Habitually Sleepy Drivers Have a High Frequency of Automobile Crashes Associated with Respiratory Disorders during Sleep

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Sleepiness is a common cause of traffic crashes with a cost of billions of dollars per year. A recent study has found that 2 to 3% of drivers are habitually sleepy while driving. However, there has not been a controlled study to define the characteristics, driving performance, or automobile crash rate of habitually sleepy drivers. The prevalence of respiratory disorders during sleep, and whether these respiratory disorders contribute to the increased automobile crash frequency, is unknown in habitually sleepy drivers. We interviewed 4,002 randomly selected drivers to define the prevalence of drivers who are habitually sleepy while driving. We studied the habitually sleepy drivers and an age- and sex-matched control group of drivers. These studies included reporting of daytime sleepiness, automobile crashes, driving performance and sleep studies. Of the 4,002 drivers interviewed, 145 (3.6%, confidence interval [CI] = 3.1 to 4.3) were habitually sleepy while driving. The habitually sleepy drivers reported a significantly higher frequency of auto crashes than control subjects (the adjusted odds ratio [OR] was 13.3, CI = 4.1 to 43). The habitually sleepy drivers had a significantly higher prevalence of respiratory sleep disorders than control subjects. For a total respiratory events index (apneas, hypopneas, and other respiratory effort–related arousals) ⩾ 15 the adjusted OR was 6.0, CI = 1.1 to 32. In the habitually sleepy drivers group, the frequency of sleep apnea (apnea–hypopnea index) between subjects with or without auto crashes was not statistically different. However, if we consider total respiratory events index, this frequency of respiratory sleep disorders was significantly higher in subjects with automobile crashes (the adjusted OR for a total respiratory event index ⩾ 15 was 8.5, CI = 1.2 to 59). Habitually sleepy drivers are a large group of drivers (1 of 30 drivers) who are involved in several fold more automobile crashes than control subjects. As these excess auto crashes can be explained in part by the presence of respiratory disorders during sleep, which are treatable, many automobile crashes in these sleepy drivers may be preventable. Our findings suggest that asking about excessive sleepiness while driving may better predict which subjects with breathing disorders during sleep have crashes than asking about overall sleepiness.

Automobile crashes are a frequent cause of serious injury and death. Sleepiness is considered a common cause of traffic crashes with a cost of crashes resulting from sleepiness of billions of dollars per year (1, 2). Respiratory disorders during sleep, such as sleep apnea, are common causes of excessive sleepiness (3) and of an increased risk of automobile crashes (4–8). In these disorders, sleep is disrupted by partial or total cessation of breathing. Sleep may be disrupted by partial obstruction (hypopneas), total obstruction (apneas), or very subtle upper airway obstructions that require measurement of esophageal pressure to detect (9). This disrupted sleep leaves patients fatigued and excessively sleepy during the day.

A recent study has found that 2 to 3% of drivers are habitually sleepy while driving (10). However, there has not been a controlled study to define the characteristics, daytime performance, and automobile crash rate of habitually sleepy drivers. No previous study has determined the prevalence of respiratory disorders during sleep in these sleepy drivers, and if respiratory disorders during sleep contribute to the increased automobile crash frequency of these sleepy drivers.

Our study addresses these questions: (*1*) What is the prevalence of habitually sleepy drivers in a large population? (*2*) What are the characteristics of these habitually sleepy drivers? (*3*) Do these sleepy drivers have more auto crashes than control subjects? (*4*) What is the prevalence of respiratory disorders during sleep in habitually sleepy drivers? (*5*) Could the respiratory disorders during sleep explain the automobile crash rate in habitually sleepy drivers?

