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A Polysomnography Study of Snoring and Obstructive Sleep Apnea in Relation to Chronic Bronchitis

Inkyung Baik, PhD[1], Jehyeong Kim, MD, PhD[2], Kihwan Jung, MD, PhD[2], Dae Wui Yoon, MS[3], Jinyoung Kim, PhD[3], Sejoong Kim, MD, PhD[2], Sungyong Lee, MD, PhD[4], Jaejeong Shim, MD, PhD[4], Kwangho In, MD, PhD[5], Kyungho Kang, MD, PhD[5], Sehwa Yoo, MD, PhD[5], Seung Hoon Lee, MD, PhD[6], Chol Shin, MD, PhD[2,3]

[1]Department of Foods and Nutrition, College of Natural Sciences, Kookmin University, Seoul,
[2]Department of Internal Medicine, [3]Institute of Human Genomic Study, College of Medicine, Korea University, Ansan Hospital, Ansan,
[4]Department of Internal Medicine, College of Medicine, Korea University, Guro Hospital, Seoul,
[5]Department of Internal Medicine, College of Medicine, Korea University, Anam Hospital, Seoul,
[6]Department of Otorhinolaryngology-Head and Neck Surgery, College of Medicine, Korea University, Ansan, Korea

Background and Objective Reportedly, snoring is associated with chronic bronchitis. This association warrants further studies including polysomnographic evaluations because of few epidemiologic studies on the association. Via a polysomnography study, we evaluated the associations of snoring, obstructive sleep apnea, and systemic inflammation with chronic bronchitis among 442 participants from a population-based cohort.

Methods At baseline, we assessed participants' serum levels of C-reactive protein, a biomarker of systemic inflammation. Over a 5-year period, we conducted overnight polysomnography and identified any new cases of chronic bronchitis.

Results After taking into account age, smoking, and other potential risk factors, the multivariate odds ratio (95% CI) for chronic bronchitis was 2.9 (95% CI, 1.3-6.4) for snorers with cumulative duration of snoring episodes ≥ 1 hour as compared with those snoring < 1 hour. This association did not change after further adjustment for the presence of apnea. Obstructive sleep apnea had no association with chronic bronchitis. A higher level of serum C-reactive protein was associated with chronic bronchitis (p value for trend < 0.05). In a joint analysis of snoring and C-reactive protein, longer cumulative duration of snoring episodes accompanied by systemic inflammation was associated with a 10-fold (95% CI, 2.9 to 37.4) increase in the multivariate odds of chronic bronchitis.

Conclusions This polysomnography study provides additional data supporting the hypothesis that snoring is associated with chronic bronchitis implying that snoring-related local and systemic inflammation may play roles in the development of chronic bronchitis.

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Key Words Snoring, Obstructive sleep apnea, Chronic bronchitis, Polysomnography.

INTRODUCTION

We first reported that snorers are at an increased risk of developing chronic bronchitis.[1] After taking into account age, body mass index (BMI), smoking, and other potential risk factors, persons snoring almost every night had a 68% [95% confidence interval (CI), 17-142%] higher risk of chronic bronchitis compared to persons who had never snored.[1] The biological mechanisms that underlie snoring's effects on chronic bronchitis include systemic and local airway inflammation.[2-6] Experimental studies have suggested snoring's vibrations may induce elevated levels of pro-inflammatory biomarkers or inflammation-related gene expressions.[2,3] These findings imply a hypothesis--the association between snoring and chronic bronchitis may be mediated through local airway inflammation, regardless of systemic inflammation. In addition, we postulate that intrathoracic pressure fluctuations, which occur due to increased inspiratory effort against the closed airway, or hypoxia during obstructive sleep apnea (OSA) may stimulate the airway inflammatory response.[4-6] Obesity, which has a strong association with OSA[7] and habitual snoring,[8] elevates systemic inflammatory status[9] to the same extent that OSA's presence

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Correspondence
Chol Shin, MD, PhD
Department of Internal Medicine,
College of Medicine,
Korea University,
Ansan Hospital, 516 Gojan 1-dong,
Danwon-gu, Ansan 425-707, Korea
Tel +82-31-412-5603
Fax +82-31-412-5604
E-mail chol-shin@korea.ac.kr

does when independent of obesity.[10-12] No studies to date have carefully investigated these possible mechanisms regarding the relationships between chronic bronchitis and snoring, OSA, and systemic inflammation.

