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*Sleepiness, Driving, and Accidents*

# Sleep-Disordered Breathing and Motor Vehicle Accidents in a Population-Based Sample of Employed Adults

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**Summary:** Studies have consistently shown that sleep apnea patients have high accident rates, but the generalizability of the association beyond clinic populations has been questioned. The goal of this investigation was to determine if unrecognized sleep-disordered breathing in the general population, ranging from mild to severe, is associated with motor vehicle accidents. The sample comprised 913 employed adults enrolled in an ongoing study of the natural history of sleep-disordered breathing. Sleep-disordered breathing status was determined by overnight in-laboratory polysomnography and motor vehicle accident (MVA) history was obtained from a statewide data base of all traffic violations and accidents from 1988 to 1993. Men with five or more apneas and hypopneas per hour of sleep [apnea-plus-hypopnea index (AHI) >5], compared to those without sleep-disordered breathing, were significantly more likely to have at least one accident in 5 years (adjusted odds ratio = 3.4 for habitual snorers, 4.2 for AHI 5–15, and 3.4 for AHI >15). Men and women combined with AHI >15 (vs. no sleep-disordered breathing) were significantly more likely to have multiple accidents in 5 years (odds ratio = 7.3). These results, free of clinic selection bias, indicate that unrecognized sleep-disordered breathing in the general population is linked to motor vehicle accident occurrence. If the association is causal, unrecognized sleep-disordered breathing may account for a significant proportion of motor vehicle accidents. **Key Words:** Sleep apnea—Sleep disorders—Epidemiology—Sleep—Accidents—Sleep-disordered breathing.

Sleep disorders that compromise daytime performance may account for a substantial portion of sleep-related motor vehicle accidents (MVAs) (1–5). Sleep-disordered breathing (SDB), a condition strongly linked with excessive daytime sleepiness, is of particular concern because its prevalence in adults is high (6). Furthermore, most people with SDB have not been diagnosed or treated (7).

Several studies have shown that patients with clinically diagnosed SDB, i.e. sleep apnea syndrome, perform poorly on driving simulation tests (8–10) and tend to have an accident rate between two and seven times higher than patients without sleep apnea syndrome (1,11–14). Most of these studies relied on patients' recall of accident history, which may be biased, but similar findings have been reported from two studies with an objective measure of accident history (1,12). In a recent study, Marburg researchers found the accident rate of sleep apnea patients decreased signficantly after treatment for 1 year with nCPAP (15).

The clinic-based findings have consistently indicated that SDB is a risk factor for MVAs and have provided useful information for clinical assessment of patients' driving risks. However, small sample sizes and potential biases, including self-selection or referral of patients with severe daytime performance deficits and unknown truthfulness in admitting to previous accidents, preclude generalization of the existing study findings beyond clinic settings. The goal of this investigation was to determine the risk of MVAs associated with unrecognized SDB, particularly in the severity range of mild to moderate, where prevalence is particularly high.

## METHODS

In this cross-sectional study, data from 5-year MVA records and polysomnography of 913 participants in a

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population-based study of the natural history of SDB were analyzed.

The sample comprised licensed motor vehicle drivers, ages 30–60, who had completed an overnight study protocol as part of the Wisconsin Sleep Cohort Study. The protocol included in-laboratory polysomnography to assess SDB and an interview with questions on driving habits, perceived general sleepiness, and the occurrence of situation sleepiness. The sample construction has been previously described (6); inclusion criteria for this investigation were a good quality polysomnographic recording of at least 4 hours of sleep and at least one period of rapid eye movement (REM) sleep, possession of a driver's license, and a self-report of driving at least 1,000 miles per year. Out of the total number of individuals who had completed the overnight study protocol at the time of this investigation (n = 964), a total of 51 was excluded due to: unacceptable polysomnographic recordings (n = 17), self-report of driving less than 1000 miles per year (n = 26) , no driver's license and self-report of no driving (n = 6), and self-reported driving but no driver's license (n = 2).

