.

Conclusions: A significant proportion of occult SDB in the general population would be missed if screening or case finding were based solely on increased body habitus or male sex. Breathing pauses and obesity may be particularly insensitive for identifying SDB in older people. A better understanding of predictive factors for SDB, particularly in older adults, is needed.

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EPIDEMIOLOGIC RESEARCH has shown that sleep-disordered breathing (SDB) is common but largely undiagnosed in the general adult population.[1] Although uncertainty remains as to the level of SDB that should prompt therapy, there is a clear need for evidence-based strategies to target persons with SDB who might benefit from diagnosis and treatment. For this purpose, a deeper understanding of the patterns of SDB occurrence and of its predictive factors is needed. At present, most of our understanding of SDB correlates comes from observations of patients diagnosed as having sleep apnea syndrome, the clinical entity of SDB. Clinical reports have consistently shown that SDB tends to occur predominantly in men during middle age, and that habitual snoring, obesity, and large neck girth are strong predictors of SDB.[2] However, because only a small fraction of SDB is diagnosed, patients with SDB ascertained through sleep clinics are probably not representative of affected persons in the community.

Findings from several population-based studies have confirmed that snoring and obesity are predictors of SDB.[3-10] However, data from these studies cast doubt on the generalizability of other clinic-based observations to the large proportion of undiagnosed SDB cases in the population. Population-based studies, for example, have shown that although the prevalence of SDB is higher in men compared with women, the excess male prevalence is less than would be expected from early reports that most patients with sleep apnea were men.[11,12] Furthermore, population-based studies suggest that SDB prevalence in older adults may be considerably higher than in middle-aged adults, the predominant age group in SDB patient populations.[7,13]

PARTICIPANTS AND METHODS

STUDY SAMPLE AND DATA COLLECTION

The SHHS design included overnight in-home polysomnography (PSG) on a sample comprising participants from 8 established cohort studies, including the Atherosclerosis Risk in Communities Study, the Cardiovascular Health Study, the Framingham Heart Study Offspring and Omni Cohorts, the Strong Heart Study, the New York Hypertension Cohorts, the Tucson Epidemiologic Study of Airways Obstructive Diseases, and the Tucson Health and Environment Study. The study design and methods have been described.[14] In brief, a short questionnaire on sleep characteristics and other factors was administered to parent cohort participants 39 years and older when the SHHS was initiated. Respondents to the questionnaire were sampled by random, sequential, or nonprobability strategies, depending on the study site, and then recruited for participation in the SHHS.

The main sources of data for this analysis were the questionnaire, in-home PSG, and measures of neck girth and weight collected during the home visit. Previously recorded data on height and waist and hip circumferences were obtained from the parent cohorts. Race, age, and sex were extracted from questionnaire responses. Variables for snoring were constructed from self-reported questionnaire data on snoring frequency and loudness. From responses to the questions "Have you ever snored now or at anytime in the past," and, if yes, "How often do you snore now?" the following categories were created: "nonsnorer" (answered no to the"ever snored?" or "currently snore?" question), "moderate" snorer (currently snore up to 2 nights per week), "habitual" snorer (currently snore ≥3 nights per week), and "do not know." A variable for snoring loudness was based on responses to the question "How loud is your snoring?" which was asked of those responding positively to the "ever snored?" question. The following categories for loudness were defined: "no sound" (no snoring), "little sound" (snoring slightly louder than breathing), "somewhat loud" (as loud as or louder than talking);"extremely loud" (audible through a closed door), and "do not know." Responses to the question "How often do you have times when you stop breathing during your sleep?" were categorized as "never," "sometimes" (up to 3 nights per week), "often" (3-7 nights per week), and "do not know."

The overnight protocol was conducted in participants' homes during an evening visit. Prior to applying the PSG leads, participants, were weighed using a calibrated scale, and their neck circumferences were measured to the nearest 0.5 cm using standard methods.[15] The PSG, conducted with the Compumedics PS-2 PSG system (Compumedics Pty Ltd, Abbotsford, Australia), provided the following data over the sleep period: electroencephalogram, chin electromyogram, and electro-oculogram to identify sleep state; chest and abdominal respiratory excursions detected by inductive plethysmography (Respitrace; Ambulatory Monitoring, Ardsley, NY), nasal and oral airflow by thermocouple (Protec, Woodinville, Wash), and arterial oxyhemoglobin saturation by finger-pulse oximetry (Nonin, Minneapolis, Minn) to detect abnormal breathing events; electrocardiogram; body position (mercury gauge sensor); and ambient light.

