Obstructive Sleep Apnea: A Risk Factor for Work Disability

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Study Objective: To examine obstructive sleep apnea (OSA) as a risk factor for work disability.

Patients and Setting: Consecutive patients referred to the University of California San Francisco Sleep Disorders Center with suspected OSA (n = 183).

Design: All patients underwent overnight polysomnography after completing a written survey which assessed work disability due to sleep problems, occupational characteristics and excessive daytime sleepiness (EDS) defined as an Epworth Sleepiness Scale score > 10.

Results: Among 150 currently employed patients, 83 had OSA on polysomnography (apnea-hypopnea index ≥ 5). Compared with patients in whom both OSA and EDS were absent, patients with the combination of OSA and EDS were at higher risk of both recent work disability (adjusted odds ratio [OR], 13.7; 95% confidence interval [CI], 3.9–48) and longer-term work duty modification (OR, 3.6; CI, 1.1–12). When either OSA or EDS were absent, the strength of the association with work disability was less than when both OSA and EDS were present. When OSA was examined without respect to EDS, patients with OSA were at increased risk of recent work disability relative to patients without OSA (OR 2.6; 95% CI 1.2–5.8), but the association of OSA with longer-term work duty modification did not meet standard criteria for statistical significance (OR = 2.0, 95% CI 0.8–5.0).

Conclusions: The combination of OSA and EDS contributes to work disability, and OSA by itself contributes to recent work disability. These findings should highlight to employers and clinicians the importance of OSA in the workplace to encourage patients to be screened for OSA, particularly in situations of decreased productivity associated with EDS.

Keywords: Obstructive sleep apnea, work disability, excessive daytime somnolence, risk factor

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OBSTRUCTIVE SLEEP APNEA (OSA) IS CHARACTERIZED BY SLEEP FRAGMENTATION LEADING TO FATIGUE, DAYTIME SOMNOLENCE, AND DECREASED cognitive function (including concentration difficulties, memory impairment, and decreased learning skills).[1] OSA is common, the majority of cases are thought to be undiagnosed, and treatment generally results in improved symptoms and function.[2,3] Given that perhaps 5% of adults in Western countries are thought to have OSA, this condition could logically be thought to result in large economic costs in the form of lost work productivity.[2,4-6] Certainly, investigators have documented that undiagnosed OSA is associated with large increases in healthcare costs in working age populations.[7] Thus, increasing public and employer awareness of OSA to help identify undiagnosed cases would appear to be an attractive strategy from an economic and public health perspective. However, few studies have specifically examined the impact of OSA and resultant sleepiness on work disability, including work absences and decreased productivity while on the job.[6]

In a population with sleep disturbances referred for clinical evaluation, we evaluated the association between OSA and work disability. We examined the extent to which a diagnosis of OSA, in the presence or absence of excessive daytime somnolence (EDS), is associated with lost work productivity and disability. Furthermore, we evaluated the association of disability due to sleepiness with various occupational characteristics, some more cognitive and others more physically active in nature.

METHODS

Patients

Consecutive patients seen at the University of California, San Francisco (UCSF) Sleep Disorders Center were included in the study if they were of working age (18 to 65 years old), had worked within the previous 5 years, completed a standard intake survey, and, after clinical history and physical examination, had suspected sleep apnea leading to performance of a sleep study. There were no exclusions on the basis of comorbid conditions. Data were collected over an approximately 6-month period of time. Because consecutive eligible patients were included in analysis, the patients in this cohort should be largely representative of patients seen in the UCSF Sleep Disorders Center. Generally, the majority of the patients seen in this clinic were referred by their primary care physicians for suspected sleep disorders while a minority come from subspecialists such as pulmonologists, otolaryngologists, cardiologists, and neurologists. Of the 198 otherwise eligible patients based on age, 15 patients had left the workforce ≥ 5 years ago, leaving 183 patients for analysis. The study was approved by the UCSF institutional review board.

