Snoring and Obstructive Sleep Apnea Among Former World Trade Center Rescue Workers and Volunteers

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Background: Snoring is a common symptom among workers with adverse health effects from their World Trade Center (WTC) occupational exposures. Rhinitis and upper airway disease are highly prevalent among these workers. Rhinitis has been associated with snoring and, in some studies, with obstructive sleep apnea (OSA). We examined the association of WTC exposure and findings on nocturnal polysomnogram, as well as known predictors of OSA in this patient population. **Methods:** One hundred participants with snoring underwent a polysomnogram to exclude OSA. Comorbidities had been previously evaluated and treated. The apnea-hypopnea index (AHI) defined and categorized the severity of OSA. Age, sex, body mass index (BMI), and WTC exposure variables were examined in bivariate and multiple regression analyses. **Results:** Our study sample had a similar prevalence of five major disease categories, as we previously reported. OSA was diagnosed in 62% of the patients and was not associated with any of those disease categories. A trend toward increasing AHI with increasing WTC exposure duration failed to reach the statistical significance ($P = 0.14$) in multiple regression analysis. An elevated AHI was associated with BMI ($P = 0.003$) and male sex ($P < 0.001$). **Conclusions:** OSA was associated with BMI and male sex but not with occupational WTC exposure indicators in this patient population.

Snoring is a commonly reported symptom among individuals with adverse health effects from their World Trade Center (WTC) work exposures. Our previous studies have documented the high prevalence of rhinitis and upper airway disease (UAD) among these workers,[1,2] presumably as a result of exposure to a large quantity of large aerodynamic diameter and caustic dust particles, as well as other irritants in the fumes and smoke at the WTC site.[3] Rhinitis has been associated with snoring[4] and, in some studies, with obstructive sleep apnea (OSA).[5] Similar associations have been proposed for gastroesophageal reflux disease,[6] which is also very prevalent among these workers.[2] We examined the association of results of nocturnal polysomnogram (PSG) and WTC exposures as well as known predictors of OSA[7] in this patient population.

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MATERIALS AND METHODS

All study patients were former rescue and recovery workers and volunteers at the WTC disaster site, who had met eligibility criteria to receive medical services at the WTC Health Effects Treatment Program (WTC HETP) at Mount Sinai Medical Center. The exposure duration criterion consisted of a minimum of 24 hours of rescue, recovery, and service restoration work (or volunteering) during the period from September 11 to 30, 2001, or of 80 hours from September 11 to November 30, 2001. The worksite location criterion included sites south of Canal Street, the Staten Island landfill, the barge loading piers, work in the office of the Chief Medical Examiner, the New York City Fire Department, and state and federal agencies. Virtually every occupational group present during the rescue and recovery of the WTC site is represented in the WTC HETP population.

Patients had initially presented from January 9, 2003, to October 31, 2006, for individualized clinical evaluation and treatment of persistent symptoms. Their symptoms and medical conditions were evaluated and categorized as described previously.[2] In brief, physicians' diagnoses were based on clinical symptoms, physical findings, supportive diagnostic test data, or response to specific treatment. A diagnosis of UAD required the presence of at least three symptoms of rhinitis,[8] persistent for more than 8 weeks and unrelated to an infection, perennial, with or without associated symptoms of sinusitis, pharyngitis, or laryngitis (in most cases documented by flexible rhinolaryngoscopy and/or paranasal sinus computed axial tomography scan studies). A rhinosinusitis symptom inventory and severity score (maximum being 36) was established by means of a previously published instrument.[9] A diagnosis of lower airway disease (LAD) required the presence of symptoms of dyspnea associated with cough and wheezing, the exclusion of infectious neoplastic diseases, etc. A diagnosis of gastroesophageal reflux disease (GERD) required the presence of heartburn with a frequency of at least once or twice weekly, and a response to a trial of proton pump inhibiting antacid,[10] with appropriate testing in selected cases.[11] Mental health diagnoses were confirmed and coded by psychiatrists or psychologists, according to the Diagnostic and Statistical Manual, 4th revision. A diagnosis was deemed WTC-related when the symptoms began while at the WTC site or within 6 months of the last day worked, depending on the type of physical or mental health condition. Acute or chronic users of alcohol, strong sedatives, and opiates were, on the other hand, excluded from this study.

The first 100 patients who met the aforementioned criteria, complained of snoring, and underwent a nocturnal PSG were included in this analysis. High-likelihood symptoms, craniofacial or pharyngeal abnormalities predictive of OSP were neither investigated systematically nor used as inclusion or exclusion criteria. The rationale for that was that several highly prevalent comorbidities in this patient population could be potentially associated with snoring and other sleep-related abnormalities and behaviors that we deemed important to investigate by means of PSGs. The Mount Sinai School of Medicine Institutional Review Board approved this retrospective review exempting it from the requirement for informed consent.