As stated in our previous study,[1] we think further epidemiologic studies are warranted to reevaluate the association between snoring and OSA and chronic bronchitis and to explore the underlying mechanisms for such associations, particularly studies including polysomnography (PSG), to provide objective measures of snoring and OSA. Thus, in the present study, we evaluated whether the presence of snoring and of OSA, as assessed by PSG, is associated with chronic bronchitis. We also explored systemic inflammation's role in this association.

METHODS

Study Design and Population

We carried out a cross-sectional study, embedded in a population-based cohort study within the Korean Genome Epidemiology Study (KoGES). Information regarding the KoGES's ongoing, prospective cohort study is available elsewhere.[1,13] Briefly, the cohort members consist of 5,015 male and female Korean citizens aged 40 to 69 years in 2001, who participated in comprehensive health examinations and on-site interviews at Korea University Ansan Hospital. Each participant signed a Human Subjects Committee-approved informed consent form prior to their health examination. Participants completed an interviewer-administered questionnaire that included questions on demographic information, medical history and health conditions, family disease history, and lifestyle. Cohort members have been followed up biennially via scheduled site visits.

In our Ansan Sleep Cohort Study, which is an investigation via PSG, we first enrolled the 5,015 cohort members, using disproportional stratified sampling to allow efficient analyses. Based on the questions about presence and frequency of snoring, we stratified the cohort members into habitual snoring (snoring 4 nights per week or more) and non-habitual snoring (no snoring or snoring less than 4 nights).

Then, we randomly selected 50% of the habitual snorers (habitual snorers were 17% of all cohort members) and 10% of the non-habitual snorers, selecting a group with similar proportions to the snoring group regarding sex and number of members in each of the 10-year age range groups. Ultimately, we included 637 study participants with a participation rate of 75 percent. All participants underwent overnight PSG between August 27, 2001 and March 16, 2005. When comparing their incidences of chronic bronchitis over the 5-year period, we observed no difference between our participants and the other cohort members, who did not participate in the PSG.

For this current study, we excluded participants who reported on the baseline questionnaires that they had a physician's diagnosis of a major disease, such as chronic obstructive pulmonary disease, cancer, cardiovascular disease, tuberculosis, and asthma (n = 85); or had experienced cough and sputum production on most days for at least 3 months in the preceding year (n = 6); who did not complete the follow-up interviews (n = 47); or whose serum C-reactive protein (CRP) levels were 4 mg/L or higher, based on assay results from the baseline health examination (n = 57). This left 442 individuals for analysis.

Chronic Bronchitis

Chronic bronchitis was defined as the presence of cough and sputum production on most days for at least 3 months each year, for at least 2 successive years.[14,15] The 2001, 2003, and 2005 questionnaires included questions used in the European Community Respiratory Health Survey[16] to reveal respiratory symptoms and chronic bronchitis. Based on the responses to the questions, we considered that chronic bronchitis cases included only individuals who reported chronic bronchitis in the absence of a physician's diagnosis of asthma.

Measurement of C-Reactive Protein

All participants fasted for at least 8 hours before blood collection began. Using the turbidimetric immunoassay method, we assessed participants' serum concentrations of CRP, a systemic inflammation biomarker, at baseline. We defined the top tertile of serum CRP levels (≥ 1.8 mg/L) as a high level of systemic inflammation and the bottom 2 tertiles as a low level of systemic inflammation.

