

Hypertension in Sleep Disordered Breathing

Snoring as Part of a Dose–Response Relationship Between Sleep-Disordered Breathing and Blood Pressure

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Summary: This report addresses the hypothesis that snoring without significant apneas and hypopneas (simple snoring) is associated with elevated blood pressure and cardiovascular disease (CVD). Data on blood pressure, previously diagnosed cardiovascular disease, and sleep-disordered breathing (SDB) status from a population-based sample of 580 adults was analyzed. Systolic and diastolic blood pressures, adjusted for age, sex, and body mass index, increased stepwise across categories of no SDB, simple snoring, mild, moderate, and more severe SDB ($p < 0.05$). A similar and significant trend was seen for CVD prevalence. The results provide evidence that simple snoring represents the beginning of the SDB severity spectrum and that simple snoring has a proportionately smaller but, nevertheless, significant, risk for elevated blood pressure and CVD. **Key Words:** Sleep—Obstructive sleep apnea—Arterial pressure—Cardiovascular disease—Epidemiology.

The high prevalence of unrecognized sleep-disordered breathing (SDB), ranging from mild to severe, has accentuated the need to quantify adverse health outcomes associated with this condition, particularly at the milder end of its severity spectrum. In a previous report on a subset of the Wisconsin Sleep Cohort Study sample ($n = 147$), we described a dose–response relationship between hypertension and the number of apneas and hypopneas per hour of sleep (AHI) (1). We also found that snorers with no or few apneas ($AHI < 5$) had blood pressures that were slightly higher in both wake and sleep than blood pressures of the control group ($AHI < 5$, nonsnorers). We recently updated this analysis, using a much larger sample ($n = 501$), and found the same association of simple snoring with slightly elevated systolic blood pressures (Fig. 1). Although blood pressure differences between simple snorers and controls were not statistically significant, the consistency of the trend, particularly for blood pressure in the early morning, was intriguing and provided the impetus for this report.

Simple snoring is widely believed to represent the beginning of the SDB continuum, but there has been

considerable controversy regarding its potential harm. In a very thorough review, Hoffstein painstakingly summarized numerous studies on hypertension, cardiovascular disease, and stroke (2). Of 19 studies on the relationship of snoring with hypertension only five studies (all of which relied on secondary blood pressure data) had positive findings. A higher proportion of studies of vascular disease outcomes had positive findings (9/15). After considering methodologic differences, study limitations, and biologic inconsistencies, Hoffstein concluded that snoring is not associated with hypertension or other cardiovascular outcomes.

Considering the paucity of previous support, to further entertain the hypothesis that simple snoring is associated with cardiovascular outcomes would seem pointless. However, given the modest, rather than strong, association between SDB defined solely by apneas and hypopneas and blood pressure, we would expect the association for simple snoring and cardiovascular disease to be fairly weak. Consequently, if there truly is an association for simple snoring, it is doubtful that any of the previous studies were methodologically strong enough to discern it with significance. The hypothesis that simple snoring is even weakly associated with cardiovascular morbidity warrants adequate testing due to the large number of people who snore. The goal of the study reported here was to determine if