The recordings were scored using standard criteria for identification of sleep stages.[16] The polysomnographic software used in conjunction with the manual scoring permits the use of different criteria for identification of apneas and hypopneas. For this analysis, apnea was defined as a complete or almost complete cessation of airflow, indicated by reduction to 25% or less of baseline amplitude for 10 seconds or more, and hypopnea was defined as a clear decrease in airflow or thoracoabdominal excursion to 70% or more of baseline for at least 10 seconds. Only apneas and hypopneas that were accompanied by a 4% or greater decrease in oxygen saturation were counted. Sleep-disordered breathing was quantified by the frequency of apneic and hypopneic events per hour of sleep (apnea-hypopnea index [AHI]). The sample for this analysis included participants with scored PSG studies who met criteria for "fair quality" or better as described by Redline et al.[17]

STATISTICAL ANALYSIS

Sleep-disordered breathing status for this analysis was indicated by 3 AHI categories with cut points of 5 and 15, and a dichotomous variable (ie, AHI <15, AHI ≥15). Analyses were performed using SAS statistical software (SAS Institute Inc, Cary, NC). Differences in AHI means and proportions by categories of predictor variables were assessed for significance using *t* tests and χ^2 tests, as appropriate. Multiple logistic regression was used to investigate the associations of predictor variables with SDB prevalence, indicated by an AHI of 15 or greater. We evaluated the need to adjust for the multicenter design by adding terms for the centers in the regression models. When entered into the regression models, the site variables had no appreciable effect on any of the associations of interest and were ultimately not included. Age in years was modeled as a linear continuous variable and (when its effect was statistically significant) with an age-squared term. Body habitus measures were modeled as quartile categories and linear continuous variables with and without the addition of squared terms. Because the squared terms were not statistically significant in the regression models of interest and a linear trend over the quartile variables was evident, we used the linear continuous variables. To determine if associations of snoring and body habitus with SDB varied by age, sex, and race, interaction terms were tested in multiple logistic regression models. Statistical significance of main and interaction effects were assessed with Wald χ^2 and likelihood ratio χ^2 tests for continuous and categorical effects, respectively.

In the present study, we investigated the association of sex, age, race, snoring, and obesity with SDB in community-dwelling adults, using data from 6119 participants in the Sleep Heart Health Study (SHHS), a multicenter cohort study of SDB and cardiovascular disease. The large, uniformly studied cohort of men and women in the SHHS is well suited for investigating patterns of SDB occurrence as it extends from early middle age to old age and is ethnically and geographically diverse.

RESULTS

A total of 5615 participants had complete data on all demographic, body habitus, self-reported snoring and

Table 1. Sample Characteristics by Sleep-Disordered Breathing Severity*

Characteristic	No. of Participants	Apnea-Hypopnea Index <5	5-14	≥15
Total sample	5615	53	29	18
Sex				
Male	2648	42	33	25
Female	2967	63	26	11
Age, y				
39-49	519	70	19	10
50-59	1648	60	24	16
60-69	1668	49	32	19
70-79	1425	46	33	21
80-99	355	44	36	20
Race				
White	4330	54	29	17
African American	418	54	26	20
American Indian	586	44	33	23
Other	281	62	25	13
Snoring frequency				
Nonsnorer	632	70	21	9
Moderate (<3 nights/wk)	1449	60	27	12
Habitual (3-7 nights/wk)	1897	39	33	28
Do not know	1637	56	28	15
Snoring loudness				
No sound	632	70	21	9
Little sound	825	63	26	11
Somewhat loud	2048	47	32	21
Extremely loud	427	29	33	38
Do not know	1683	55	29	16
Reported breathing pauses				
Never	2205	58	28	15
Sometimes (<3 nights/wk)	347	44	30	27
Often (3-7 nights/wk)	181	22	29	49
Do not know	2882	53	30	17
Body mass index†				
Quartile I	1403	69	22	10
Quartile II	1403	62	26	13
Quartile III	1405	51	32	17
Quartile IV	1404	31	37	32
Waist-to-hip ratio‡				
Quartile I	1399	68	21	12
Quartile II	1406	57	29	14
Quartile III	1404	48	32	19
Quartile IV	1406	40	34	26
Neck girth§				
Quartile I	1230	69	21	10
Quartile II	1353	62	26	12
Quartile III	1405	51	31	18
Quartile IV	1627	35	35	29

*Data are percentage of patients unless otherwise specified; percentages may not sum to 100% because of rounding.