Polysomnographic Measurement of Snoring and OSA

To determine the presence and severity of snoring and OSA, we conducted PSG evaluations of the participants over a 5-year period. They underwent overnight PSG at Korea University Ansan Hospital's sleep laboratory, which has a computerized PSG device (Alice 4; Respironics, Atlanta, GA, USA). The evaluations measured the following parameters: electroencephalogram, electrooculogram, submental and leg electromyogram, electrocardiogram, airflow through the nose and mouth, chest and abdominal respiratory movement, pulse oximetry, microphone recording for any snoring sound, and body position. According to the standard criteria,[17] trained sleep technologists, who were blinded to the outcome, manually scored the PSG results, including any apnea and hypopnea.

For our purposes, apnea was defined as the absence of airflow for 10 seconds, and hypopnea was defined as a discernible reduction in airflow associated with a reduction in oxygen saturation by at least 4% from the baseline. We obtained apnea-hypopnea indices (AHI, the average number of apnea-hypopnea events per sleep hour) and the cumulative duration of each participant's snoring episodes. In this study, we defined OSA patients as those with AHIs of 5 events/hour or greater.

Potential Risk Factors

Trained interviewers administered the questionnaires to participants. On the 2001 questionnaire, we collected information on demographic characteristics, including age; sex; income; occupation; history of occupational exposure to dust or chemicals; marital status; education; and lifestyle factors, including smoking status, alcohol consumption, and physical activity. A previous study shows how we calculated daily alcohol consumption (g/day) and total metabolic equivalent of task per hour (MET/hour) scores.[13] Trained health professionals performed a comprehensive health examination on each participant, measuring height (cm) and body weight (kg) to the nearest 0.1 cm and 0.1 kg, respectively, without shoes and then calculating BMI (kg/m^2). On the 2003 questionnaire, we collected data regarding any rhinitis diagnosed by physicians in 2001 or earlier.

Statistical Analysis

We calculated descriptive statistics for study participants' baseline characteristics, dividing them into 2 categories based on cumulative duration of snoring episodes (< 1 hour or ≥ 1 hour). To evaluate the statistical difference between these categories, we performed unpaired t-tests for continuous data and Kruskal-Wallis tests for categorical data. To evaluate the associations of snoring and OSA with chronic bronchitis and systemic inflammation, we conducted logistic regression analyses and estimated odds ratios (ORs) of chronic bronchitis or of a high level of sys-

Table 1. Comparison of characteristics according to cumulative duration of snoring episodes, as recorded during polysomnographic evaluation

Variables	Cumulative duration of snoring episodes		p-value*
	< 1 hour	≥ 1 hour	
No. (%) of participants	318 (72.0)	124 (28.0)	
Polysomnographic measures (2001-2006)†			
Cumulative duration of snoring episodes, mean ± SD (min)	13.8 ± 17.5	122.3 ± 52.0	< 0.001
Duration of sleep, mean ± SD (hours)	6.2 ± 1.0	6.6 ± 0.8	< 0.001
Apnea-hypopnea index, mean ± SD	5.4 ± 9.5	12.7 ± 14.8	< 0.001
Diagnosis of obstructive sleep apnea (%)‡	29.3	54.8	< 0.001
Baseline measurement (2001-2002)†			
Age, mean ± SD (years)	49.1 ± 7.2	48.0 ± 6.6	0.13
Male (%)	55.0	83.1	< 0.001
Monthly wage of < 10^6 won (%)§	12.6	3.2	< 0.01
Occupation (%)			
White-collar job	17.0	19.4	0.56
Blue-collar job	55.4	67.7	< 0.05
Others	27.7	12.9	< 0.01
History of occupational exposure (%)			
To dust	20.8	17.7	0.48
To chemicals	9.4	10.5	0.74
Living with spouse (%)	90.6	96.8	< 0.05
Educational level of > 9 years (%)	73.9	81.5	0.10
Smoking status (%)			
Current smokers	18.6	35.5	< 0.001
Former smokers	22.6	28.2	0.22
Passive smoking among never-smokers (%)	32.6	42.2	0.22
Body mass index, mean ± SD (kg/m^2)	24.9 ± 2.7	26.4 ± 3.0	< 0.001
Alcohol consumption, mean ± SD (g/day)	10.1 ± 22.6	23.7 ± 36.4	< 0.001
Physical activity, mean ± SD¶	24.1 ± 9.4	23.3 ± 8.6	0.43
Average daily sleep, mean ± SD (hours)	6.6 ± 1.5	6.4 ± 1.3	0.37
Serum C-reactive protein, mean ± SD (mg/L)	1.3 ± 1.0	1.4 ± 1.0	0.23