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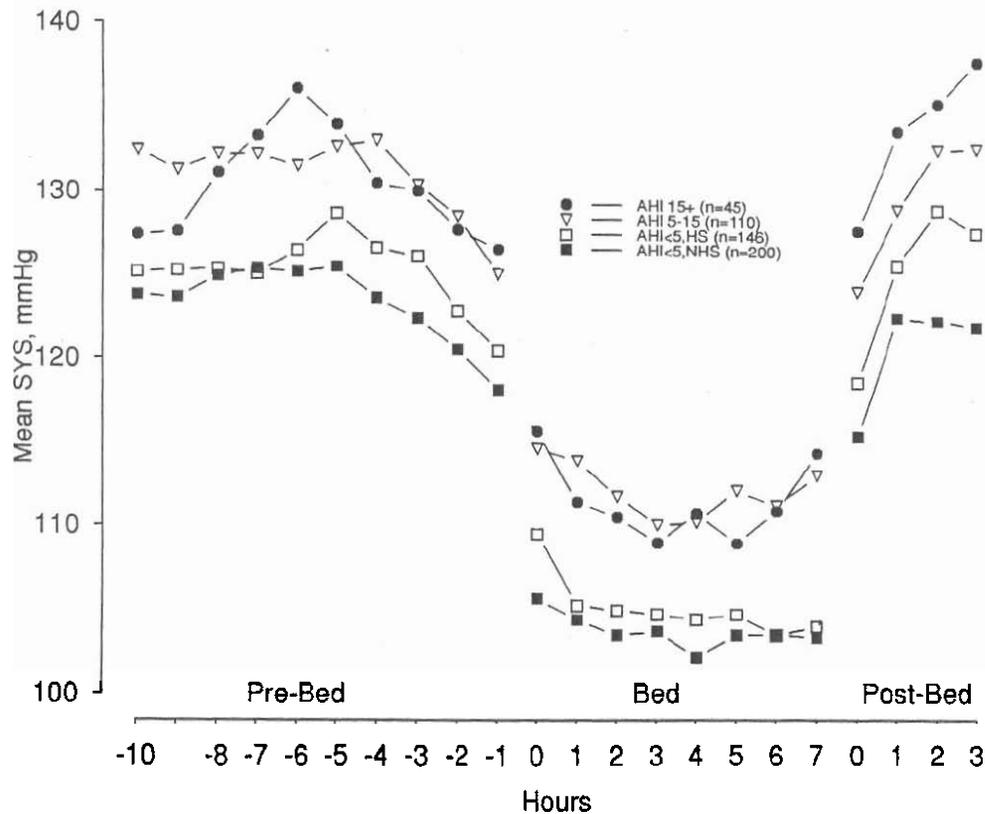


FIG. 1. Systolic blood pressure during wakefulness and sleep measured by ambulatory monitor, Sleep Cohort Study ($n = 501$). Open box is the simple snoring category (AHI < 5, habitual snorer [HS]); solid box is the no sleep disordered breathing category (AHI < 5, not habitual snorer [NHS]).

habitual simple snoring is part of a dose-response relationship of SDB with blood pressure and cardiovascular disease. For this, we used data from the entire sample of the Wisconsin Sleep Cohort Study that provided the methodologic strengths of a large population-based sample, a wide range of SDB severity, and precise laboratory measures.

METHODS

The sample was recruited from a defined sampling frame of approximately 5000 state of Wisconsin employees, ages 30–60 years (3). Data were obtained during an overnight study protocol conducted at a specially designed sleep laboratory. The data for this analysis, available on 805 cohort participants, included overnight polysomnography, blood pressure taken prior to bedtime and after arising in the morning, measurement of weight and height, and reported medical history. Blood pressure was measured by conventional standard mercury sphygmomanometer according to the American Heart Association recommendations. Measurements were made using the left arm with an appropriately sized cuff, after participants had been seated for 15 minutes. Three readings at 5 minute intervals of systolic and diastolic (phase V) blood pressures were recorded.

The polysomnography included recording of sleep state parameters (electroencephalograph [EEG], electrooculograph [EOG], and electromyograph [EMG]), breathing (oral airflow, nasal airflow, and rib cage and abdominal excursions), heart rate (electrocardiograph [ECG]), and oximetry (see Ref. 3 for details). All records were scored by trained technicians and reviewed by one of two sleep clinicians. Events with no airflow for 10 seconds or more were scored as apneas, and events with a 40% or more reduction in respiratory effort accompanied by a 4% or more desaturation were scored as hypopneas.

To describe SDB, AHI was calculated for each participant. Simple snoring status was based on a participant's response to a question on snoring frequency according to what bedpartners and others have told them and AHI from polysomnography. Participants were coded as simple snorers if they reported a snoring frequency of 3–7 nights per week and their AHI was <5.

Systolic and diastolic pressures in the evening and morning (a.m., p.m.) were based on the average of the three readings for each parameter. Body mass index (BMI, weight/height²) was used to describe body habitus. SAS statistical software was used for descriptive analyses and for multiple linear and logistic regression modeling.

