# THE ASSOCIATION BETWEEN SLEEP APNEA AND THE RISK OF TRAFFIC ACCIDENTS

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## ABSTRACT

***Background and Methods*** Drowsiness and lack of concentration may contribute to traffic accidents. We conducted a case–control study of the relation between sleep apnea and the risk of traffic accidents. The case patients were 102 drivers who received emergency treatment at hospitals in Burgos or Santander, Spain, after highway traffic accidents between April and December 1995. The controls were 152 patients randomly selected from primary care centers in the same cities and matched with the case patients for age and sex. Respiratory polygraphy was used to screen the patients for sleep apnea at home, and conventional polysomnography was used to confirm the diagnosis. The apnea–hypopnea index (the total number of episodes of apnea and hypopnea divided by the number of hours of sleep) was calculated for each participant.

***Results*** The mean age of the participants was 44 years; 77 percent were men. As compared with those without sleep apnea, patients with an apnea–hypopnea index of 10 or higher had an odds ratio of 6.3 (95 percent confidence interval, 2.4 to 16.2) for having a traffic accident. This relation remained significant after adjustment for potential confounders, such as alcohol consumption, visual-refraction disorders, body-mass index, years of driving, age, history with respect to traffic accidents, use of medications causing drowsiness, and sleep schedule. Among subjects with an apnea–hypopnea index of 10 or more, the risk of an accident was higher among those who had consumed alcohol on the day of the accident than among those who had not.

***Conclusions*** There is a strong association between sleep apnea, as measured by the apnea–hypopnea index, and the risk of traffic accidents. (N Engl J Med 1999;340:847-51.)



IN Spain, the annual cost of traffic accidents is equivalent to 1 to 2 percent of the gross national product.[1] Obstructive sleep apnea syndrome is estimated to affect 4 percent of men and 2 percent of women in middle age.[2] It is characterized by repeated collapses of the upper airway during sleep, resulting in nocturnal hypoxemia and fragmented sleep. The associated cerebral dysfunction may be manifested as abnormal daytime drowsiness and lack of concentration. Drowsiness and lack of concentration are frequent causes of traffic accidents.[3,4]

The National Commission on Sleep Disorders Research in the United States estimated the overall cost of accidents related to drowsiness in 1988 as $43 billion to $56 billion. The commission found that drowsiness may be involved in 36 percent of all fatal traffic accidents and in 42 to 54 percent of all accidents.[5]

Earlier studies of the effect of sleep apnea syndrome on driving ability, in which 30-to-90-minute tests in driving simulators were used, showed reductions in concentration, increased reaction times, and recurrent periods of sleep.[6,7] Retrospective analyses found that people with sleep apnea had rates of traffic accidents that were two to three times as high as those among people without sleep apnea or in the general population.[8-10] We conducted a case–control study of the association between sleep apnea and the risk of traffic accidents.

## METHODS

### Subjects

Eligible case patients were all drivers 30 to 70 years of age who received emergency treatment at General Yagüe Hospital in Burgos or the Marqués de Valdecilla University Hospital in Santander as a result of traffic accidents on interurban highways in Spain from April through December 1995. A maximal interval of two months was allowed between the date of the accident and study entry.

Control subjects were randomly selected from among patients in three primary health care centers in Burgos and three in Santander. Patients with known chronic illnesses and those who had been involved in a traffic accident in the previous two months were excluded from the control group. One or two controls were selected for each case patient and were matched individually for age (within two years) and sex.

The following exclusion criteria applied to both case patients and controls: illness explicitly defined by law as rendering a person incapable of driving a motor vehicle; neurologic or psychiatric sequelae of the accident that were likely to interfere with or impede participation in the study; injuries to the brain or thorax or to the spinal cord that had resulted from the accident and that might produce an abnormal ventilatory pattern; tracheotomy; legal proceedings due to suspected or confirmed excessive alcohol intake; use of illicit drugs such as heroin or cocaine on the day of the accident; a life expectancy of less than one year due to cancer or other disease; and social or other problems that would impede the use of polygraphy in the home, unless the patient agreed to

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undergo polygraphic examination in the hospital. Patients with a previous diagnosis of obstructive sleep apnea according to polysomnography were eligible; home screening with respiratory polygraphy was not performed in these patients. No patients who had been admitted to intensive care were included. However, three patients with fractures or other injuries were studied in their hospital beds.