*Data compared between groups, using the Kruskal-Wallis test for categorical variables and the t-test for continuous variables. †During this period, we collected or assessed information on these measures. ‡Defined as apnea-hypopnea index ≥ 5 events/hour. §This wage corresponds approximately to the government-set minimum wage for a family of 3 persons. ¶Average daily metabolic equivalents per hour.
SD: standard deviation.

temic inflammation with a 95% CI. Using the < 1 hour cumulative snoring group as a comparison (reference), we calculated ORs for the ≥ 1 hour cumulative snoring group. Likewise, we calculated ORs for the OSA group, using the non-OSA group as a reference. Potential confounding variables in the multivariate models were age, BMI, sex, income, occupation, history of occupational exposure to dust or chemicals, marital status, education, smoking status, passive smoking (among participants who had never smoked), alcohol consumption, physical activity, average daily sleep time, and rhinitis diagnosis. Furthermore, we took serum levels of CRP into account in the multivariate models. In the models, we fitted age, BMI, and CRP as continuous variables and entered the other variables as categorical variables. We also examined the association between snoring and chronic bronchitis according to smoking status. Because approximately 77% of study participants reported having never smoked or being ex-smokers, however, we present here only data for non-smokers, not for current smokers. In the analyses, we did not categorize current smokers by smoking intensity, because only 14 persons reported smoking more than 20 cigarettes per day.

RESULTS

We documented 41 cases of new-onset chronic bronchitis (9.3%) during the 5-year period. Table 1 presents the study participants' characteristics. Snorers in the ≥ 1 hour cumulative snoring group were more likely to show the following, as compared to the < 1 hour group: diagnosis of OSA, male, smoker, greater BMI, and consumption of a greater amount of alcohol (p value < 0.001)(Table 1).

Table 2 shows the associations of snoring and of OSA with chronic bronchitis. We observed that ≥ 1 hour cumulative snoring episodes associated positively with chronic bronchitis, after taking into account age, BMI, and other potential risk factors. After further adjustment for serum levels of CRP assayed at baseline and for the presence of OSA, snorers with ≥ 1 hour cumulative snoring episodes still had at least a 2.9-fold higher OR (95% CI, 1.3 to 6.4) for having chronic bronchitis than did those in the < 1 hour snoring group (Table 2). When we conducted further analyses on the 339 non-smokers, the OR for chronic bronchitis was 5.09 (95% CI, 1.93 to 13.43) for snorers in the snoring ≥ 1 hour group compared with the reference group, after controlling for the Model 3 covariates. Among all participants, OSA was not significantly associated with chronic bronchitis (Table 2) as well as among non-smokers (data available from authors on request).

Table 3 demonstrates the association between the baseline measurement of serum CRP levels and the development of chronic bronchitis. In multivariate models, higher levels of CRP, reflecting elevated systemic inflammatory responses, were significantly associated with the development of chronic bronchitis during the 5-year period (p value for trend < 0.05)(Table 3).

Table 4 presents the joint analysis of snoring and systemic inflammation in relation to chronic bronchitis. After taking into account age, BMI, serum CRP levels, presence of OSA, and other risk factors, we observed that snorers with either a longer cumulative duration of snoring episodes or a higher CRP level had at least 3-fold higher odds of having chronic bronchitis. Moreover, those with both conditions had at least 10-fold higher odds of having chronic bronchitis as compared to those snoring < 1 hour and having low CRP levels (p value for trend < 0.001)(Table 4).