Outcome Variable: Work Disability

Conceptually, we approached work disability in sleep apnea as representing the interplay between disease-related impairment and intrinsic occupational and personal factors that

promote recent productivity loss or longer-term work duty modifications. Operationally, we sought to quantify these 2 complementary domains of work disability on the basis of structured survey responses. To accomplish this, we asked patients to complete a written survey prior to their clinic visit (see Appendix for the complete battery). Survey items assessing disability were originally developed from the authors' research on work disability in asthma and rhinitis.[8-13] Certain of these items were originally adapted from the Current Population Survey, the National Health Interview Survey, and the Migraine Work and Productivity Loss Questionnaire.[14-16]

We quantified the frequency of recent work disability based on self-report of the 4-week cumulative incidence of: missed complete work days and, separately, missed partial workdays due to sleeping problems; falling asleep on the job; and low (< 90%) self-rated job effectiveness. We determined these disability items only in the recent past because we felt that respondents would have difficulty recalling with precision such items as missed work days more remotely than the last 4 weeks.

We quantified work duty modification based on self-report of the incidence of missed promotion, changes in job duties, job schedule, job pay, or change in job specifically attributed to problems with sleep. Because such work duty modifications are by their nature unlikely to occur in any short term period of time, we determined such modifications as their 5-year cumulative incidence and termed this work disability category, "longer-term work duty modifications."

Although our work disability questions were adapted from validated questionnaires, our questionnaire has not previously been validated in patients with suspected obstructive sleep apnea. Therefore, we evaluated the psychometric properties of our work disability items by (1) assessing its internal consistency with Cronbach α analysis and (2) examining the internal structure of the question items with factor analytic techniques.

Predictor Variables

Analysis 1: OSA and Excessive Daytime Somnolence

Our primary predictor variables in this analysis were the presence or absence of OSA, as defined by polysomnography results, and the presence or absence of excessive daytime somnolence (EDS). Because we wished to assess the effects of OSA in both the presence and absence of EDS, patients were grouped into one of 4 mutually exclusive categories: (1) OSA present and EDS present, (2) OSA present and EDS absent, (3) OSA absent and EDS present or (4) OSA absent and EDS absent.

In a separate sensitivity analysis, we also tested whether a diagnosis of OSA was associated with work disability without taking into account whether patients had EDS or not. That is, we compared patients with OSA to patients without OSA in terms of their risk of work disability but, in this sensitivity analysis, did not further subdivide patients by the presence or absence of EDS.

To determine whether patients had OSA or not, each patient underwent overnight polysomnography. Based on polysomnography, we calculated the apnea-hypopnea index (AHI) based on the total number of episodes of either cessation (apnea) or decrease in airflow per hour. Apnea was defined as the cessation of airflow for ≥ 10 sec; hypopnea was defined as a decrease

Table 1—Baseline Characteristics Among 183 Subjects of Working Age (18 to 65 Years) with Suspected Obstructive Sleep Apnea

Characteristic*	Complete sample (n = 183)	Currently employed (n = 150)
Age, mean (SD), years	44.8 (10.8)	43.7 (10.2)
Sex (female)	45 (25%)	32 (21%)
Smoking history		
Never	94 (51%)	78 (52%)
Current	19 (10%)	15 (10%)
Past	70 (38%)	57 (38%)
Obstructive lung disease†	50 (27%)	41 (27%)
Body mass index‡		
Underweight (< 18.5)	5 (3%)	4 (3%)
Normal (18.5–24.99)	38 (21%)	30 (20%)
Overweight (25–29.99)	63 (34%)	53 (35%)
Obese (30+)	77 (42%)	63 (42%)
Epworth Sleep Scale, mean (SD)	9.8 (5.6)	9.8 (5.7)
OSA Status		
None (AHI < 5)	80 (45%)	67 (45%)
Mild (AHI 5–14)	32 (17%)	27 (18%)
Moderate (AHI 15–29)	34 (19%)	28 (19%)
Severe (AHI 30+)	37 (20%)	28 (19%)