### Evaluation of Subjects

The subjects completed a general questionnaire regarding personal habits, diseases, and use of medications. Another questionnaire for patients who had been in traffic accidents focused on the presence or absence of drowsiness at the time of the accident and on possible causes of drowsiness unrelated to sleep apnea, such as alcohol intake, lack of sleep, and fatigue. There was also a questionnaire on symptoms and signs of sleep apnea, including daytime drowsiness as measured by the Epworth Sleepiness Scale, an eight-item questionnaire designed to evaluate the subject's likelihood of falling asleep in common situations.[11] Scores range from 0 (least sleepy) to 24 (most sleepy). The validity of the scale has been established.[12] The questionnaires were administered by trained interviewers, usually at the subject's home. In addition, a questionnaire on snoring focused on the presence or absence of habitual snoring and its intensity. This questionnaire has a reported sensitivity of 94 percent and a specificity of 58 percent.[13]

Nocturnal respiratory polygraphy was performed at home with the Apnoscreen II system (CNS-Jaeger), which produced a computerized recording of variations in arterial oxygen saturation, heart rate (measured by electrocardiography), oronasal air flow (measured by thermistors), thoracic–abdominal movement (measured by thoracic–abdominal belts), body position, and intensity of snoring. Conventional polysomnography was performed whenever a case patient or control subject had abnormal findings on respiratory polygraphy or when the diagnosis of sleep apnea was suspected. The maximal allowable interval between respiratory polygraphy and polysomnography was two months.

The studies were approved by our institutional committees on investigation. Written informed consent was obtained from all the participants.

### Quality Control

To evaluate the reliability of the data, the results from a random sample of 50 questionnaires were compared with the results from 50 other interviews, conducted by different interviewers. No significant differences were found.

The respiratory polygraphic results were assessed manually by two investigators (one at each center) according to criteria established in validation studies.[14] A total number of respiratory events (apnea or hypopnea) per hour below 8 indicated negative results (i.e., the absence of sleep apnea), 8 to 24 events per hour indicated indeterminate results (possible sleep apnea), and more than 24 indicated positive results (definite sleep apnea).

The rate of agreement among observers in the analysis of the respiratory polygraphic results was studied by exchange and blind manual reanalysis of 105 studies; the rate of agreement was 95 percent, with a kappa coefficient of 86 percent (95 percent confidence interval, 78 to 93 percent).

### Conventional Polysomnography

The presence or absence of sleep apnea was determined on the basis of the polysomnographic record of data from a complete night's sleep. Analysis was carried out by two experienced neurophysiologists who used standard criteria.[15] Hypopnea was defined according to the recommendations of the Spanish Society of Pneumology and Thoracic Surgery as a substantial decrease in oronasal air flow with desaturation (a decrease of at least 4 percent in saturation), arousal, or both.[16] An apnea–hypopnea index, defined as the total number of episodes of apnea and hypopnea divided by the number of hours of sleep, was calculated for each participant. Polysomnograms were considered positive when the apnea–hypopnea index was five or more.

### Statistical Analysis

Qualitative variables were expressed as percentages, and quantitative variables as means ±SD. A P value of 0.05 or less in a two-sided test was considered to indicate statistical significance, and 95 percent confidence intervals were calculated for results.