DISCUSSION

In a population-based, cross-sectional study, we evaluated snor-

Table 2. Association of snoring and obstructive sleep apnea with chronic bronchitis

Models for chronic bronchitis	Cumulative duration of snoring episodes		Apnea-hypopnea index	
	<1 hour	≥ 1 hour	< 5 events/hr	≥ 5 events/hr
Case/Noncase	23/295	18/106	25/256	16/145
Age-adjusted OR (95% CI)	Reference	2.18 (1.13-4.21)	Reference	1.15 (0.58-2.26)
Age and BMI-adjusted OR (95% CI)	Reference	2.45 (1.24-4.85)	Reference	1.21 (0.61-2.42)
Model 1: Multivariate OR (95% CI)*	Reference	2.77 (1.26-6.10)	Reference	1.21 (0.57-2.58)
Model 2: Multivariate OR (95% CI)†	Reference	2.86 (1.28-6.38)	Reference	1.15 (0.54-2.46)
Model 3: Multivariate OR (95% CI)‡	Reference	2.90 (1.27-6.59)	Reference	0.94 (0.43-2.06)

Boldface type indicates a p-value < 0.05.
*In Model 1, we adjusted data for age (continuous), BMI (continuous), sex, income (monthly wage of < 10^6 or ≥ 10^6 won), occupation (white-collar, blue-collar, or other), occupational dust exposure (yes or no), occupational chemical exposure (yes or no), marital status (married or other status), education (< 9 or ≥ 9 years), smoking status (never smoked, former smoker, or current smoker), passive smoking among the "never smoked" (yes or no), alcohol consumption (non-drinkers or currently drinking alcohol, at < 5.1 g, 5.1-15 g, 15.1-30 g, or > 30 g/day), quartiles of physical activity (metabolic equivalents per hour daily), quartiles of sleep duration during polysomnography, and a physician's diagnosis of rhinitis (yes or no). †In Model 2, we further adjusted data for serum levels of C-reactive protein (continuous) with the covariates from Model 1. ‡In Model 3, we further adjusted data for categories of cumulative duration of snoring episodes and the presence of obstructive sleep apnea with the covariates from Model 2.
OR: odds ratio, CI: confidence interval, BMI: body mass index.

Table 3. Association between C-reactive protein and chronic bronchitis

Models for chronic bronchitis	C-reactive protein			p-value for trend*
	Tertile 1	Tertile 2	Tertile 3	
Median, mg/L (range)	0.2 (0.1-0.8)	1.3 (0.9-1.7)	2.3 (1.8-3.9)	
Case/Noncase	11/144	9/134	21/123	
Age-adjusted OR (95% CI)	Reference	0.88 (0.35-2.19)	2.24 (1.04-4.83)	0.06
Age and BMI-adjusted OR (95% CI)	Reference	0.92 (0.37-2.29)	2.42 (1.10-5.30)	< 0.05
Model 1: Multivariate OR (95% CI)†	Reference	0.96 (0.36-2.59)	3.01 (1.28-7.04)	< 0.05
Model 2: Multivariate OR (95% CI)‡	Reference	0.95 (0.35-2.62)	3.36 (1.40-8.08)	< 0.05

Boldface type indicates a p-value < 0.05.
*We fitted C-reactive protein as a continuous variable in the model. †In Model 1, we adjusted data for age (continuous), BMI (continuous), sex, income (monthly wage of < 10^6 or ≥ 10^6 won), occupation (white-collar, blue-collar, or other), occupational dust exposure (yes or no), occupational chemical exposure (yes or no), marital status (married or other status), education (< 9 or ≥ 9 years), smoking status (never smoked, former smoker, or current smoker), passive smoking among "never smoked" (yes or no), alcohol consumption (non-drinkers or currently drinking alcohol, at < 5.1 g, 5.1-15 g, 15.1-30 g, or > 30 g/day), quartiles of physical activity (metabolic equivalents per hour daily), quartiles of sleep duration during polysomnography, and a physician's diagnosis of rhinitis (yes or no). ‡In Model 2, we further adjusted data for the categories of cumulative duration of snoring episodes and the presence of obstructive sleep apnea with the covariates from Model 1.
OR: odds ratio, CI: confidence interval, BMI: body mass index.