†Body mass index (calculated as weight in kilograms divided by the square of height in meters) quartiles. Women: I, 15.9 to <24.4; II, 24.4 to <27.6; III, 27.6 to <31.7; IV, 31.7 to <58.9. Men: I, 16.7 to <25.4; II, 25.4 to <28.0; III, 28.0 to <30.9; IV, 30.9 to <56.5.

‡Waist-to-hip ratio quartiles. Women: I, 0.53 to <0.82; II, 0.82 to <0.89; III, 0.89 to <0.96; IV, 0.96 to <1.34. Men: I, 0.68 to <0.92; II, 0.92 to <0.97; III, 0.97 to <1.01; IV, 1.01 to <1.05.

§Neck girth (measured in inches) quartiles. Women: I, 10.2 to <13.0; II, 13.0 to <13.8; III, 13.8 to <14.6; IV, 14.6 to <19.5. Men: I, 11.8 to <15.4; II, 15.4 to <15.9; III, 15.9 to <16.9; IV, 16.9 to <23.2.

breathing pause variables, and AHI. Regarding the study sample, 53% were women, 77% were white, and the mean±SD age was 63.5±10.7 years. The mean±SD AHI was 8.8±12.2; the median was 4.5 with a range from 0 to 149. Of the sample, 18% had an AHI of 15 or greater and were therefore categorized as having SDB.

Figure 1. Smoothed plot (5-year moving average) of the prevalence of an apnea-hypopnea index (AHI) of 15 or greater by age.

Table 1 gives the proportions of the sample in 3 categories of AHI (<5, 5-15, and ≥15) by demographic and other factors. The AHI category was significantly associated with each factor, but the proportions are not adjusted. Consequently, the distributions should be viewed as descriptive only.

Defined as an AHI of 15 or greater, SDB was approximately twice as prevalent in men compared with women. A small increase in SDB prevalence was observed with increasing 10-year age groups. To investigate the age trend further, we plotted the average prevalence of an AHI of 15 or greater for 5-year age intervals, moving by 1-year increments over the entire age range. The resulting unadjusted smoothed plot (**Figure 1**) shows a plateau effect for prevalence in our sample beginning at approximately age 60 years. The pattern after age 85 years is not clear owing to the small number of participants in this oldest age group. All body habitus measures were strongly associated with an AHI of 15 or greater.

As expected, SDB was associated with self-reported snoring and breathing pauses. The prevalence of an AHI of 15 or greater increased with increasing categories of snoring frequency, loudness of snoring, and breathing pauses. Cross tabulations of these variables showed that although the variables are correlated, snoring frequency, loudness, and reported pauses each conveyed some different information. Nearly all of the extremely loud snorers and those with reported breathing pauses of 3 or more nights per week were also habitual snorers (92% and 88%, respectively). Most habitual snorers, however, did not report extremely loud snoring or breathing pauses: 79% and 92% of the habitual snorers reported lesser categories of snoring loudness and breathing pause frequency, respectively.

Of all the categories of demographic or predictor factors investigated, self-reported frequent breathing pauses (>3 nights per week) had the highest prevalence (49%) of an AHI of 15 or greater. However, the sensitivity of this symptom was low: of all participants with an AHI of 15 or greater, only 89 (9%) of 1006 had reported frequent breathing pauses.

The results of modeling an AHI of 15 or greater using multiple logistic regression are given in **Table 2**.