METHODS

Stage 1: Telephone Interview of a Random Sample of the Population

Subjects were randomly chosen from the telephone book in a geographical area of 184,434 inhabitants, including the western Spanish city of Cáceres. This area consists of 80 towns divided into 16 administrative regions. Fifty percent of the population lived in towns with less than 20,000 inhabitants and they were considered a rural population. The sample size was determined from a prevalence of habitual sleepiness when driving of 2.5% (95% confidence interval [CI] = 1.6 to 3.9). This prevalence comes from a preliminary study (11) of 801 subjects. In the present study the number of interviews to perform was proportionally distributed to the population size of the 16 administrative regions. Two professional pollsters conducted the telephone interviews. Only households were selected and if there was no answer then a new number was chosen at random. The interviews were performed between 6:00 P.M. and 10:00 P.M. in order to obtain less interference with the working schedule. The interviews were offered to any and all the members of the household who had a driving license and who regularly drove an automobile or truck (motorcycles were excluded). The interview contains 26 questions including: anthropometric data, the driver's occupation, years of driving, number of hours driven per month, frequency and intensity of snoring, presence of habitual or sporadic sleepiness when driving, the number of auto crashes during the last 5 yr, the number of auto crashes due to falling asleep at the wheel, measurement of subjective daytime sleepiness, and number of hours of sleep per night. We excluded 13 questionnaires which, in the interviewer's opinion, were answered untruthfully.

The questionnaire of Stage 1 was used to identify the prevalence of habitually sleepy drivers and to analyze the possible bias between the drivers who agreed to be interviewed in Stage 2 and the drivers who did not agree to an interview in Stage 2.

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Using 45 subjects, a concordance study was done between the two professional interviewers and a physician member of the project for the definition of a habitually sleepy driver. The kappa index between the physician and both interviewers was 0.81 and 0.85, respectively.

Stage 2: Cases and Control Studies

This stage consisted of an extensive personal interview carried out in habitually sleepy drivers and a control group of age- and sex-matched drivers, chosen at random from the 3,857 drivers, who were not habitually sleepy while driving. All habitually sleepy drivers and control subjects were invited to have further studies, including: (*1*) a detailed series of questions done in person by a trained interviewer, which repeated and amplified the questionnaire in Stage 1, including questions about personal habits, illnesses, tobacco smoking, alcohol drinking, and drug usage. The questionnaire also has symptoms and signs of sleep apnea and other diseases causing sleepiness, a subjective measurement of sleepiness (Epworth Sleepiness Scale) (12), frequency and intensity of snoring (13), work and sleep schedule, and frequency of insomnia. They were also asked the number of hours slept per night, whether they were professional drivers, the number of hours driven per month, if they have habitual or sporadic sleepiness when driving, the presence of nodding-off at the wheel, number of auto crashes in the last 5 yr, and the automobile crashes caused by falling asleep at the wheel; (*2*) measurement of height, weight, neck circumference, awake oxyhemoglobin saturation, and spirometry; (*3*) testing on Steer Clear (14), a performance test simulating monotonous highway driving; and (*4*) nocturnal polysomnography measuring electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), oxyhemoglobin saturation, oral–nasal airflow (thermister), thoracic and abdominal movements by means of inductive plethysmography (Respitrace; NIMS, Miami Beach, FL), and esophageal pressure. An esophageal catheter was introduced transnasally and advanced until it obtained a positive pressure during the inspiration and then it was pulled back until it obtained a clear negative pressure during the inspiration. It was calibrated following a technique previously described (15). Once the subject was comfortable in bed, a baseline recording was obtained for 1 min (2 epochs) in quite supine wakefulness. The analysis of sleep stages, arousal, and awakening were analyzed using standard procedures (16, 17).

Definitions

A driver was defined as being a habitually sleepy driver if he became so sleepy while driving that he feared falling asleep, and if this severe sleepiness while driving occurred at least 1 of every 3 times he drove on a highway. Automobile crash was defined as a highway auto crash that resulted in damage to the vehicle or personal injury. Urban auto crashes were not included. Excessive subjective sleepiness was determined using the Epworth Sleepiness Scale; a sum $\geqslant 9$ was defined as excessive sleepiness. A subject was considered a habitual snorer if he said snoring always or nearly always while sleeping.