Table 4. Joint analyses of snoring and C-reactive protein in relation to chronic bronchitis

Snoring	CRP*	Case/Noncase	Multivariate OR (95% CI)	
			Model 1†	Model 2‡
< 1 hour	Low level	10/203	Reference	Reference
≥ 1 hour	Low level	10/75	3.62 (1.29, 10.15)	3.65 (1.28, 10.44)
< 1 hour	High level	13/92	3.83 (1.49, 9.82)	3.84 (1.49, 9.85)
≥ 1 hour	High level	8/31	10.34 (2.91, 36.73)	10.43 (2.91, 37.43)
p-value for trend			< 0.001	< 0.001

Boldface type indicates a p-value < 0.05.
*A low CRP level is defined as < 1.8 mg/L and a high CRP level is defined as ≥ 1.8 mg/L. †In Model 1, we adjusted data for age (continuous), BMI (continuous), sex, income (monthly wage of < 10^6 or ≥ 10^6 won), occupation (white-collar, blue-collar, or other), occupational dust exposure (yes or no), occupational chemical exposure (yes or no), marital status (married or other status), education (< 9 or ≥ 9 years), smoking status (never smoked, former smoker, or current smoker), passive smoking among "never-smoked" (yes or no), alcohol consumption (non-drinkers or currently drinking alcohol, at < 5.1 g, 5.1-15 g, 15.1-30 g, or > 30 g/day), quartiles of physical activity (metabolic equivalents per hour daily), quartiles of sleep duration during polysomnography, and a physician's diagnosis of rhinitis (yes or no). ‡In Model 2, we further adjusted data for the presence of obstructive sleep apnea with the covariates from Model 1.
OR: odds ratio, CI: confidence interval, CRP: C-reactive protein.

ing and OSA via overnight PSG and found a positive association between snoring and newly-identified chronic bronchitis over a 5-year period. After taking into account age, smoking, BMI, and other potential risk factors of chronic bronchitis, we observed that snorers with a longer cumulative duration of snoring episodes had a 2.9-fold (95% CI, 1.3 to 6.6) higher chance of having chronic bronchitis as compared to those snoring less than 1 hour. We also observed that higher levels of normal CRP values are associated with the development of chronic bronchitis. Furthermore, we observed that snoring had a stronger association with chronic bronchitis when combined with systemic inflammation.

In a previous study, we reported the first data on the association between self-reported snoring and chronic bronchitis, as developed over a 4-year follow-up period.[1] After taking into account chronic bronchitis risk factors, persons who snored every night or almost every night had a 68% (95% CI, 17% to 142%) excess in their risk of having chronic bronchitis as compared with those who had never snored. Furthermore, we observed that this association was strong among those who had never smoked, suggesting that snoring is a novel risk factor for chronic bronchitis and, thus, snorers who are non-smokers may be a high-risk population regarding bronchitis.[1] In this, our second report on snoring and chronic bronchitis, we used PSG to explore potential mechanisms whereby systemic inflammation is associated with snoring and/or bronchitis. As expected, we observed a consistent and strong association between an objective measure of snoring and chronic bronchitis. In particular, this association showed significance independent of systemic inflammation and other potential risk factors, but it became stronger in the presence of elevated systemic inflammation. In our results, OSA did not have a noticeable independent association with

chronic bronchitis, partly because a majority of OSA patients (86%) had mild or moderate apnea symptoms. Because this sleep-disordered breathing is prevalent among snorers, however, we cannot rule out OSA's possible effects on the association we observed between snoring and chronic bronchitis.