*Data are presented as number (column percentage) except where indicated otherwise. †Self-reported physician diagnosis of COPD, chronic bronchitis, or asthma. ‡Based on patient self-report of height and weight.

in airflow combined with ≥ 4% decrease in oxygen saturation. According to established guidelines, patients were classified as having OSA if the AHI was ≥ 5.[17] We also graded the severity of OSA and presented these findings in Table 1.[17] However, because the number of subjects in any given strata of OSA severity was low, we analyzed the association of OSA with work disability by dichotomized subjects as either meeting or failing to meet criteria for OSA (AHI ≥ 5 or AHI < 5). We did so because we did not want to under-power the analysis by attempting to compare small numbers of subjects in each strata of OSA severity.

To evaluate potential excessive daytime somnolence, the written survey instrument included the items in the Epworth Sleepiness Scale (ESS).[18] The ESS asks the respondent to rate their likelihood of falling asleep in 8 different daily situations but does not include any questions about the likelihood of falling asleep at work. Scores > 10 of 24 indicate EDS (i.e., ESS > 10 is a "positive" result on the scale).[18]

Analysis 2: Individual Job Characteristics

In this analysis, the predictor variables were specific job characteristics while the outcome variable remained work disability. The survey form asked subjects whether their work involved a variety of activities that could be affected by sleep disordered breathing, such as operating heavy equipment or performing fine hand movements. These job characteristics were not mutually exclusive; for example, patients could report that their job involved both reading printed text as well as supervising other employees. The Appendix has the complete list of the 13 items queried. To facilitate interpretation, these 13 job performance characteristics

were condensed into 7 categories of related activities, some of which were more cognitive or sedentary in nature while others were more physically active or interactive (Table 4). These groupings were made based on the authors' subjective assessment of which categories would involve related neurocognitive worker processes and were done on an *a priori* basis before the results of statistical analyses. For example, reading "printed text or instructions" and reading "a visual display screen or terminal" were condensed into a condensed into a single category because these activities were felt to be similar in nature.

Covariates

Age, gender, and tobacco smoking history (defined as current smoker, former smoker, or never smoker) were assessed in our survey instrument. Medical history was obtained by asking patients, via questionnaire using a checklist, if they had ever received a physician diagnosis of various common medical conditions, including obstructive lung diseases. Height and weight were also ascertained as part of this questionnaire.

Statistical Analysis

We performed statistical analysis using Stata/SE software (version 9.2, College Station, TX). For univariate associations, we used the χ^2 test for categorical variables (for example, in examining the univariate relationship between OSA and work disability), the *t*-test for examining continuous normally distributed variables, and the Wilcoxon rank-sum test for examining continuous nonparametric variables (for example, in examining the relationship between OSA and the ESS). Where appropriate, 95% confidence intervals (CI) were calculated for proportions using the binomial distribution.

To examine the association between OSA and/or excessive daytime somnolence on the risk of work disability, we used multivariate logistic regression to control for potential confounding variables. These included variables known or suspected to be related to respiratory disease or work disability based on prior research.[19] These potential confounders were age, gender, tobacco history, and a self-reported history of physician-diagnosed obstructive lung disease (asthma, chronic bronchitis, chronic obstructive pulmonary disease [COPD]). Information on educational attainment and race/ethnicity were not available. Body mass index was not included as a covariate because OSA is likely on the causal pathway between BMI and work disability (that is, higher BMI increases the likelihood and severity of OSA).[4]

In our primary multivariate analysis, our models included as outcome (dependent) variables either recent work disabilities or longer-term work duty modification and included as predictor (independent) variables the potential confounders and three indicator (yes/no) variables representing (1) OSA without EDS, (2) EDS without OSA, and (3) both OSA and EDS. Thus, patients with neither OSA or EDS comprised the referent group and, by definition, the odds ratio [OR] of work disability was 1.0 for subjects in this referent group. In other words, the 3 other combinations of OSA and EDS were compared to this referent group lacking both OSA and EDS.