Percentages were compared with use of the chi-square test, and means with Student's t-test or analysis of variance for more than two variables; the Scheffé test was used for multiple comparison of means in cases of significant results by analysis of variance. Nonparametric tests were used when the conditions for parametric tests were not fulfilled.[17] The logistic-regression model was used to adjust the data in the study of the relation between the dependent variable, whether a traffic accident had occurred (yes or no), and the independent variable, abnormal or normal apnea–hypopnea index. In some analyses, the apnea–hypopnea index was divided at 5, 10, and 15 to create subgroups. Odds ratios were adjusted for the following variables: use or nonuse of alcohol, presence or absence of visual-refraction disorders, body-mass index (the weight in kilograms divided by the square of the height in meters), years of driving, use or nonuse of medications causing drowsiness, work and sleep schedule (work during the day and sleep at night or some other pattern), kilometers driven per year, and presence or absence of arterial hypertension. We examined the effects of the inclusion or exclusion of variables in the model.[18] We used the Enter program of the Statistical Package for the Social Sciences to introduce variables, with a maximum of 20 iterations.[19]

## RESULTS

We analyzed data on 254 subjects: 102 case patients (40 percent) and 152 controls (60 percent). Of 363 people who were potentially eligible, 41 were excluded: 15 who lived outside the province, 14 who had had urban accidents, 8 who were outside the age limits, 1 who lacked a driver's license, and 3 for other reasons. In addition, 9 patients who were originally included had to be excluded because of a change of residence or repeated absence from home, and 59 declined to participate. The overall participation rate was 79 percent — 71 percent for case patients and 89 percent for controls.

Of the participants, 196 (77 percent) were men and 58 (23 percent) were women; the mean (±SD) age was 44±10 years. Comparison of those who participated and those who did not showed no significant differences in terms of age, sex, or city of origin. To account for possible bias in the results, we conducted additional analyses that assumed the least favorable circumstances in the calculation of the odds ratio — that is, that all eligible subjects who either discontinued the study or declined to participate would have had a negative polysomnographic result.

The initial comparisons of case patients and controls in terms of different variables (e.g., age, sex, and body-mass index) showed no significant differences, except in the number of kilometers driven per year, which was higher for case patients than for controls (Table 1). There were no significant differences in terms of the coexisting conditions we examined, except for hypertension (present in 15 percent of case patients and 6 percent of controls, P=0.02).

**TABLE 1.** CHARACTERISTICS OF CASE PATIENTS AND CONTROLS.*

| CHARACTERISTIC | CASE PATIENTS (N=102) | CONTROLS (N=152) |
|---|---|---|
| Age (yr) | 44±9 | 43±9 |
| Body-mass index | 25.9±3.5 | 25.6±3.2 |
| Years of driving | 20±10 | 19±8 |
| Kilometers driven per year | 24,011±22,359 | 16,978±18,760† |
| Daytime work schedule (%) | 73.5 | 69 |
| Nighttime sleep schedule (%) | 93 | 88 |
| Smokers (%)‡ | 50 | 56 |
| Prior traffic accident (%)§ | 19 | 18 |
| No loss of consciousness (%) | 96 | 99 |
| No obstructive sleep apnea, narcolepsy, or restless-leg syndrome (%) | 99 | 100 |
| Visual-refraction disorder (%) | 62 | 52 |
| No psychiatric disorders (%) | 96 | 98 |
| No medications causing drowsiness (%) | 94 | 96 |
| Arterial hypertension (%) | 15 | 6¶ |
| Alcohol consumption (%)‖ | 89 | 86 |

*Plus–minus values are means ±SD. The body-mass index is the weight in kilograms divided by the square of the height in meters.

†P=0.007.

‡Smokers were patients who said they were smokers when the study was performed.

§Persons who had ever been involved in a traffic accident as a licensed driver were excluded as controls.

¶P=0.02.

‖Patients who said they drank any amount of alcohol at least once a week when the study was performed were included.