An apnea was an event of $\geqslant 10$ s of absence of airflow and hypopnea when airflow decreased $\geqslant 40\%$, for at least 10 s with a drop in oxygen saturation $\geqslant 4\%$, or final arousal (18). Apnea–hypopnea index (AHI) was defined as the total number of episodes of apnea and hypopnea divided into the number of hours slept.

All arousals that were not caused by apneas or hypopneas were evaluated to determine if the arousal was due to an increased respiratory effort. We considered an arousal to be due to an increased respiratory effort (respiratory effort–related arousal) if all the following were present: (*1*) in the two or more breaths previous to an arousal, there were increasing negative esophageal pressures with a peak $\geqslant 40\%$ of the mean obtained in 2 epochs in wakefulness before the beginning of sleep; (*2*) esophageal pressure was getting less negative in the arousal (increase of $\leqslant 20\%$ over the mean obtained in 2 epochs of wakefulness); and (*3*) progressive decline of esophageal pressure previous to the arousal did not coincide with the increase of oral–nasal flow. A total respiratory event index was determined by adding the number of respiratory effort–related arousals per hour of sleep to the AHI.

Our institutional committee on investigation approved the protocol study, and written consent was obtained.

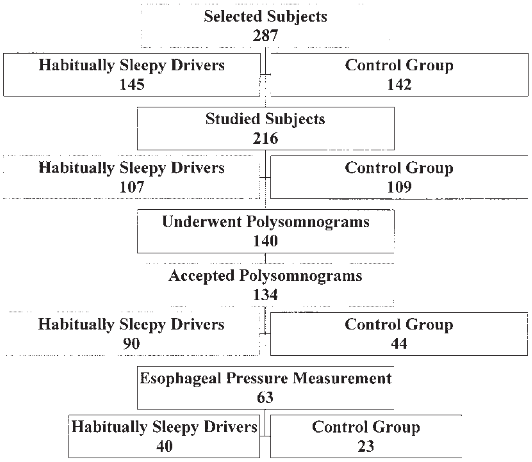

Figure 1. From 287 subjects initially selected (145 habitually sleepy drivers and 142 control subjects), 216 subjects agreed to the further studies of Stage 2 (107 habitually sleepy drivers and 109 control subjects). From these, 140 underwent polysomnograms but six polysomnograms were excluded as they had less than 3 h of sleep time. The remaining polysomnograms (134 polysomnograms), 90 habitually sleepy drivers, and 44 control subjects, were included. Forty habitually sleepy drivers and 23 control subjects were able to tolerate esophageal pressure measurement of at least 2 h of sleep during polysomnogram. This last group was used to evaluate the total respiratory events index. Subjects dropped out of the study because of lack of interest or inability to tolerate the esophageal catheter.

Statistics

The control group was matched by age and sex to the group of habitually sleepy drivers. Owing to the loss of subjects, in each step of the study (Figure 1), the comparative analysis was performed considering the group of habitually sleepy drivers and the control group as independent sampes (nonpaired). Qualitative variables were expressed as percentages, and quantitative variables as means ± SD. A p value lower than 0.05 in a two-sided test was considered as statistically significant, and 95% CI were calculated for results. The comparison of proportions was made with Fisher exact test and that of mean values through comparison of means (Student's *t*) if data presented a normal distribution; otherwise, the nonparametric Mann-Whitney test was used. Different logistic regression models were used to analyze the relation between the dependent variable, habitually sleepy driver (yes or no), and the independent variables such as AHI, total respiratory events index, or occurence of automobile crash (yes or no). Other logistical regression models considered the dependent variable, whether an automobile crash had happened (yes or no) in the group of habitually sleepy drivers, and as independent variable, total respiratory events index. Odds ratios (OR) were adjusted to different potentially confounding variables depending on the logistic regression model used. We examined the effects of the inclusion of exclusion of variables in the model (19). We used the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL) to introduce variables, with a maximum of 20 iterations (20).