The data for this investigation included SDB status determined by self-reported snoring frequency and polysomnographic findings, state records of 5-year MVA history, driving characteristics, alcohol use, and self-reported occurrence of chronic daytime sleepiness. No data were available from drivers who had been involved in accidents on their perceived sleepiness at the time of the accident.

The polysomnography consisted of a standard montage of surface leads to record analog data on breathing during sleep. Sleep state was monitored by electroencephalography (EEG), electrooculography (EOG), and submental electromyography (EMG). Airflow was detected at the nares by end-tidal carbon dioxide (capnograph) and at the mouth by thermistry (ProTec thermocouple, ProTec, Woodinville, WA). Respiratory effort was measured by chest and abdominal excursions using calibrated inductance plethysmography (Respitrace, Ambulatory Monitoring, Ardsley, NY). Arterial oxygenation was recorded by finger-pulse oximetry (Omeda #3740, Omeda, Englewood, CO). The polysomnography records were manually scored using conventional criteria (16). Each 30-second epoch of the recordings was scored for sleep stage and presence of an apnea (absence of airflow for 10 seconds or more with either no respiratory effort or opposing chest and abdomen excursions indicating attempt to breathe against a closed airway) or hypopnea (reduction in respiratory effort with a ≥4% dip in oxygen saturation).

The total number of scored apneas and hypopneas, divided by the number of hours of sleep (apnea-plus-hypopnea index, AHI) was determined for each participant as the summary measure of SDB. For categorical analyses, AHI cutpoints at 5 and 15 were used.

Motor vehicle accident data for the sample were obtained from the Wisconsin Department of Transportation Accident Data Base. In Wisconsin, police or other law enforcement at the accident scene process the report; in the absence of police, drivers must file a report for any MVA in which there is property damage of $500 or more or if anyone is injured. The abstracted data consisted of information on all traffic violations and reported crashes for the 5-year period of November 1, 1988 through October 31, 1993. The entire procedure of identifying and linking accident records with the cohort data base was done electronically such that confidentiality was maintained. Linked files were temporary and could be accessed by one data analyst only. From the MVA history over the 5-year study period, we determined the number of crashes, fault, injury occurrence, and whether a citation for a motor vehicle violation was issued.

Because study participants were enrolled continuously during the 5-year period that data were available, the temporal relationships between the polysomnography and accident varied in the sample. All participants had at least 1 year of MVA history prior to study enrollment. In relation to the 5-year period of accident history, polysomnography was completed in year 2 by 21.5%, year 3 by 22%, year 4 by 30.2%, and year 5 by 20.8%.

Data were analyzed with SAS (17) and SUDAAN (18) software for descriptive statistics, contingency tables, and multiple logistic regression analysis of stratified samples. Odds ratios were estimated for having an accident history (single or multiple, at fault or not at fault) over the 5-year study period for drivers with SDB compared to those without SDB (i.e. not a habitual snorer and an AHI <5). The potential confounding effects and interactive effects of sex, age, miles driven, and alcohol consumption were assessed by addition of these variables singly and jointly in the regression models. The role of sleepiness as an explanatory factor was investigated in this manner. Sleepiness was also explored as an independent predictor of accident history. Significance of regression coefficients was determined by the Wald $\chi^2$ test. Two-tailed p values of 0.05 or less were considered statistically significant.