Table 2. Odds Ratios (95% CIs) for Variables and an AHI of 15 or Greater Estimated by Multiple Logistic Regression Models With Cumulative Addition of Independent Variables*

Model Term	Model 1 (Age, Sex, Race)	Model 2 (Model 1 + Body Habitus)	Model 3 (Model 2 + Snore)	Model 4 (Model 2 + Snore Loud)	Model 5 (Model 2 + Breathing Pauses)	Model 6 (Model 2 + Snore, Snore Loud, and Breathing Pauses)
Sex (male vs female)	2.70 (2.34-3.12)	1.71 (1.37-2.15)	1.60 (1.27-2.01)	1.60 (1.27-2.01)	1.59 (1.27-2.00)	1.51 (1.20-1.90)
Age (10-y increment)	1.24 (1.15-1.32)	1.36 (1.26-1.47)	1.47 (1.35-1.60)	1.49 (1.37-1.62)	1.40 (1.30-1.52)	1.52 (1.40-1.65)
Race (vs white)						
African American	1.23 (0.965-1.60)	1.13 (0.86-1.49)	1.12 (0.85-1.48)	1.19 (0.91-1.57)	1.16 (0.89-1.53)	1.17 (0.89-1.55)
American Indian	1.70 (1.37-2.11)	1.09 (0.87-1.37)	1.21 (0.95-1.53)	1.26 (1.00-1.60)	1.10 (0.87-1.40)	1.23 (0.97-1.57)
Other	0.94 (0.65-1.37)	1.13 (0.77-1.66)	1.12 (0.78-1.67)	1.19 (0.80-1.77)	1.18 (0.79-1.74)	1.17 (0.78-1.74)
BMI (5.3 kg/m^2 increment†)	...	1.60 (1.45-1.76)	1.55 (1.40-1.70)	1.57 (1.43-1.73)	1.59 (1.44-1.75)	1.55 (1.41-1.71)
Neck girth (1.7-in increment†)	...	1.48 (1.31-1.67)	1.46 (1.29-1.65)	1.42 (1.25-1.61)	1.45 (1.28-1.65)	1.42 (1.25-1.61)
Waist-to-hip ratio (0.09-unit increment†)	...	1.12 (1.01-1.23)	1.09 (0.99-1.21)	1.10 (1.00-1.22)	1.12 (1.02-1.24)	1.11 (1.00-1.22)
Snoring frequency (vs none)						
Moderate (<3 nights/wk)	...	...	1.28 (0.92-1.78)	...	...	1.02 (0.70-1.49)
Habitual (3-7 nights/wk)	...	...	2.87 (2.10-3.91)	...	...	1.75 (1.18-2.62)
Do not know	...	...	1.63 (1.19-2.25)	...	...	1.28 (0.83-1.97)
Snoring loudness (vs none or audible breathing)						
Somewhat loud	...	...	...	1.95 (1.57-2.42)	...	1.42 (1.08-1.86)
Extremely loud	...	...	...	3.96 (2.98-5.27)	...	2.21 (1.56-3.14)
Do not know	...	...	...	1.47 (1.18-1.85)	...	1.27 (0.92-1.75)
Reported breathing pauses (vs none)						
Sometimes (<3 nights/wk)	...	...	...	...	1.78 (1.34-2.37)	1.43 (1.07-1.92)
Often (3-7 nights/wk)	...	...	...	...	4.03 (2.87-5.67)	2.47 (1.72-3.53)
Do not know	...	...	...	...	1.16 (0.98-1.36)	0.99 (0.84-1.18)

*CI indicates confidence interval; AHI, apnea-hypopnea index; BMI, body mass index; and ellipses, term not included in the model.
†1 SD.

Model 1 includes only the demographic factors of sex, age, and race. Compared with women, men had 2.7 times the odds of having an AHI of 15 or greater. Based on a model with age in years as a continuous variable, a 10-year age increment was associated with an increase in the odds of having an AHI of 15 or greater by 24%. Consistent with Figure 1, the addition of an age-squared term indicated that SDB prevalence began to level off after age 60 years. The age-squared term, however, was of borderline statistical significance ($P = .03$) and was not statistically significant in later models. Compared with whites, American Indians were more likely to have an AHI of 15 or greater (odds ratio [OR], 1.7).

Body mass index (BMI), neck circumference, and waist-to-hip ratio were significantly associated with an AHI of 15 or greater when added individually to model 1. When all 3 were included in the model simultaneously (Table 2, model 2), BMI and neck circumference had independent effects, but the effect of waist-to-hip ratio was negligible. The ORs for an AHI of 15 or greater with an increment of 1 SD in BMI and neck circumference were 1.6 and 1.5, respectively.