In our sensitivity multivariate analysis in which we examined the association between work disability and OSA without taking into account EDS, the same work disability outcome variables were used and the same potential confounders were included in analysis as predictor variables. However, rather than using indicator variables representing various combinations of OSA and EDS, we simply had one predictor variable (yes/no) representing OSA. Thus, in this analysis, subjects without OSA were the referent group to which subjects with OSA were compared.

Recent work disability was examined as both its individual components and the composite outcome (any recent work disability). The prevalence of any individual longer-term work duty modification was low; therefore, multivariate logistic regression analysis was only performed on the composite outcome of any longer-term work duty modification.

To examine the relationship between job and the risk of work disability, we used multivariate logistic regression. In this analysis, we examined both the entire cohort of currently employed patients with suspected OSA (including those who were ultimately found not to have OSA on polysomnography) (n = 150) as well as only the subset of currently employed patients who were found to have OSA on polysomnography (n = 83). The first analysis was intended to examine which types of job characteristics are associated with work disability among patients generally with suspected sleep disorders while the second analysis was intended to examine this association specifically among patients with diagnosed OSA. Using multivariate analyses, we controlled for sociodemographic characteristics, tobacco history, and comorbid obstructive lung disease. In the analysis of all currently employed patients, we also controlled for a diagnosis of obstructive sleep apnea based on the AHI obtained from our sleep studies.

RESULTS

Baseline Characteristics

Baseline patient characteristics are shown in Table 1. The mean age was 45 (SD = 11 years) and 75% of the patients were male. More than half of patients examined (55%) had OSA, which subsumed a range of severity based on the AHI. Patients with OSA were older than those without OSA and had a higher average AHI (Table 2).

Psychometric Properties of Work Disability Questionnaire

In order to assess the internal consistency of the items we used to assess disability, we calculated Cronbach α values for the 4 measures of recent work disability and the 5 measures of work duty modification. The Cronbach α values were 0.60 and 0.81, respectively, and thus appeared to have reasonable internal consistency.[20] In a principal component analysis of all nine work disability items simultaneously, a scree plot demonstrated a fall off to < 1.0 after the second eigen value, suggesting that our questionnaire represented 2 constructs.[21] Factor analysis demonstrated that all 9 work disability items loaded positively on Factor 1 (eigen value 3.5), with the 5 work duty modification variables contributing strongly (range 0.63−0.81) and the 4 recent work disability variables loading less strongly (range 0.35−0.56). Factor 2 (eigen value 1.3) was distinguished by positive loading from all 4 recent work disability variables and negative loading from

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Table 2—Univariate Analysis of Relationship Between OSA and Personal Characteristics, Sleep Status, and Work Disability Among Currently Employed Patients (N = 150)

	OSA Absent (AHI < 5) (n = 67)	OSA Present (AHI ≥ 5) (n = 83)	P-value*
Age, mean (SD), years	41 (10)	46 (10)	0.002
Sex (female)	19 (28%)	13 (16%)	0.06
ESS (SD)	9 (5)	11 (6)	0.06
AHI (SD)	1 (1)	33 (29)	< 0.001
RECENT WORK DISABILITY, PAST 4 WKS			
Complete full missed work day	6 (9%)	15 (18%)	0.11
Partial missed work day	22 (32%)	38 (46%)	0.11
Fell asleep on the job	16 (24%)	30 (36%)	0.11
Decreased job effectiveness	31 (46%)	54 (65%)	0.02
Any recent work disability	*43 (64%)*	*64 (77%)*	*0.08*
LONGER-TERM WORK DUTY MODIFICATION, PAST 5 YR			
Pay cut taken	6 (9%)	3 (4%)	0.17
Missed a promotion	6 (9%)	4 (5%)	0.31
Changed job schedule	9 (13%)	14 (17%)	0.56
Changed job duties	6 (9%)	6 (7%)	0.70
Changed job or employer	6 (9%)	4 (5%)	0.31
Any longer-term work duty modification	*12 (18%)*	*19 (23%)*	*0.45*