**TABLE 2.** RELATION BETWEEN SLEEP APNEA AND TRAFFIC ACCIDENTS.*

| APNEA–HYPOPNEA INDEX† | CASE PATIENTS (N=102) | CONTROLS (N=152) | UNADJUSTED OR (95% CI) | ADJUSTED OR (95% CI)‡ |
|---|---|---|---|---|
| | no. of patients (%) | | | |
| ≥5 | 29 (28.4) | 7 (4.6) | 8.2 (3.4–19.6) | 11.1 (4.0–30.5) |
| ≥10 | 21 (20.6) | 6 (3.9) | 6.3 (2.4–16.2) | 7.2 (2.4–21.8) |
| ≥15 | 17 (16.7) | 5 (3.3) | 5.8 (2.1–16.5) | 8.1 (2.4–26.5) |

*OR denotes odds ratio, and CI confidence interval.

†The three categories of the apnea–hypopnea index are not mutually exclusive, because the number of cases in each category was not high enough to make a proper analysis. It was not possible to calculate the adjusted odds ratio when all lost case patients (i.e., those who were eligible but did not enroll or complete the study) were considered to have negative polygraphic studies, because most of them did not complete the initial questionnaire.

‡The logistic-regression model for the adjusted odds ratio considered the presence or absence of an accident as the dependent variable and the apnea–hypopnea index as the independent variable; potential confounders were entered, such as alcohol consumption, visual-refraction disorders, body-mass index, years of driving, age, involvement in previous accidents, use of medication causing drowsiness, smoking, work and sleep schedule, kilometers driven per year, and coexisting conditions (including psychiatric disorders and arterial hypertension). The apnea–hypopnea scores ≥5, ≥10, and ≥15 are all based on a single continuous index divided at three different levels.

The unadjusted and adjusted odds ratios for having a traffic accident were calculated with use of different cutoff points (an apnea–hypopnea index of ≥5, ≥10, or ≥15) in order to assess the sensitivity of the analysis to the cutoff point (Table 2). The unadjusted odds ratio associated with an apnea–hypopnea index of 10 or more was 6.3 (95 percent confidence interval, 2.4 to 16.2). The adjusted odds ratio associated with an apnea–hypopnea index of 10 or more was 7.2 (95 percent confidence interval, 2.4 to 21.8). When all case patients who did not enroll or complete the study were assumed to have had negative results on respiratory polygraphic studies, the odds ratio associated with an apnea–hypopnea index of 10 or more was 4.1 (95 percent confidence interval, 2.1 to 17.4).

For patients who had had accidents, the possible influence of circumstances specific to the day of the accident was also analyzed. No significant differences were found between groups (data not shown). Factors examined included fatigue (having driven for two or more hours when the accident happened), a good previous night's rest, and loss of consciousness just before the accident.

Alcohol consumption was also evaluated by direct questioning of case patients.[20] Drivers with an apnea–hypopnea index of 10 or higher had higher alcohol consumption on the day of the accident, but the difference was not significant (8.7 g for an apnea–hypopnea index of ≥10 vs. 6.1 g for an index of <10, P=0.39). When we restricted our analysis to patients who had consumed alcohol on the day of the accident, those who had an apnea–hypopnea index of 10 or more had an odds ratio of 11.2 for having a traffic accident (95 percent confidence interval, 3.8 to 32.9), as compared with patients with an apnea–hypopnea index below 10. When we made a similar comparison for those who had not consumed alcohol, the odds ratio was 4.0 (95 percent confidence interval, 1.3 to 12.0) (Table 3).

The mean score on the Epworth Sleepiness Scale for case patients was 5.9, as compared with 5.7 for controls (P=0.67). Patients with an apnea–hypopnea index of 5 or more had a mean score of 8.0 on the Epworth scale, and those with an index below 5 had a mean score of 7.5 (P=0.67). The results on the snoring scale were similar; 55 percent of the case patients and 53 percent of the controls were snorers (P=0.89).