With the addition of the body habitus variables, the OR for SDB and American Indian ethnicity decreased and was not statistically significant. This indicated that the excess risk of SDB for American Indian heritage observed in model 1 was explained by increased measures of body habitus.

In models 3 to 5, the variables for reported snoring and breathing pauses were strongly associated with an AHI of 15 or greater. Odds ratios for an AHI of 15 or greater with self-reported habitual snoring, very loud snoring, or breathing pauses were 2.9, 4.0, and 4.0, respectively. The "moderate" or "sometimes" and "do not know" level of each of the variables also tended to be associated with increased risk of SDB as well. When added simultaneously to the model, coefficients of these variables dropped in magnitude but remained statistically significant (Table 2, model 6). Interaction terms for habitual and loudest snoring with breathing pauses were added to model 6 but were not statistically significant (all $P > .1$).

To determine if associations of the predictor variables (snoring, breathing pauses, and body habitus) with an AHI of 15 or greater differed by sex, age, or race, interaction terms were tested in separate logistic regression models. Significant interactions were found for age with the body habitus variables, age with reported breathing pauses, and sex with snoring frequency and loudness.

Age modified the effects of the body habitus variables with respect to the outcome variable of an AHI of 15 or greater. An attenuated effect with increasing age is shown in **Figure 2** with ORs for an AHI of 15 or greater estimated for an increase of 1 SD in BMI, computed for 5 points along the age range. The OR (95% confidence interval) for BMI and an AHI of 15 or greater at age 40 years was 2.0 (1.7-2.4) and dropped to 1.3 (1.1-1.5) by age 80 years. The associations of neck circumference and waist-to-hip ratio with an AHI of 15 or greater also decreased with age and became statistically nonsignificant by age 80 and 70 years, respectively.

Similarly, ORs for an AHI of 15 or greater and breathing pauses decreased with age group (**Figure 3**); at age

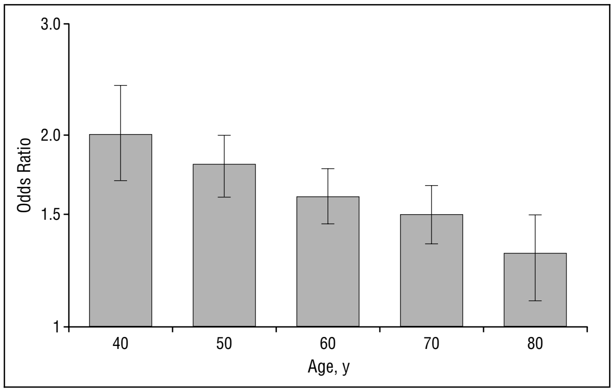

Figure 2. Logarithmic scale of odds ratios (calculated for ages 40, 50, 60, 70, and 80 years) for an apnea-hypopnea index of 15 or greater associated with a body mass index increment of 5.3 kg/m^2, adjusted for sex and race. Error bars indicate 95% confidence interval.

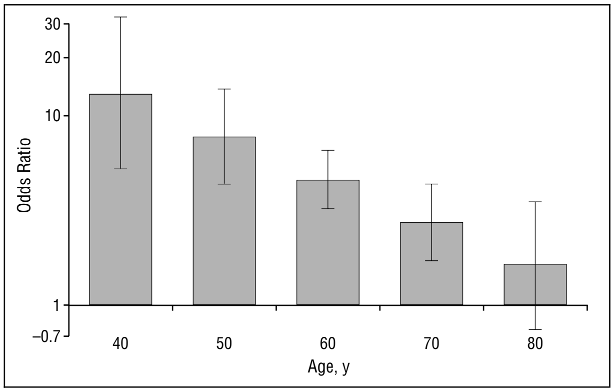

Figure 3. Logarithmic scale of odds ratios (calculated for ages 40, 50, 60, 70, and 80 years) for an apnea-hypopnea index of 15 or greater associated with self-reported breathing pauses of sometimes and often vs never, adjusted for sex and race. Error bars indicate 95% confidence interval.