Percentages shown are column percentages (e.g., 18% of patients with OSA had a "complete full missed work day" in the last 4 weeks).
*P-value obtained using χ^2 test for the categorical variables of work disability and gender, the t-test for age, and the Wilcoxon rank-sum test for the nonparametric continuous variables ESS and AHI.

all 5 work duty modification measures. After orthogonal rotation, with a value of 0.50 as the cutoff for determining meaningful loading, all 5 work duty modification items loaded on Factor 1 but not on Factor 2 and all 4 recent work disability items loaded on Factor 2 but not on Factor 1. Principal component analysis was thus consistent with our work disability questionnaire containing 2 constructs, and factor loading patterns were consistent with the first construct representing the longer-term work duty modification items and the second construct representing the recent work disability items.[22,23]

Prevalence of Work Disability

The prevalence of work disability among currently employed patients with OSA (AHI ≥ 5) was substantial (Table 2). More than three quarters indicated recent work disability (n = 64/83; 77%; 95% CI 67%–86%). Overall, a substantial minority of patients had some form of longer-term work duty modification due to sleep problems (n = 19/83; 23%; 95% CI 14%–33%).

The prevalence of recent work disability was higher among those with OSA than those without the condition, although, in these univariate analyses, the P value was not always less than the conventional cut-off for statistical significance. There was no clear association between OSA and longer-term work duty modification in univariate analyses.

OSA and EDS as Risk Factors for Work Disability

As shown in Table 3, after controlling for potential confounders, the combination of OSA and EDS was associated with an increased risk of both recent work disability and longer-term work duty modification. There was also an elevated risk of any recent work disability for subjects with EDS but without OSA. Several estimated ORs suggested an increased risk of either recent work disability or longer-term work duty modification but had wide confidence intervals which included no association. For example, the point estimate of the OR suggested an association between OSA without EDS and any recent work disability but this finding did not meet the standard threshold for statistical significance (OR 2.3; 95% CI 0.8–6.0). The wide confidence intervals for many of our estimates reflect the relatively small sample sizes and lack of strong statistical power for some analyses.

With respect to the individual components of recent work disability, the combination of OSA and EDS was associated with an increased risk of all such individual components (Table 3). The results were mixed in terms of achieving standard levels of statistical significance when either OSA or EDS were absent, although the point estimate for the OR was in all cases greater than 1 (greater than when both OSA and EDS were absent).

In a separate sensitivity analysis, we examined OSA as a risk factor for work disability without taking into account EDS. In multivariate analysis, adjusting for the same potential confounders, patients with OSA were at increased risk of recent work disability because of sleep problems, compared to patients without OSA (OR 2.6; 95% CI 1.2–5.8). There was a suggestion that OSA may also be associated with longer-term work duty modification, (OR = 2.0, 95% CI 0.8–5.0), but this finding did not meet standard criteria for statistical significance.

Job Performance Characteristics and Risk of Work Disability

Among all currently employed patients (n = 150), 4 of 7 job performance characteristics were statistically significantly associated with either recent work disability or longer-term work

Table 3—Multivariate Analysis of Work Disability Attributed to Sleep Problems Among Currently Employed Patients (N = 150)

	OSA Absent & EDS Absent* (n = 40) OR [Referent]	OSA Present & EDS Absent* (n = 39) OR (95% CI)	OSA Absent & EDS Present* (n = 27) OR (95% CI)	OSA Present & EDS Present* (n = 44) OR (95% CI)
RECENT WORK DISABILITY, PAST 4 WEEKS				
Complete full missed work day	1.0	2.0 (0.4–11)	1.7 (0.3–9.3)	5.6 (1.3–24)
Partial missed work day	1.0	1.8 (0.6–5.4)	2.9 (1.0–8.5)	5.4 (2.0–15)
Fell asleep on the job	1.0	1.2 (0.2–6.1)	11.0 (2.6–46)	18.1 (4.6–71)
Decreased job effectiveness	1.0	2.7 (1.0–7.2)	2.3 (0.8–6.5)	5.7 (2.1–15)
Any recent work disability	*1.0*	*2.3 (0.8–6.0)*	*8.3 (2.1–33)*	*13.7 (3.9–48)*
LONGER-TERM WORK DUTY MODIFICATION, PAST 5 YRS				
Any longer-term work duty modification†	*1.0*	*2.3 (0.6–9.6)*	*2.4 (0.6–9.1)*	*3.6 (1.1–12)*