As we suggested in our previous report, the underlying mechanisms for the association between snoring and chronic bronchitis may involve local airway inflammation and systemic inflammation.[1] Animal experiments have provided data supporting the hypothesis that mechanical trauma due to repeated snoring vibrations may induce airway inflammation,[2,3] although no study has yet evaluated this hypothesis in humans. Studies on OSA patients show that AHI correlates positively with pro-inflammatory biomarkers, such as interleukin-6 and interleukin-8,[5,6] and suggest a link between OSA and bronchial inflammation.[4-6] Whether OSA itself has an association with systemic inflammation, independent of obesity, is still unclear, due to inconsistent findings.[10-12,18-20] Nevertheless, OSA and snoring commonly coexist with obesity,[7,8] and researchers have observed elevated CRP levels in heavier persons.[9] Based on the finding that systemic inflammation is related to inflammation of the lower airway[21] and reduced lung function,[22-24] we suggest the interaction between local and systemic immune responses may contribute to the etiology of chronic obstructive pulmonary disease.[25]

Our present study produced findings consistent with our previous report supporting the hypothesis that snoring is associated with chronic bronchitis[1] and also supporting a mechanism whereby snoring-related, local inflammation, accompanied by systemic inflammation, may lead to the development of chronic bronchitis. In the interpretation of our findings, however, several limitations should be taken into account. This study used objective measures from PSG evaluations for information on snoring exposure. Because we conducted the PSG over 5 years, our data drew on cross-sectional observations, and this obscured the temporal relationship between snoring exposure and outcome. Thus, our findings need to be interpreted as indicated in our earlier findings from a prospective investigation of snoring and chronic bronchitis.[1] Cases of chronic bronchitis were based on self-reports but not confirmed by means of a physician's diagnosis. However, the potential misclassification of outcomes is unlikely to be differential, and its influence on the findings is unimportant.[26] Although we attempted to enroll more potential cases of OSA from this population-based cohort, we found a small number of severe OSA cases, which did not allow analyses on any associations between severe OSA and chronic bronchitis.

In summary, our PSG study provides additional data supporting the hypothesis that snoring is associated with chronic bronchitis implying that snoring-related local and systemic inflammation may play roles in the development of chronic bronchitis. Further investigations assessing lung function, as linked to snoring-related local and systemic inflammation, may be useful for understanding the etiology of chronic bronchitis.

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Conflicts of Interest

The authors have no financial conflicts of interest.