## RESULTS

Accident history and other characteristics of the sample are shown in Table 1. Participants were involved in a total of 227 motor vehicle crashes over the 5-year study period. Of the participants with a positive accident history, 13% had more than one crash during

**TABLE 1.** *Sample description; Sleep Cohort Study (n = 913)*

| Characteristic | |
|---|---|
| Age in years: mean, standard deviation | 45.1 (7.8) |
| Gender | |
| Men: n, % | 542 (59) |
| Women: n, % | 371 (41) |
| SDB status: n, % | |
| No SDB (AHI < 5, not habitual snorer) | 318 (35) |
| AHI < 5, habitual snorer | 374 (40) |
| AHI 5–15 | 133 (15) |
| AHI > 15 | 88 (10) |
| 5-year MVA history: n, % | |
| 1 MVA | 165 (18) |
| >1 MVA | 24 (3) |
| At fault for any MVA | 86 (9) |

SDB, sleep-disordered breathing; AHI, apnea-plus-hypopnea index; MVA, motor vehicle accident.

the 5-year period. There were no immediate fatalities from any of the crashes.

Odds ratios for having a positive accident history comparing people with SDB to those without SDB are shown in Table 2. Gender-specific odds ratios were adjusted for age and miles driven per year; odds ratios for the total sample were additionally adjusted for gender. Adjusting for usual alcohol consumption and education did not alter the odds ratios. Men with SDB, compared to those without SDB, had 3× the odds of having an accident in 5 years ($p < 0.001$). Odds ratios did not increase with SDB severity, and there were no associations for women. In contrast, the odds ratios for SDB and multiple crashes were positive for both men and women with SDB. Using the total sample and controlling for gender, the odds ratios were statistically significant. Overall, drivers with AHI >5 (vs. no SDB) were 4.6× more likely to have multiple crashes in a 5-year period. None of the associations was stronger when the accident history was restricted to crashes in which fault had been assigned to the participant.

We investigated hypersomnolence as a mechanism by which SDB might correlate with accident history. Several indicators of sleepiness were tested as explanatory variables, including perceived sleepiness (frequent excessive daytime sleepiness, not feeling rested regardless of amount of sleep time) and self-reported somnolent behavior (falling asleep or dozing while watching TV or at meetings, dozing while driving). For these variables, participants were coded as positive if they reported a frequency of often (at least 5× per month). Continuous variables were created from the Epworth Sleepiness Scale, a self-rating scale of the likelihood of dozing in several hypothetical situations and from the multiple sleep latency test (MSLT), an objective measure of the propensity to fall asleep (available on a subset of the sample; n = 453). Addition of the individual sleepiness variables did not substantially change the magnitude or the statistical significance of any of the odds ratios for SDB and accident history. We also investigated the possibility that drivers with a combination of sleepiness and SDB had the greatest likelihood of having a positive accident history. None of the interactions of SDB and sleepiness measures, however, was significant in predicting accident history.

Self-reported sleepiness, regardless of SDB status, was explored further as an independent predictor of accident history. None of the variables for perceived chronic sleepiness or sleepy behavior was significantly related to accident occurrence. Mean scores on the ESS did not differ significantly by accident history status. For men, MSLT scores were, on average, lower (indicating greater propensity to fall asleep) for those with MVAs than were the scores for men with no MVAs, but differences were not statistically significant (Table 3).

## DISCUSSION

This investigation has shown, for the first time, a link between polysomnographically determined SDB in the general population and objectively measured

**TABLE 2.** *Association of SDB and 5-year MVA history estimated by adjusted OR, 95% CI; Sleep Cohort Study, n = 913[a]*

| | Any MVA in 5 years | | | Mulitple MVA in 5 years | | |
|---|---|---|---|---|---|---|
| SDB category | Women OR (95% CI) | Men OR (95% CI) | Total OR (95% CI) | Women OR (95% CI) | Men OR (95% CI) | Total OR (95% CI) |
| No SDB | (Reference category) | | | | | |
| Habitual snorer, AHI < 5 | 0.9 (0.5, 1.6) | 3.4[b] (1.8, 6.9) | 1.5[b] (1.0, 2.4) | 3.3 (0.9, 12.0) | 2.2 (0.7, 7.0) | 2.9[b] (1.0, 8.6) |
| AHI 5–15 | 0.8 (0.3, 2.0) | 4.2[b] (1.6, 11.3) | 1.9 (0.9, 3.8) | 4.5 (0.8, 25.0) | 1.8 (0.2, 14.0) | 3.1 (0.8, 12.7) |
| AHI > 15 | 0.6 (0.2, 2.5) | 3.4[b] (1.4, 8.0) | 1.6 (0.8, 3.1) | 2.4 (0.2, 25.0) | 11.9[b] (1.1, >25) | 7.3[b] (1.8, >25) |