*Multivariate logistic regression controlling for age, gender, tobacco history (ex smoker, current smoker vs. never smoker), and presence of obstructive lung disease (asthma, chronic bronchitis, or chronic obstructive pulmonary disease). "OSA Present" defined as AHI ≥ 5. "EDS present" defined by a positive Epworth Sleepiness Scale score > 10. All combinations of OSA and EDS are compared to patients lacking both OSA and EDS (referent group). The OR of work disability for patients lacking both OSA and EDS was therefore, by definition, 1.0 in this referent group.

†Individual types longer-term work duty modifications due to sleep problems (pay cut taken, missed a promotion, changed job schedule, changed job duties, and changed job or employer) were each too infrequent for separate analysis in logistic regression model. Thus, only the composite endpoint is presented.

Abbreviations: OSA, obstructive sleep apnea; EDS, excessive daytime somnolence; OR, odds ratio; CI, confidence interval.

duty modification, after controlling for confounders (Table 4). Shift work with periodic changes in sleep schedule (OR 3.3; 95% CI 1.2–9.7) and carrying out precise measurements, hand movements, or calculations (OR 4.3; 95% CI 1.2–16; P = 0.03) were each associated with an increased risk of work duty modification. Reading printed text or display screens was associated with an increased risk of recent work disability (OR 8.3; 95% CI 1.8–37). Conversely, working with heated materials or foods was associated with a decreased risk of recent work disability (OR 0.2; 95% CI 0.06–0.9). Among patients found to have OSA on polysomnography (n = 83), shift work was also associated with longer-term work duty modification (OR 5.2; 95% CI 1.3–21; P = 0.02) and reading printed text or display screens was also associated with recent work disability (OR 7.9, 95% CI 1.1–60; P = 0.04). Other associations were not statistically significant, but the point estimates for the OR's were in most cases similar to the estimates made on the larger cohort of all currently employed patients.

DISCUSSION

Our study provides some of the first empirical evidence to support the long-held suspicion that OSA is associated with work disability. Patients with the combination of OSA and excessive daytime somnolence (EDS) were at increased risk of both recent work disability and longer-term work duty modification even relative to a population with suspected sleep apnea referred for sleeping problems. Moreover, the point estimate for the risk of these work disabilities was in all cases higher when both OSA and EDS were present than when either of these were absent, suggesting that both may be important in contributing to the risk of work disability.

Although it is frequently asserted that OSA and EDS result in impaired work function and increased work disability, few studies have been performed to validate this claim.[6] Mulgrew and colleagues performed what is perhaps the most thorough prior examination of this subject.[24] They examined Canadian patients referred to a tertiary-care respiratory sleep clinic and found that EDS, as assessed by the Epworth Sleepiness Scale, was related to work limitation in time management, mental-interpersonal relationships, and work output.[24] However, in their group as a whole, OSA was not related to a statistically significant increase in work limitation when compared to subjects referred to their center who did not have OSA on polysomnography. We speculate that potential explanations include insufficient statistical power or the fact that, in the words of the authors, "work limitation was consistently elevated" in the referent group (subjects referred to their center who turned out not to have OSA).[24] Indeed, this is a challenge to our own study insofar as our own referent group, being subjects with suspected sleep apnea based on clinical history but without OSA on polysomnography, might be expected to have more work disability caused by sleepiness than the general population. In fact, the prevalence of work disability among subjects without OSA was surprisingly high (e.g., 64% overall recent work disability). The nature of the referent group thus tends to reduce the ability to detect differences due to OSA both in our study and in that by Mulgrew and colleagues. The fact that we did find some aspects of work disability associated with OSA and EDS makes these findings all the more noteworthy.