REFERENCES

1. Baik I, Kim J, Abbott RD, Joo S, Jung K, Lee S, et al. Association of snoring with chronic bronchitis. *Arch Intern Med* 2008;168:167-73.
2. Puig F, Rico F, Almendros I, Montserrat JM, Navajas D, Farre R. Vibration enhances interleukin-8 release in a cell model of snoring-induced airway inflammation. *Sleep* 2005;28:1312-6.
3. Almendros I, Acerbi I, Puig F, Montserrat JM, Navajas D, Farré R. Upper-airway inflammation triggered by vibration in a rat model of snoring. *Sleep* 2007;30:225-7.
4. Salerno FG, Carpagnano E, Guido P, Bonsignore MR, Roberti A, Aliani M, et al. Airway inflammation in patients affected by obstructive sleep apnea syndrome. *Respir Med* 2004;98:25-8.
5. Carpagnano GE, Kharitonov SA, Resta O, Foschino-Barbaro MP, Gramiccioni E, Barnes PJ. Increased 8-isoprostane and interleukin-6 in breath condensate of obstructive sleep apnea patients. *Chest* 2002;122:1162-7.
6. Devouassoux G, Lévy P, Rossini E, Pin I, Fior-Gozlan M, Henry M, et al. Sleep apnea is associated with bronchial inflammation and continuous positive airway pressure-induced airway hyperresponsiveness. *J Allergy Clin Immunol* 2007;119:597-603.
7. Banno K, Walld R, Kryger MH. Increasing obesity trends in patients with sleep-disordered breathing referred to a sleep disorders center. *J Clin Sleep Med* 2005;1:364-6.
8. Svensson M, Lindberg E, Naessen T, Janson C. Risk factors associated with snoring in women with special emphasis on body mass index: a population-based study. *Chest* 2006;129:933-41.
9. Visser M, Bouter LM, McQuillan GM, Wener MH, Harris TB. Elevated C-reactive protein levels in overweight and obese adults. *JAMA* 1999;282:2131-5.
10. Shamsuzzaman AS, Winnicki M, Lanfranchi P, Wolk R, Kara T, Accurso V, et al. Elevated C-reactive protein in patients with obstructive sleep apnea. *Circulation* 2002;105:2462-4.
11. Yokoe T, Minoguchi K, Matsuo H, Oda N, Minoguchi H, Yoshino G, et al. Elevated levels of C-reactive protein and interleukin-6 in patients with obstructive sleep apnea syndrome are decreased by nasal continuous positive airway pressure. *Circulation* 2003;107:1129-34.
12. Punjabi NM, Beamer BA. C-reactive protein is associated with sleep disordered breathing independent of adiposity. *Sleep* 2007;30:29-34.
13. Baik I, Shin C. Prospective study of alcohol consumption and metabolic syndrome. *Am J Clin Nutr* 2008;87:1455-63.
14. Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. American Thoracic Society. *Am J Respir Crit Care Med* 1995;152:S77-121.
15. Definition and classification of chronic bronchitis for clinical and epidemiological purposes. A report to the Medical Research Council by their Committee on the Aetiology of Chronic Bronchitis. *Lancet* 1965;1:775-9.
16. de Marco R, Zanolin ME, Accordini S, Signorelli D, Marinoni A, Bugiani M, et al. A new questionnaire for the repeat of the first stage of the European Community Respiratory Health Survey: a pilot study. *Eur Respir J* 1999;14:1044-8.
17. Rechtschaffen AK. A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Los Angeles: UCLA Brain Information Service/Brain Research Institute;1968.

18. Guilleminault C, Kirisoglu C, Ohayon MM. C-reactive protein and sleep-disordered breathing. *Sleep* 2004;27:1507-11.
19. Ryan S, Nolan GM, Hannigan E, Cunningham S, Taylor C, McNicholas WT. Cardiovascular risk markers in obstructive sleep apnoea syndrome and correlation with obesity. *Thorax* 2007;62:509-14.
20. Sharma SK, Mishra HK, Sharma H, Goel A, Sreenivas V, Gulati V, et al. Obesity, and not obstructive sleep apnea, is responsible for increased serum hs-CRP levels in patients with sleep-disordered breathing in Delhi. *Sleep Med* 2008;9:149-56.
21. Walter RE, Wilk JB, Larson MG, Vasan RS, Keaney JF Jr, Lipinska I, et al. Systemic inflammation and COPD: the Framingham Heart Study. *Chest* 2008;133:19-25.
22. Shaaban R, Kony S, Driss F, Leynaert B, Soussan D, Pin I, et al. Change in C-reactive protein levels and FEV1 decline: a longitudinal population-based study. *Respir Med* 2006;100:2112-20.
23. Fogarty AW, Jones S, Britton JR, Lewis SA, McKeever TM. Systemic inflammation and decline in lung function in a general population: a prospective study. *Thorax* 2007;62:515-20.
24. Hancox RJ, Poulton R, Greene JM, Filsell S, McLachlan CR, Rasmussen F, et al. Systemic inflammation and lung function in young adults. *Thorax* 2007;62:1064-8.
25. Wouters EF. Local and systemic inflammation in chronic obstructive pulmonary disease. *Proc Am Thorac Soc* 2005;2:26-33.
26. Baik I, Lee SH, Choi JH, Abbott RD, Kim J, Jung K, et al. Association of snoring with chronic bronchitis-In reply. *Arch Intern Med* 2008;168:1930.