80 years or older, breathing pauses were not significantly associated with an AHI of 15 or greater. There was also a trend showing decreased associations of snoring frequency and loudness with an AHI of 15 or more as age increased.

For women, the proportions of an AHI of 15 or greater in nonsnorers, moderate snorers, and habitual snorers were 3%, 7%, and 20%, respectively, and for men were 19%, 18%, and 33%, respectively. It is clear that the sensitivity and specificity of habitual snoring as a marker for an AHI of 15 or greater is poor for both men and women. However, there is a stronger trend for SDB in women to increase with severity of snoring; this is reflected by the higher ORs for an AHI of 15 or greater with snoring for women compared with men (**Figure 4**).

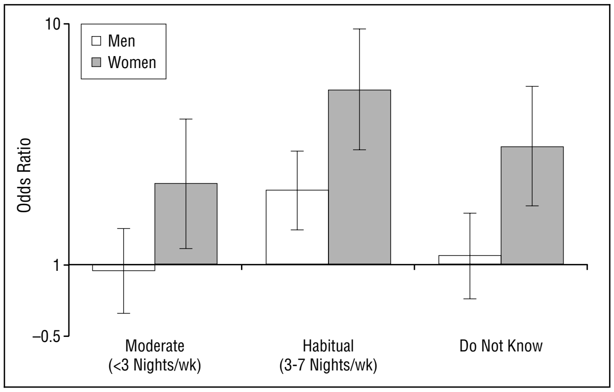

Figure 4. Logarithmic scale of odds ratios for an apnea-hypopnea index of 15 or greater associated with self-reported snoring frequency of moderate and habitual snoring vs nonsnorer by sex, adjusted for age and race. Error bars indicate 95% confidence interval.

COMMENT

Using the SHHS baseline data, we found that the demographic pattern of SDB includes a moderately higher risk for men compared with women and a small increase in risk with age. Additional significant predictors of SDB included increased measures of body habitus and self-reported habitual snoring, very loud snoring, and frequent self-reported breathing pauses. We also found that some of the associations of these predictors and SDB varied by the demographic characteristics.

DEMOGRAPHIC PATTERNS OF SDB PREVALENCE

The OR of 2.7 for an AHI of 15 or greater and male sex, adjusted for age and race, is smaller than expected based on previous reports of a strong predominance of men in SDB patient populations,[2] but it is in agreement with every published population-based study of SDB in men and women.[3-10] The high prevalence of occult SDB in both men and women in the general population is widely acknowledged, but our findings, based on a large sample of women ranging in ages from 39 to 98 years, further underscore the need for more attention to diagnosis of SDB in women.

Our finding that there was little increase in AHI in those older than 60 years is not consistent with a large upswing in incidence or significant worsening of SDB with aging in later life. If correct, this finding supports the need for a new perspective on SDB in later life, but several sources of bias must be addressed. Recruitment strategies varied by study site, depending on the parent cohort characteristics and sample size quotas. Selection was not random, and it is possible that selection and participation were slightly greater for younger snorers. Overrepresentation of younger snorers would tend to reduce an age-related increase in prevalence. However, when the sample was stratified on habitual snoring status, the increase in prevalence with age tended to plateau at age 60 years in both strata. Thus, it is unlikely that selective recruitment explains the age trend in our sample. If the participation rate was higher among the healthiest of the older people, but not among the younger people, the prevalence of SDB in older age groups would be underestimated. However, a "healthy volunteer" bias is well documented for younger as well as older participants in population studies.

Bias could arise if error in PSG-determined SDB status varied by age, but we found no evidence that older age was significantly associated with overall study success or the average duration of the 7 PSG signals[18] Of greater concern, the sample would be biased toward lower SDB prevalence among the older participants if there is significant mortality associated with SDB. Recent stud-

Table 3. Frequency of Self-reported Habitual Snoring by Age Group*

Age Group, y	Women: Habitual Snorer	Women: Do Not Know	Men: Habitual Snorer	Men: Do Not Know
<50	25	24	49	16
50-59	29	31	50	18
60-69	29	33	53	18
70-79	18	48	32	26
80-99	8	55	16	35

*Data are percentage of patients.

ies have shown significant associations of SDB and cardiovascular morbidity, but there has been no direct evidence that SDB shortens life. Prospective data from SHHS follow-up PSG studies on the cohort will be able to address more definitively how SDB changes during later life.