TABLE 1

DISTRIBUTION OF POPULATION ACCORDING TO SAMPLING STRATUM

	Females	Males	
Age Group	n (%)	n (%)	Total
18–34 yr	639 (41)	931 (59)	1,570
35–54 yr	538 (31)	1,181 (69)	1,719
55–84 yr	53 (7)	660 (93)	713
Total*	1,230 (31)	2,772 (69)	4,002

* Mean age ± SD of 4,002 subjects is 40.4 ± 14 yr.

TABLE 2

PREVALENCE OF HABITUALLY SLEEPY DRIVERS BY GROUPS OF AGE AND SEX

	Sleepy Drivers	
	%	CI
Age, yr		
18–34	2.87	2.12–3.85
35–54	4.65*	3.73–5.79
55–84	2.81	1.77–4.38
Sex		
Men	4.65[†]	3.91–4.38
Women	1.30	0.77–2.15

* $p < 0.01$ (compared with 18- to 34-yr-old group).

[†] $p < 0.001$.

RESULTS

Prevalence of Habitually Sleepy Drivers

We contacted 4,002 licensed automobile drivers who were regularly driving in 4,490 telephone calls (89% acceptance rate). Of the 4,002 drivers interviewed, 145 (3.62%, CI = 3.07 to 4.26) were habitually sleepy while driving. Table 1 shows the age and sex of the population interviewed. Table 2 shows that the prevalence of habitual sleepiness while driving is highest in middle age and males.

Analysis of Samples

Our sample of drivers in Stage 1 had a lower percentage of females than males. To be certain that our sample truly reflected the population of all drivers, we compared the percentage of drivers who were female in our sample to that of all drivers in Spain. We found that the percentage of females in our sample (31%) was similar to percentage of female drivers in Spain (34%).

Figure 1 shows the number of subjects selected initially and the number of subjects studied in Stage 2.

We did the following analyses to demonstrate that the sample of subjects tested in Stage 2 was not selected to favor our hypotheses. We compared the characteristics of: (*1*) drivers who agreed to the interview in Stage 2 and the drivers who did not agree to participate in Stage 2; (*2*) the drivers who underwent polysomnograms and those who did not agree to a polysomnogram; and (*3*) those drivers who were and were not able to tolerate esophageal pressure measurement for at least 2 h during sleep. We found that the only differences between these groups were: (*1*) a higher proportion of subjects were snorers in the group of control subjects who participated in Stage 2, and (*2*) there was a significantly higher proportion of snorers among control subjects undergoing polysomnogram than control subjects not having a polysomnogram.

TABLE 3

CHARACTERISTICS OF HABITUALLY SLEEPY DRIVERS

	Sleepy Drivers (*n = 107*)	Control Subjects (*n = 109*)	p Value
Sex, male, %	87	87	NS
Age, yr	41 ± 11	40 ± 4	NS
Body mass index, kg/m^2	28 ± 4	26 ± 4	< 0.001
Neck circumference, cm	41 ± 4	39 ± 4	< 0.001
Hypertension, %	13	4	< 0.05
Morning fatigue, %	44	21	< 0.001
Habitual snorer, %	58	26	< 0.001
Apneas observed, %	24	14	< 0.05
Sex dysfunction, %	11	1	< 0.01
Epworth Sleepiness Scale	9.6 ± 4.1	5.5 ± 2.7	< 0.001
Epworth Sleepiness Scale ⩾ 9, %	50	12	< 0.001
Sleep, hours per night	6.6 ± 1.1	7 ± 1	< 0.01
Professional drivers, %	12	4	< 0.05
Hours driven/mo	65 ± 80	26 ± 38	< 0.001

Definition of abbreviation: NS = nonsignificant.

We did not find statistically significant differences in age and sex when comparing habitually sleepy drivers and the control subjects in each of the steps of the study (Figure 1). There was not a statistically significant difference in age and sex between the habitually sleepy drivers who had and did not have automobile crashes.