The WTC exposure variables included arrival at the WTC site within the first 48 hours of the terrorist attack, exposure to the dust cloud generated by the collapsing towers on September 11, 2001 (by itself as a dichotomous variable or with five levels of decreasing intensity), and WTC specific occupational exposure duration (in weeks).

A patient was considered as a lifetime nonsmoker if he/she had smoked less than 20 packs of cigarettes (or 12 oz. of tobacco) in a lifetime or less than 1 cigarette/d (or 1 cigarette/wk) for 1 year. A minimum of 12 months was required to deem a patient a former smoker.[12]

Body mass index (BMI) was calculated for each patient at the time of the initial evaluation and was also categorized into four levels (underweight, $\leq$18.5 kg/m^2; normal, 18.5 to 24.9 kg/m^2; overweight, 25 to 29.9 kg/m^2; and obese, $\geq$30 kg/m^2).

Nocturnal PSGs were conducted using Embla recording systems (Embla, Broomfield, CO), consisting of nocturnal recordings of the following physiologic channels: C3-A2 and C4-A1 electroencephalogram (sampled at 256 Hz), right and left electrooculogram, a single bipolar electrocardiogram, chin electromyogram, oxyhemoglobin saturation by pulse oximetry, chest and abdominal excursion by inductance plethysmography, airflow by an oronasal thermocouple, and body position by a mercury gauge. Continuous positive airway pressure titration was performed on 12 of the PSGs. In those cases, only the diagnostic phase of the PSG was used for this study. The apnea-hypopnea index (AHI) served to define and categorize the severity of OSA into four categories: normal, <5 events/hr; mild, 5 to 15 events/hr; moderate, 15 to 30 events/hr; and severe $\geq$30 events/hr.[13] A frequency of 5 events/hr of more was used to diagnose periodic leg movements of sleep, and a ratio of 2:1 for a rapid eye movement (REM) over non-REM related effect on the AHI.

Statistical Analyses

To determine whether the study sample was representative of our previously reported study population,[2] χ^2 testing was used to compare proportions of the following categorical variables: sex, language spoken, major occupational groups, lack of health insurance, clinical diagnoses of UAD and LAD, gastroesophageal reflux disease, psychological illness, musculoskeletal diseases, and arrival at the WTC site within 48 hours of the terrorist attack. The *t* test was used to compare age and WTC occupational exposure duration.[2] Only the proportion of patients with UAD (68% in the present series vs 78.5% in our previous one) differed significantly. The sample was thus considered representative of the WTC HETP patient population.

Age, sex, BMI, smoking status, and WTC exposure variables were examined in bivariate and multiple regression analyses as predictors of AHI. The latter was treated as a categorical, a continuous, or a logarithmically transformed variable, as appropriate for different analyses. Besides the four-level categorization of AHI described earlier,[13] we also categorized AHI as a dichotomous variable with AHI $\geq$15 as the cutoff in post hoc analyses. Both methods produced identical results, and only the first one is presented. Depending on the analysis, BMI and occupational WTC exposure variables were also treated as a continuous or a categorical variable (with the levels described before).

Bivariate analyses were conducted with the Pearson correlation, χ^2, or *t* tests as appropriate.[14] Multivariate analyses included multiple linear regressions for predictors of AHI,[14] with all variables entered on the same step. A *P* level of 0.05 was used to test for statistical significance for all analyses, which were conducted using the SPSS statistical package,[15] and 95% CIs were calculated for all estimates.

RESULTS

Table 1 summarizes the characteristics and major disease categories diagnosed in this patient population. Former smokers had stopped smoking with a median of 12 years before their evaluation (interquartile range, 5 to 16 years). OSA was diagnosed in 62% of the patients who presented with snoring. Other findings on PSGs included periodic leg movements of sleep in 20 patients (nine without OSA) and a REM-related increase in AHI in 23 patients (six with an overall AHI less than 5 events/hr).

TABLE 1. Characteristics of the Patient Population (n = 100)

Characteristic	*n* or Mean ± SD
Male sex, *n*	79
Age, yr	47 ± 8
AHI, events/hr	20.0 ± 24.8
BMI, kg/m^2	30.6 ± 5.4
Smoking status	
Lifetime nonsmokers	55
Former smokers	34
Present smokers	11
WTC exposure duration, wk	19.2 ± 14.4
Arrival at WTC within 48 hr	45
Major disease categories	
Upper airway disease	68
Lower airway disease	46
Gastroesophageal reflux disease	62
Psychological disease	55
Musculoskeletal disease	18

Bivariate analyses did not reveal any association between OSA and the five major presumably WTC-related disease categories (UAD and LAD, gastroesophageal, psychological, or musculoskeletal disease; data not shown). The rhinosinusitis symptom score did not differ between OSA (18.5 ± 9.1) and non-OSA (20.9 ± 10.5) patients ($P = 0.33$). There was a significant correlation between AHI and BMI ($r = 0.318$, $P = 0.001$). Table 2 shows that categories of AHI were also correlated with male sex ($P = 0.002$). Smoking status, on the other hand, was not correlated ($P = 0.122$). Because there seemed to be more former smokers among OSA patients (27 of 34), smoking status was retained for multivariate analyses. Although there seemed to be a trend toward a larger proportion of workers who arrived at the WTC site within the first 48 hours of the attack having elevated AHI, this association failed to reach statistical significance ($P = 0.60$). There was also no statistically significant association with occupational WTC exposure duration ($P = 0.61$) or with level of exposure to the dust cloud on September 11, 2001 (data not shown).