SDB, sleep-disordered breathing; MVA, motor vehicle accident; OR, odds ratio; CI, confidence interval; AHI, apnea-plus-hypopnea index.
[a] Gender specific OR adjusted for age and miles driven per year; OR for total sample adjusted for age, miles driven per year, and gender.
[b] $p > 0.05$.

**TABLE 3.** *Sleepiness by MSLT and MVA history status; Sleep Cohort Study (n = 453)*

| | MSLT score[ab] | |
|---|---|---|
| | Women mean (SE) | Men mean (SE) |
| No MVA | 9.3 (0.4) | 8.8 (0.3) |
| 1 MVA | 9.7 (0.8) | 7.9 (0.7) |
| >1 MVA | 9.1 (1.6) | 4.5 (2.7) |

MSLT, multiple sleep latency test; MVA, motor vehicle accident; SE, standard error.
[a] $p > 0.05$ for all comparisons.
[b] Sleep latency average over four trials.

MVA history. Compared to people without SDB, men who were habitual snorers or had an AHI >5 were at least 3× as likely to have had at least one accident, and men and women combined with AHI >15 were 7× more likely to have had multiple accidents in the study period. All associations were independent of age and average miles driven per year, and alcohol use, BMI, and education were ruled out as confounders. Surprisingly, the people with both SDB and self-reported sleepiness were not most likely to have an accident history; there was no evidence for an interaction of sleepiness with SDB. It is possible that error in measuring sleepiness by self-report precludes meaningful analysis of an explanatory role. Sleepiness is undoubtedly a constellation of distinct conditions, and our questions may lack adequate sensitivity and specificity to the aspect of sleepiness relevant to driving performance.

Our findings of an association of SDB and accident history, although based on the largest sample analyzed to date, must still be viewed with caution for several reasons. Although we accounted for factors that could potentially confound the association between SDB and accidents, there may be unrecognized factors that could lead to a spurious relationship. However, it is not likely that unknown factors could generate an odds ratio for SDB and accidents as high as 3.0. Of greater concern is the low study power due to the number of outcomes (a total of 165 participants had one accident and only 24 had multiple accidents). Consequently, the 95% confidence intervals for all the estimates, and particularly those for the risk of multiple accidents, are wide. If the true values of the odds ratios are at the lower end of the confidence intervals, the associations between SDB and accidents may be of little practical significance; on the other hand, if they are at the upper end, they may be so strong that they explain a large proportion of all accidents. The lack of precise point estimates also makes it difficult to determine if accident risk varies by SDB severity.

The study findings are based on state accident records. Missing from this analysis were trivial accidents (for which a state report is not mandatory) and any serious accidents in which drivers were able to evade police involvement. Drivers with a bad driving record who fear insurance problems or legal repercussions may be among those who fail to report an accident. It would be difficult to avoid police attention for accidents involving two cars or injuries, but it is possible that single-car crashes in remote areas could go unreported if the driver so desired. Sleepiness is thought to be a significant cause of one-car crashes in particular, so state report data may disproportionately miss accidents of people with SDB (14,19). If so, our analysis would underestimate the association between SDB, as well as sleepiness, with MVAs.