Our finding seems contrary to the widely held hypothesis that older age is a strong risk factor for SDB, but data from some other studies also suggest a plateau in SDB prevalence in those older than 65 years. In one of the earliest studies, Ancoli-Israel et al[13] found an extremely high prevalence of SDB in community-dwelling people older than 65 years, and the prevalence of 44% for an AHI higher than 20 is often cited.[13] However, the lack of a continual rise in prevalence from age 65 to 99 years in the sample led the investigators to conclude that the age-related increase must occur before age 65 years. Some investigators have found a linear association of SDB prevalence with age when SDB is defined as an AHI higher than 5, but when defined with higher cut points, a different trend is seen. In a recent report from the population-based cohort from Hershey, Pa, with ages ranging from 20 to 100 years, prevalence of SDB based on obstructive events for men showed a larger increase for younger vs middle-aged groups compared with the increase for middle-aged vs older age groups.[4] Furthermore, SDB prevalence defined as an AHI of 20 or greater decreased slightly from middle to older age. Similarly, data from a cohort drawn from residents of Basque Country, Spain, with ages ranging from 30 to 70 years, showed little or no increase in SDB prevalence defined by an AHI higher than 20 for men older than 59 years.[6]

PREDICTORS OF SDB: OBESITY AND SELF-REPORTED SLEEP-RELATED BREATHING EVENTS

Three measures of body habitus were related to SDB, but less strongly than would be expected based on the high prevalence of obesity and morbid obesity in sleep apnea patient populations. Based on our data, the OR for an AHI of 15 or greater with a BMI difference of 10 kg/m^2 and an AHI of 15 or greater is only 2.4. This lower than expected association indicates that a significant portion of the general population with SDB would be missed if only obese people were targeted for SDB evaluation.

In a model that included all 3 body habitus variables, the effect size for an AHI of 15 of higher was greatest for BMI and was negligible for waist-to-hip ratio. Recent studies have focused on upper body fat distribution as the critical obesity parameter in SDB,[19-21] but our findings indicate that excess body mass is an important predictor of SDB.

AGE AND SEX AS MODIFIERS OF THE EFFECTS OF OBESITY AND SELF-REPORTED BREATHING DISTURBANCES ON SDB

We found SDB in older people was poorly predicted by higher BMI, neck circumference, waist-to-hip ratio, and self-reported breathing pauses, suggesting that SDB in older people would be missed if case finding or referral were based on body habitus and reported breathing pauses. The reason for the differences in the SDB risk factors by age is not clear.

The decreased importance of body habitus as a predictor of SDB in older people may be due to age differences in how well current measures reflect the past status of weight and other body habitus measures that would be relevant to the onset of SDB. Although little is known about the natural history of SDB, Lugaresi and Plazzi[22] and others have speculated that progression from the onset of SDB pathogenesis to the condition of frequent apnea and hypopnea episodes takes decades. Current measures of body habitus in older people may either underestimate or overestimate their obesity status of decades past. The recent increase in obesity at all ages in the United States[23] implies that the older SHHS participants would have probably been less obese when they were middle-aged compared with the obesity status of participants who are presently middle-aged. If true, using current obesity measures would lead to an attenuation of the cross-sectionally determined OR for SDB with obesity in older, but not younger, participants.

Our findings are also consistent with the hypothesis that SDB in older people is a condition distinct from that in younger people. This hypothesis has been supported by findings that SDB in older people, in contrast to SDB in younger people, is not related to sleepiness and hypertension[4,24-27] and that snoring (a strong marker for obstructive SDB) decreases past middle age.[24,28,29] In **Table 3**, our data show the latter, with a 1.8-fold decrease in prevalence of habitual snoring from age between 50 and 60 to 70 years and older. However, the decline in self-reported snoring with age should be interpreted with caution. Older people may be less able to report their snoring status and other sleep-related breathing disturbances accurately because of the loss of a bed partner, hearing problems, or other age-related changes. We found an increase in the "do not know" response for snoring frequency for ages 70 years and older, and it might be suspected that true snorers who would have been able to report their snoring correctly at a younger age become uncertain in old age. However, if this were the case, the OR for the "do not know" category and an AHI of 15 or greater would tend to increase with age, concomitant with the decrease in the association for habitual snoring and an AHI of 15 or greater. This was not the case: as age increased, the OR for the "do not know" vs nonsnorer category also decreased.