Characteristics of Habitually Sleepy Drivers

Compared with nonsleepy drivers, habitually sleepy drivers have many characteristics frequently observed in respiratory disorders during sleep as they were more overweight, more likely to snore, report apneas while sleeping, have morning fatigue, and hypertension (Table 3). Epworth Sleepiness Scale was higher in the habitually sleepy drivers than in control subjects, but only 50% of the habitually sleepy drivers described overall excessive daytime sleepiness (Epworth ⩾ 9). We did not find differences among these groups in the years of driving, proportion of urban drivers, work and sleep schedule, tobacco smoking, use of drugs causing sleepiness, or the mean amount of alcohol consumed. There were no clinically significant differences in awake oxyhemoglobin saturation or spirometry.

Automobile Crashes

Habitually sleepy drivers had a greater frequency of nodding-off at the wheel than control subjects (Table 4). The reported automobile crash rate in habitually sleepy drivers was approximately 10 times greater than control subjects. The difference remained statistically significant when the automobile crash rate was calculated using the hours driven (Table 4). A higher proportion of habitually sleepy drivers reported having at least one automobile crash in the past 5 yr than control subjects (Figure 2). The OR was 13.3 (CI = 4.1 to 43) adjusted to the confounding variables as hypertension, drugs causing sleepiness, body mass index, sex, age, alcohol consumed, insomnia, hours slept per night, work and sleep schedule, professional drivers, hours driven per month, and years of driving. A higher proportion of habitually sleepy drivers reported at least one automobile crash due to falling asleep while driving within the past 5 yr than control subjects (Figure 2).

The excessive sleepiness during the day (Epworth Sleepiness Scale) does not explain the increase in the automobile crash risk in habitually sleepy drivers (OR = 1.2, CI = 0.5 to 2.6). These sleepy drivers performed poorer on Steer Clear

TABLE 4

ACCIDENTS AND PERFORMANCE ON STEER CLEAR

	Sleepy Drivers (*n = 107*)	Control Subjects (*n = 109*)	p Value
Nodding-off while driving, %*	81	20	< 0.001
Habitual nodding-off while driving, %	25	0	< 0.001
Auto crash rate[†]	0.439 ± 0.767	0.056 ± 0.268	< 0.001
Auto crash rate/h driven[‡]	0.034 ± 0.11	0.003 ± 0.016	< 0.001
Steer clear[§]	1.9 ± 3	1.2 ± 1.3	< 0.05

* In the past 5 yr.

[†] Auto crash/driver/5 yr.

[‡] Auto crash/driver/5 yr/h driven per month.

[§] % of errors.

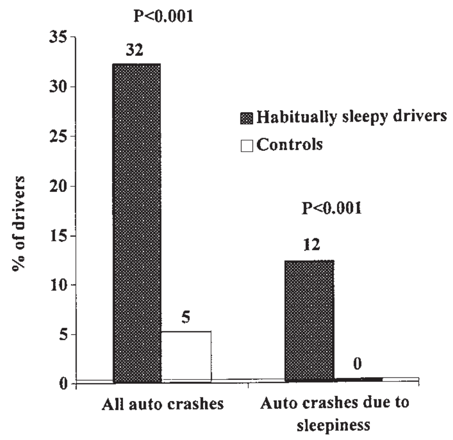

Figure 2. Percentage of drivers with one or more automobile crashes during the last 5 yr in habitually sleepy drivers and control subjects. The bars on the left represent the percentage of subjects with one or more automobile crashes in habitually sleepy drivers and control subjects taking into account all the auto crashes. The bars on the right indicate the aforementioned, but taking into account only automobile crashes due to falling asleep while driving.