Interestingly, our study found that different job characteristics appeared to be associated with differing risk of work disability. Some job functions which might be thought of as more cognitive in nature, such as "reading printed text or display screens" and "precise measurement, hand movement or calculations" were associated with an increased risk of work disability. Conversely, "working with heated materials or food," which might be thought of as more physically active in nature, was associated with a decreased risk of work disability. The size of our sample has precluded us from detecting statistically significant

Table 4. Job Performance Characteristics and the Risk of Work Disability Among

Job performance characteristic†	All Currently Employed Patients (n = 150)		OSA present (n = 83)	
	Any recent work disability (past 4 weeks) OR (95% CI) P-Value	Any longer-term work duty modification (past 5 years) OR (95% CI) P-Value	Any recent work disability (past 4 weeks) OR (95% CI) P-Value	Any longer-term work duty modification (past 5 years) OR (95% CI) P-Value
Shift work with periodic changes in sleep schedule	0.9 (0.3–2.8) P = 0.99	**3.3 (1.2–9.7) P = 0.03**	1.2 (0.2–7.0) P = 0.88	**5.2 (1.3–21) P = 0.02**
Reading printed text or display screens	**8.3 (1.8–37) P = 0.006**	0.8 (0.1–4.5) P = 0.82	**7.9 (1.1–60) P = 0.04**	0.2 (0.02–1.4) P = 0.10
Carrying out precise measurements, hand movements, or calculations	1.2 (0.5–2.7) P = 0.70	**4.3 (1.2–16) P = 0.03**	1.5 (0.4–5.4) P = 0.58	3.5 (0.7–19) P = 0.14
Operating light equipment, heavy equipment, or a motor vehicle	0.8 (0.3–1.7) P = 0.49	0.8 (0.3–2.1) P = 0.68	2.1 (0.6–6.8) P = 0.23	1.5 (0.5–4.7) P = 0.49
Working with heated materials or foods	**0.2 (0.06–0.9) P = 0.03**	0.8 (0.15–4.4) P = 0.81	0.2 (0.03–2.2) P = 0.20	0.9 (0.08–9.6) P = 0.90
Interacting with the public by telephone or face to face	0.8 (0.3–1.9) P = 0.60	0.6 (0.2–1.4) P = 0.23	1.5 (0.4–5.4) P = 0.55	0.6 (0.2–1.9) P = 0.34
Supervising other employees	1.5 (0.7–3.1) P = 0.31	0.8 (0.3–1.8) P = 0.55	1.8 (0.5–5.9) P = 0.36	0.6 (0.2–1.8) P = 0.35

*Multivariate logistic regression analysis controlling for age, gender, tobacco history, presence of concomitant obstructive lung disease, and diagnosis of sleep apnea. †Job characteristics are not mutually exclusive. Categories were derived from combining related items that are delineated in the Appendix.

differences when true differences may have existed in some cases; however, the point estimates for the OR of work disability were generally consistent with the hypothesis that more cognitively related functions might be related to a increased risk of work disability while more physically active functions might be related to a decreased risk. Of note, our findings when analyzing only the subset of patients with confirmed OSA had even wider confidence intervals and fewer statistically significant associations. Because the point estimates of the ORs were similar in most cases to those estimates made when all currently employed patients with suspected OSA were analyzed, these wider confidence intervals may have been a reflection of the smaller statistical power expected from a smaller sample size. However, we must be careful not to overstate our conclusions here, and further research is clearly necessary. Nonetheless, we believe that our findings related to job performance characteristics at least provoke interesting questions and hypothesis. For example, it may be intuitively appealing to imagine that work that requires more mental acuity or is more sedentary in its nature may be more impaired by EDS while work which is more physically active or interactive may be relatively less hampered by EDS. Alternatively, work which presents more potential for physical danger may stimulate increased attention or vigilance that, in turn, allows workers to overcome somnolence.