Because the distribution of AHI was skewed, it was logarithmically transformed before regression analyses. In multiple linear regression analyses (Table 3), the association between WTC exposure duration and log AHI (for every 20 weeks of WTC exposure, AHI increased by 12%) approximated but failed to reach ($P = 0.097$) statistical significance in comparison with what was observed when using categorical AHI in bivariate analyses (Table 2). Smoking status was similarly not significantly associated with log AHI ($P = 0.327$). On the other hand, log AHI was significantly associated with higher BMI ($P = 0.003$) and with male sex ($P < 0.001$).

DISCUSSION

A diagnosis of OSA was associated with BMI and male sex in this sample of former WTC workers and volunteers. We did not observe any statistically significant association of OSA with any of the major disease categories in these patients, namely, presumably

TABLE 2. Bivariate Analyses of AHI Categories

AHI Categories	Sex (Male/Female)	Arrival Within 48 hr of Attack (95% CI)	Exposure Duration, wk (95% CI)
Normal (AHI <5)	23/15	39.5% (24.0–55.0)	17.4 (13.2–21.6)
Mild OSA	18/4	40.9% (20.4–61.4)	19.1 (13.7–24.5)
Moderate OSA	13/2	46.7% (21.5–71.9)	23.1 (15.9–30.2)
Severe OSA	25/0	56.0% (36.5–75.5)	20.2 (12.6–27.9)
Total	79/21	45.0%	19.3
P	0.002	0.60	0.61

TABLE 3. Multiple Linear Regression Models of Risk Factors for Obstructive Sleep Apnea (Log AHI as Dependent Variable)

	β Coefficient	95% CI	*P*
WTC exposure duration	0.006	−0.002–0.013	0.097
Age	0.000	−0.014–0.014	0.976
Male sex	0.640	0.369–0.910	<0.010
Body mass index	0.030	0.010–0.050	0.003
Smoking status	−0.175	−0.627–0.178	0.327

WTC-related UAD and LAD or gastroesophageal reflux disease, or with the three WTC occupational exposure risk factors that we examined (ie, arrival at the WTC within the first 48 hours of the attack, direct or level exposure to the dust cloud on September 11, 2001, and duration of WTC-related occupational exposures).

Our previous work described the clinical diagnoses of former WTC workers and volunteers who sustained exposures to dust, smoke, and fumes.[2] The frequency with which clinicians record snoring on these patients' symptom inventories may be related primarily to the extensively reported prevalence of rhinitis and UAD,[2] because that is a well-documented association,[4] attributed to increased upper airway resistance due to inflammation-related tissue swelling. Whether rhinitis is also associated with OSA remains hypothetical.[16] Equally suggestive but still unproven is the association between OSA and gastroesophageal reflux disease,[17–19] which is also highly prevalent among the former WTC workers.[2,11] Our data failed to provide support for either association. Previously published reports on cigarette smoking as a risk factor for OSA have yielded contradictory results,[20–22] and ours did not suggest an association. Early arrival at the WTC site is a risk factor for clinically diagnosed WTC-related LAD and gastroesophageal reflux disease[2,11] and chronic posttraumatic stress disorder symptoms.[23] Our data did not show an association of this risk factor (or with WTC exposure duration and other exposure variables) with a diagnosis of OSA. If the association achieved statistical significance in studies with larger samples, our investigation suggests that WTC exposure would probably be a weaker predictor for AHI than BMI or male sex.

Among the strengths of this study is the fact that the patient population includes a wide range of occupations and WTC specific occupational exposure intensities, which favor generalizability and allowed the comparisons that we examined. We did not rely on questionnaires or other prediction tools to select patients, given the well-established limitations of those tools,[24–26] but also because that could have limited the examination of some of the risk factors for OSA. The slightly lower prevalence of UAD in this group compared with our previously reported one should have not mitigated any potential effect and in fact may have afforded slightly more power to detect a difference if there had been one. Limitations of our study include the fact that the patient population is biased toward more symptomatic individuals, either by physician or self-referral.

Our data suggest that a diagnosis of OSA is primarily related to the well-described male predominance of this patient population[2] and also to excessive weight. The latter factor may deserve further exploration in this population given the high prevalence of substantial and disabling psychological and physical comorbidities,[2] disabilities and treatments, all of which may favor weight gain. It is also possible that aggressive clinical investigation of a population with high prevalence of rhinitis-associated snoring, and known risk factors for OSA, may lead to earlier diagnosis than would be the case in the general population.

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