TABLE 1. Characteristics of the sample (*n* = 805) according to sleep-disordered breathing category

Variables	No SDB ^a (<i>n</i> = 317)	Simple snoring ^b (<i>n</i> = 283)	AHI 5–15 (<i>n</i> = 121)	AHI 15–30 (<i>n</i> = 51)	AHI > 30 (<i>n</i> = 33)
Age, years, mean (SD)	44 (7.4)	45 (8.1)	47 (7.5)	49 (7.5)	46 (7.7)
BMI, mean (SD)	27 (5.1)	30 (5.7)	32 (6.1)	33 (5.9)	38 (9.1)
Neck girth (cm), mean (SD)	37 (3.8)	39 (4.2)	40 (3.8)	42 (3.3)	44 (3.3)
Waist: hip ratio, mean (SD)	0.87 (.09)	0.91 (.08)	0.92 (.10)	.95 (.06)	.98 (.06)
Blood pressures (mm Hg), mean (SD)					
p.m. systolic	120 (12)	126 (15)	129 (15)	133 (14)	140 (17)
p.m. diastolic	79 (9)	83 (10)	84 (9)	87 (10)	88 (10)
a.m. systolic	117 (15)	124 (16)	128 (16)	132 (18)	137 (17)
a.m. diastolic	80 (10)	83 (11)	86 (10)	88 (10)	93 (10)
Cardiovascular disease (%) ^c	1	5	5	10	13

^a AHI < 5, non-snorer.^b AHI < 5, habitual snorer.^c Previously diagnosed angina, myocardial infarct, coronary artery disease, or congestive heart failure.

RESULTS AND DISCUSSION

Sample characteristics according to SDB category are shown in Table 1. The systematic increase in established SDB risk factors and cardiovascular parameters across the categories ranging from no SDB, to simple snoring, to moderate–severe sleep apnea is striking and reinforces the appropriateness of placement of simple snoring at the beginning of the SDB spectrum. A dose–response trend for SDB and cardiovascular outcomes remained after adjustment for confounding factors of age, BMI, and sex (Table 2). Systolic and diastolic blood pressures, both in the a.m. and p.m., were significantly higher for the simple snorer group as compared to the group with no SDB. However, in contrast to our preliminary findings using 24-hour blood pressures (Fig. 1), the association was not restricted to the a.m. pressures. Analysis of the association of SDB with cardiovascular disease, using logistic regression to control for age, sex, and body mass index, yielded odds ratios that indicated a dose–response trend. Compared to the no SDB category, the odds ratios (95% confidence interval) for SDB categories were: 3.8 (1.1, 14) for simple snoring, 3.3 (1.0, 14) for AHI 5–15, 4.8 (1.1, 23) for AHI 15–30, and 6.6 (1.1, 38) for AHI >30. The odds ratio for simple snoring and previously diagnosed cardiovascular disease indicates that simple snorers, as compared to individuals of similar BMI, age, and

sex without SDB, were nearly four times as likely to have cardiovascular disease. Thus, considering simple snoring as the beginning of the SDB severity spectrum, there was a dose–response relationship between SDB and nearly all of the cardiovascular conditions we investigated.

This analysis is based on self-report for snoring status, so substantial misclassification may be present. The validity of self-reported snoring is poorly understood (4). Studies comparing one-night objectively measured snoring with self-reported usual snoring frequency are limited because the true night-to-night variability of snoring is unknown. However, the error introduced by misclassification in the present analysis would most likely be random error, and this would result in underestimation of the association of simple snoring and the outcomes. Thus, it is improbable that low validity of self-reported snoring could account for our findings.

CONCLUSION

This investigation provides support for the inclusion of simple snoring in the SDB continuum. The increased risk of having elevated blood pressure or cardiovascular disease associated with simple snoring is small but statistically significant. Most important, the

TABLE 2. Association of sleep-disordered breathing and blood pressure, adjusted for age, sex, body mass index, and antihypertensive medication use^a

	No SDB ^b	Simple ^c snoring	AHI 5–15	AHI 15–30	AHI > 30
Blood pressure, mm Hg					
p.m. systolic, mean (SE) ^d	122 (0.8)	126 (0.8)	125 (1.3)	126 (2.0)	130 (3.0)
p.m. diastolic, mean (SE) ^d	80 (0.5)	82 (0.6)	82 (0.9)	83 (1.4)	82 (2.1)
a.m. systolic, mean (SE) ^d	120 (0.8)	123 (0.9)	123 (1.4)	125 (2.2)	126 (3.3)
a.m. diastolic, mean (SE)	81 (0.6)	82 (0.6)	83 (1.0)	83 (1.5)	85 (2.2)

^a Users of antihypertensive medication were excluded from analyses (*n* = 97).^b AHI < 5, non-snorer.^c AHI < 5, habitual snorer.^d *p* < 0.05 for simple snoring versus no SDB categories.

findings indicate that the condition is not benign. For conditions with high prevalence, even a very small association with a serious outcome is important in terms of population health.

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