The lack of finding an association between SDB and accident history for women is puzzling. Even at the highest end of the 95% confidence interval, the odds ratio for women did not reach the estimate for men. It is possible women and men, at the same SDB severity level, differ in impairment relevant to driving performance. Alternatively, men and women may perceive internal cues to sleepiness differently. Data previously reported on our cohort showed that self-reported sleepiness was more prevalent in women compared to men (6). If men fail to perceive sleepiness while driving, they cannot take countermeasures and thus will be at higher risk for accidents. It is also possible that men and women do not differ in the perception of sleepiness that is hampering performance but that men keep on driving in spite of feeling sleepy. In general, risk-taking behavior and its health consequences are more common in men compared to women.

There are no obvious biases that would have caused an overestimation of the association between SDB and MVAs in our study. To the contrary, our use of a sample of employed people could cause an underestimation of the risk if driving impairment due to SDB has kept people out of the work force but does not keep them off the road. Furthermore, for some participants, up to 4 years of the 5-year accident report window occurred after the polysomnography; it is possible that those with SDB changed their driving habits. If these participants became more cautious or restricted their driving after being informed they had some "breathing pauses" during sleep (they were never told they had a disorder based on the study protocol), an underestimate of the true odds ratios would result.

Previous findings based on clinic samples have been questioned because self-selection of the most impaired drivers with SDB into clinics would overestimate the association of SDB and MVAs. However, our results, based on a sample free of clinic selection bias, were comparable in magnitude to those of clinic-based studies, indicating that impaired drivers with SDB are not overrepresented in clinic populations.

In a recent consensus statement and review on sleep apnea and driving risk, a committee of the American Thoracic Society concluded that although previous study findings indicate that some people with sleep apnea should not drive, there is no compelling evidence that apneic activity in itself increases driving risk (20). In the absence of firm data, the committee recommended that pulmonary specialists should generally warn sleep apnea patients of the potential dangers of driving while sleepy or inattentive but that decisions on driving restrictions be made on a case-by-case basis. The committee recommended that efforts be directed at determining factors such as sleepiness for targeting the sleep apnea patients at greatest risk for accidents.

Our findings suggest that the committee's recommendations would not substantially lower the number of accidents associated with SDB for two reasons. We found no evidence that perceived sleepiness identified those at greatest risk for MVAs among people with SDB, so a general warning to patients about driving "while sleepy" may not be effective. Our findings provide support for the recommendations of Findley et al. (21), whereby sleep apnea patients should be warned about the risks of driving with untreated sleep apnea, regardless of perceived sleepiness. Secondly, the comparability of our findings with those of clinic-based studies indicates that there is not a natural screening phenomenon operating whereby most of the accident-prone drivers with SDB get referred into medical care. Thus, even if a clinic assessment with good sensitivity and specificity for high accident risk among SDB patients were developed, this approach would not reach most of the people at risk, i.e. those with unrecognized SDB in the general population.

Weighing the costs and benefits of clinic-based as well as population-based intervention in regard to impaired driving associated with SDB is particularly complex and has already created controversy. Unlike other hypothesized outcomes of SDB, e.g. hypertension, MVAs put the general public at risk of increased injury and death. In considering the importance of even a small link between SDB and increased MVAs, the general public may, in self-defense, be less willing to take chances on letting people with untreated SDB drive, even though most will not cause an accident. From the individual SDB sufferer's perspective, however, mandatory treatment or restriction of driving privileges has psychological, social, and economic consequences. With conflicting interests and serious legal issues at stake, solid data on the role of SDB in increasing MVAs is imperative before interventions and public policy can be formulated. Until this point is reached, however, our findings provide support for conservative interventions with low personal cost. Specifically, driving-risk warnings, both in clinical settings and public awareness programs, should alert people with symptoms of sleep-disordered breathing (e.g. loud, habitual snoring and breathing pauses) that they may be at increased risk of accidents, regardless of whether or not they feel sleepy. We conclude that morbidity, mortality, and property damage from MVAs are likely to be an important part of the total cost of untreated SDB in the general population and that more attention to SDB as a risk factor for motor vehicle accidents is needed.

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