(Table 4) but it is not a discriminatory factor between habitually sleepy drivers with and without automobile crashes (OR = 1.1, CI = 0.8 to 1.1)

Respiratory Sleep Disorders and Automobile Crashes

To calculate the unadjusted and adjusted OR for being or not being a sleepy driver we used different cutoff points (with AHI of ≥ 5, ≥ 10, ≥ 15, and a total respiratory event index of ≥ 10, ≥ 15, ≥ 20) in order to assess the sensitivity of the analysis to the different cutoff points (Table 5). The unadjusted OR associated with AHI ≥ 10 was 3.2 (CI = 1.0 to 10). The adjusted OR for an AHI ≥ 10 was 3.8 (CI = 1.1 to 15). The unadjusted OR associated with a total respiratory event index ≥ 15 was 4.9 (CI = 1.3 to 19). The adjusted OR for a total respiratory event index ≥ 15 was 6.0 (CI = 1.1 to 32).

In the habitually sleepy drivers group, the frequency of sleep apnea in three different levels of AHI was not statistically different between subjects with and without automobile crashes (Table 6). However, in the same habitually sleepy drivers group, if we consider total respiratory events index, the frequency of respiratory sleep disorders in three different cutoff points was higher and statistically different in subjects with automobile crash. The unadjusted OR associated with a total respiratory event index ≥ 15 was 5.9 (CI = 1.3 to 28). The adjusted OR for a total respiratory event index ≥ 15 was 8.5 (CI = 1.2 to 59).

DISCUSSION

This study has several important findings: (*1*) approximately one of every 30 drivers is habitually sleepy while driving; (*2*) one-half of habitually sleepy drivers report sleepiness occurring predominantly during driving, for they do not report excessive sleepiness during all activities; (*3*) habitually sleepy drivers report falling asleep more frequently while driving and have a 13-fold increased risk of having an automobile crash than control subjects; (*4*) a high proportion of habitually sleepy drivers have an unrecognized respiratory disorder during sleep; and (*5*) the presence of respiratory disorders during sleep is an independent risk factor for auto crashes in the habitually sleepy drivers.

There have been few studies about sleepy drivers. Haraldsson and coworkers (21) found that 19% of 846 interviewed had fallen asleep at the wheel at least once. Martikainen and coworkers (22) observed that 15% of 173 drivers had nodded off at least once at the wheel during driving. Maycock (23) received questionnaires from 4,621 male drivers and found that 29% had "felt close to falling asleep while driving" during the past 12 mo. McCartt and colleagues (10) conducted interviews by telephone in 1,000 drivers in New York State. They found that 55% of drivers experienced drowsiness while driving ("so tired you could easily fall asleep") in the last year and 2.5% drove "very often" while drowsy. McCartt's 2.5% prevalence of habitually sleepy drivers is very similar to our findings of 3.6%.

TABLE 5

RELATION BETWEEN SLEEP RESPIRATORY DISORDERS AND HABITUALLY SLEEPY DRIVERS

	Sleepy Drivers	Control Subjects		
	n (%)	n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[‡]
AHI*				
≥ 5	31 (34)	6 (14)	3.3 (1.3–8.7)	4.1 (1.4–17)
≥ 10	22 (24)	4 (9)	3.2 (1.0–10)	3.8 (1.1–15)
≥ 15	17 (19)	2 (4.5)	4.9 (1.1–22)	5.6 (1.1–33)
Total respiratory events index[†]				
≥ 10	21 (52)	4 (17)	5.2 (1.5–18)	5.7 (1.3–24)
≥ 15	17 (42)	3 (13)	4.9 (1.3–19)	6.0 (1.1–32)
≥ 20	16 (40)	2 (8.7)	7.0 (1.4–34)	10.0 (1.5–66)

Definition of abbreviations: CI = confidence interval; OR = odds ratio.

* The three levels of the AHI are not mutually exclusive. The number of subjects analyzed were 134 (90 sleepy drivers and 44 control subjects), who underwent polysomnography.

[†] The three levels of the total respiratory event index are not mutually exclusive. The number of subjects analyzed were 63 (40 sleepy drivers and 23 control subjects), who had esophageal pressure measurement.