Case patients who reported drowsiness just be-

**TABLE 3.** RISK OF A TRAFFIC ACCIDENT ACCORDING TO THE PRESENCE OR ABSENCE OF SLEEP APNEA AND ALCOHOL INTAKE ON THE DAY OF THE ACCIDENT.

| VARIABLE | APNEA–HYPOPNEA INDEX ≥10 | APNEA–HYPOPNEA INDEX <10 | OR (95% CI)* |
|---|---|---|---|
| Case patients | | | |
| Alcohol consumed on day of accident | 11 | 24 | 11.2 (3.8–32.9) |
| No alcohol consumed on day of accident | 8 | 49 | 4.0 (1.3–12.0) |
| Controls | 6 | 146 | 1.0 |

*OR denotes odds ratio, and CI confidence interval. Odds ratios have not been adjusted for other variables.

fore the accident had a mean apnea–hypopnea index of 24±25, whereas those who reported being alert had a mean apnea–hypopnea index of 13.8±12 ($P=0.05$).

## DISCUSSION

We found a strong association between sleep apnea, as measured by the apnea–hypopnea index, and traffic accidents in both unadjusted and adjusted analyses. Patients with sleep apnea, as confirmed by polysomnography, had a greater probability of having a traffic accident than patients without sleep apnea. This relation persisted even after we accounted for the higher rate of nonparticipation or study discontinuation among case patients than among eligible controls. An important confounding variable (alcohol consumption) is unlikely to have been analyzed adequately on the basis of the information obtained by a questionnaire such as ours. However, we found that the consumption of alcohol on the day of the accident (even small quantities) had an important modifying effect, amplifying the relation between sleep apnea and traffic accidents. It should be noted that we excluded drivers who were subject to legal proceedings for suspected alcohol consumption.

There may be other confounding variables, apart from those we identified, which could lead to a spurious finding of a relation between sleep apnea and traffic accidents. Such factors, however, are unlikely to explain the strong associations we found.

Findley et al.[8] reported that there were more automobile accidents among 29 patients with confirmed sleep apnea than among 35 subjects without sleep apnea. Another study[10] found that patients with sleep apnea had more accidents than those without sleep apnea (adjusted odds ratio, 2.99); that study was based on 253 subjects who underwent polysomnography for various suspected sleep disorders. These studies differ from ours in that information about accidents was obtained with a questionnaire, introducing the possibility of recall bias. The studies also did not distinguish between urban and highway accidents. In highway driving, the longer distances and monotonous routine may contribute to drowsiness, and the higher velocity may increase the danger to drivers.

Young et al.[21] reported similar results, using objective methods to identify accidents and avoiding recall bias. Drivers with an apnea–hypopnea index above 15 were significantly more likely to have multiple accidents in a period of five years (odds ratio, 7.3) than drivers without sleep-disordered breathing (apnea–hypopnea index of less than 5). Their information was obtained from a data base maintained by the Wisconsin Department of Transportation, and ours from drivers involved in highway traffic accidents who received emergency services at hospitals in Burgos and Santander, Spain. These differences may partially explain the higher odds ratios in our study.

As in previous studies,[2] the Epworth scale[11,12] failed to identify subjects with a higher risk of accidents. We agree with others that drowsiness represents a constellation of different conditions. The questions from which the Epworth scale is derived may lack adequate sensitivity and specificity with regard to driving performance.[21] Nevertheless, in our study, drivers who reported drowsiness before the accident had a higher apnea–hypopnea index than those who reported being alert, although these differences were not significant.

One potential limitation of our study is that the control group may not have been representative of the general population. However, the study groups were similar, differing only in the prevalence of arterial hypertension and the number of kilometers driven per year. Moreover, our results are similar in magnitude to those of Young et al.[21] in their population-based study.

Other potentially important factors go beyond the scope of our study but should be mentioned. These include the type and seriousness of the accident, the number of vehicles involved, whether the vehicle leaves the road, and the type of collision. Our exclusion of more serious accidents suggests that the relation between accidents and sleep apnea may be even stronger than we found.

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## APPENDIX

Additional members of the Cooperative Group Burgos–Santander were I. Arroyo, J.I. García, and I. Quintana, General Yaguë Hospital, Burgos, Spain, and R. Carpizo, J. Cifrián, M.M. García, and R. Golpe, Marqués de Valdecilla University Hospital, Santander, Spain.

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