With the emergence of a distinct SDB condition in older age, a decrease in the prevalence of SDB typical of middle age might be expected. Such a decrease in older age could result from selectively greater mortality among those with the obesity-related SDB characteristics of middle age. Central sleep apnea (a condition of nonobstructive breathing pauses caused by lack of breathing effort) could account for a distinct, older-age onset of SDB. However, we found no evidence in our data that central sleep apnea was associated with age. The proportion of people with any central apnea events defined as a 10-second or longer period of no airflow and no respiratory effort was very low (91% had less than 1 central apnea event per hour), and did not increase with age. Furthermore, central sleep apnea did not explain our finding indicating that the associations of obesity and reported breathing pauses diminished with age. When people with any central apnea events were eliminated from analysis or when a term for the average number of central apnea events per hour of sleep was added to the relevant logistic regression models, the age interactions with body habitus and breathing pauses were not affected. In contrast, Bixler et al[4] reported that the prevalence of central sleep apnea in men was higher for ages ranging from 65 to 100 years compared with 20 to 64 years. Further investigation of the nature of SDB in older age is clearly warranted because identification of a distinctly different older-age onset of SDB would be highly relevant to management of SDB in older people.

The SHHS data have limitations that could potentially affect the validity of our findings. Error in measuring SDB may compromise the accuracy of the association estimates. The validity of PSG data, particularly single-night PSG, as a measure of usual SDB has been questioned. Error may result from technical limitations of the unattended PSG technology, interference of the recording procedure on sleep quality, and intrasubject nightly variation. The potential for error from these sources has been considered at the design, implementation, and analysis stages of the SHHS, and steps were taken to minimize error and to assess its magnitude.[17,30,31] The technical quality of the PSG recording and scoring was regularly monitored, and only studies of good quality or better were included in analyses.[10] Over 50% of the participants reported that their sleep during the PSG was as good or better compared with their usual sleep, indicating that most studies were not based on a highly irregular night's sleep. A study of night-to-night variation showed that the AHI recorded by the SHHS methodology was relatively stable; there was no evidence to support a strong "first night effect."[32]

We defined SDB by a dichotomous variable based on an AHI cut point of 15, approximately the beginning of the upper quartile for AHI in this sample. Although this is a commonly used cut point indicating SDB of physiological or clinical notability, its validity has not been established. However, this cut point was recommended by an international task force on standardization of definitions for sleep-related breathing disorders to indicate moderate SDB.[33]

Error in measuring SDB or any of the other study factors is of concern in estimating accurate ORs. Random error in measuring SDB could attenuate the strength of associations, but error with respect to SDB severity that differs by the covariates of interest may introduce bias in the estimates. Of greatest concern is that we have underestimated the association of AHI and age. It is possible that difficulty sleeping with the monitor is related to age or that intrasubject variability increases with age, resulting in less accurate AHI measurement for older people. Therefore, our findings indicating that AHI does not increase appreciably with age must still be interpreted with caution.

The sex difference in ORs for SDB and snoring indicates less of a dose-response association for snoring frequency and SDB in men compared with women. This finding suggests that compared with women, men may tend to overreport their snoring. Little is known about sex differences in the validity of self-reported snoring. It is possible that participation bias could account for this finding, but for such a bias to occur, self-selection of snorers into the SHHS would have to differ by sex.

In summary, the results of this study shed new light on the demographic patterns of SDB. In view of the lack

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of a marked increase of SDB prevalence in older age, the role of late-life aging in SDB needs investigation. Our findings also indicate that case finding should not be restricted to men, middle-aged, or obese persons, and it does not appear that targeting any particular ethnic group is warranted. Although we found a strong association of self-reported snoring and breathing pauses with SDB, sensitivity and specificity of these symptoms for identification of SDB were low. Of particular importance, snoring and obesity may be inappropriate for identifying SDB in older people. These finding could have important implications for targeted case finding and point to the need for further research on SDB in older people.

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