We must acknowledge certain limitations of our study. Firstly, our sample is based on a referral to a tertiary care center and as such is not population based. We also did not have information to adjust for the potential confounders of race, educational attainment, or cardiovascular or neurologic comorbidities. Additionally, the size of our sample has limited our statistical power. As such, many of our findings are suggestive but not statistically significant. With respect to many job performance characteristics for example, we believe our analysis should be viewed as exploratory in nature. Certainly, when the point estimate of effect is elevated but the confidence intervals are wide and thus included the no effect level, these results do *not exclude* an association with work disability. Next, we must note that our univariate analyses have not always met the standard cut-off for statistical significance. However, it appears that negative confounders such as the older age of patients with OSA contributed to the fact that our results achieved statistical significance in multivariate analyses. Given the relative dearth of research in this area, it is provocative that we did find several significant associations despite the relatively small study size. Furthermore, we feel that many other findings, although not conclusive at the standard threshold of 95% confidence, are provocative and will help to inform future research questions.

In summary, our results provide some of the first evidence to confirm the suspicion that OSA contributes to work disability. Furthermore, we found that some job characteristics were more likely to be associated with work disability or work duty modification than others, although our results here should be viewed primarily as hypothesis generating rather than conclusive. We hope that our findings will highlight to employers the importance of OSA in the workplace so they will encourage their employees to be screened for OSA, particularly in situations of decreased productivity associated with excessive daytime somnolence. Given the high prevalence of OSA and the fact that the majority of cases are thought to be undiagnosed, the fact that OSA appears to be associated with work disability should be of interest to both employers and clinicians concerned about their patients' livelihood.

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APPENDIX—Work Disability and Sleep Problem Survey Items

A. Recent Work Disability Items (Past 4 Weeks)

If Employed Full or Part-Time, Answer the Following:

<u>Over the past 4 weeks</u>:

How many full work days in the past 4 weeks did you miss because of sleep problems? _____ (0-28)

On how many work days in the past 4 weeks were you late for work because of sleep problems? _____ (0-28)

On how many work days in the past 4 weeks did you leave work early because of sleep problems? _____ (0-28)

In the last 4 weeks, on how many days or shifts have you fallen asleep on the job at least once? _____ (0-28)

Over the past 4 weeks, how effective would you rate yourself at work?
(100% is fully effective, and 0% is not effective at all) _____ %

B. Longer-Term Work Duty Modification Items: Change in Job Pay or Responsibilities (Past 5 Years)

In the past 5 years, have you done any of the following *because of your sleep problems*:

	Please circle best answer:		
Taken pay cut?	Yes	No	No job for 5 years
Missed a promotion?	Yes	No	No job for 5 years
Changed your job schedule?	Yes	No	No job for 5 years
Changed your job duties?	Yes	No	No job for 5 years
Changed your job or employers?	Yes	No	No job for 5 years

C. Job performance characteristics with potential relevance to sleep problems

On your current or most recent job, are you required to do any of the following? Please circle best answer:

Shift work that periodically changes your sleep schedule (day to evening, or night to day)	Yes	No
Read printed text or instructions?	Yes	No
Read a visual display screen or terminal?	Yes	No
Carry out precise measurements or calculations? (for example, surveying or bookkeeping)	Yes	No
Perform fine hand movements? (for example, typing or musical instruments)	Yes	No
Operate light equipment (for example, a hand-saw or power tools)	Yes	No
Operate heavy equipment (for example, a truck, crane or bus)	Yes	No
Drive a motorized vehicle (for example a car or fork-lift)	Yes	No
Work with other heated materials? (for example, hot glues or welding)	Yes	No
Work with heated food production? (for example, stove top or oven)	Yes	No
Deal with the public, by telephone	Yes	No
Deal with the public, face to face	Yes	No
Supervise other employees?	Yes	No