[‡] The logistic regression model for adjusted OR contemplated the presence or absence of the sleepy drivrs as the dependent variable and the AHI or the total respiratory events index as independent variable. We entered potentially confounding variables such as hypertension, body mass index, sex, age, and snoring in this model.

TABLE 6

RELATION BETWEEN AUTOMOBILE CRASHES AND SLEEP RESPIRATORY DISORDERS IN HABITUALLY SLEEPY DRIVERS

	With Auto Crash	Without Auto Crash		
	n (%)	n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[‡]
AHI*				
≥ 5	13 (45)	18 (30)	1.9 (0.8–4.8)	—
≥ 10	9 (31)	13 (21)	1.7 (0.6–4.5)	—
≥ 15	7 (24)	10 (16)	1.6 (0.5–4.8)	—
Total respiratory events index[†]				
≥ 10	9 (82)	12 (41)	6.4 (1.2–35)	6.6 (1.1–44)
≥ 15	8 (73)	9 (31)	5.9 (1.3–28)	8.5 (1.2–59)
≥ 20	8 (73)	8 (28)	7.0 (1.5–33)	8.9 (1.3–62)

* The three levels of the AHI are not mutually exclusive. The number of subjects analyzed were 90 sleepy drivers who underwent polysomnography.

[†] The three levels of the total respiratory event index are not mutually exclusive. The number of subjects analyzed were 40 sleepy drivers who had esophageal pressure measurement.

[‡] The logistic regression model for adjusted OR contemplated the presence or absence of automobile crash as the dependent variable and the total respiratory events index as independent variable. We entered potentially confounding variables such as hypertension, drug causing sleepiness, body mass index, sex, age, alcohol consumed, insomnia, hours slept per night, work and sleep schedule, professional drivers, hours driven per month, and years of driving in this model.

In our study, habitually sleepy drivers were typically male (3:1 ratio) and middle-aged (35 to 54 yr). Previous studies analyzing automobile crash data bases have found that young drivers are involved in the majority of crashes involving sleepiness (24–26). These drivers (younger than 30 yr of age) are younger than our group of middle-aged drivers who are habitually sleepy while driving. We think this difference in age may occur because the crashes labeled "due to falling asleep" in large automobile crash data bases may be the result of sporadic sleepiness in young drivers and not habitual sleepiness. The causes of sporadic sleepiness, including sleep deprivation, alcohol or drug abuse, are more prevalent in young drivers. Habitual sleepiness while driving caused by a chronic condition such as breathing disorders during sleep occurs more frequently in middle age.

In the study of McCartt and colleagues (10), sleepiness while driving occurred in younger drivers than ours. Sleep deprivation and alcohol usage among these young drivers could be important causes of sleepiness while driving in this young group of drivers. In these younger drivers McCartt and colleagues did not find association among the indicators of sleep-disordered breathing (snoring, gasping, or cessation of breathing during sleep) and sleepiness when driving.

The percentage of professional drivers was higher in habitually sleepy drivers than control subjects. Most professional drivers in this study were truck drivers. A high prevalence of respiratory disorders during sleep, chronic alterations of wakefulness/sleep rhythm, poor quality of sleep, and insufficient sleep have been observed in truck drivers (27, 28). These alterations could be the origin of habitual sleepiness while driving in these professional drivers. However, the high frequency of professional drivers (with greater number of hours driven per month) in our habitually sleepy drivers did not explain the higher rate of automobile crashes in the habitually sleepy drivers because the OR of the regression model (dependent variable to be a sleepy driver or not and independent variable one or more automobile crashes) was similar when the variable being or not professional driver was excluded. It is possible that though professional drivers have many risk factors for crashes, these drivers are more practiced, cautious, and skillful drivers and are able to overcome their many risk factors for a crash.

The reported automobile crash rate and proportion of auto crashes were several fold higher than that in control subjects (Table 4 and Figure 2) and remained significantly higher when other potentially confounding variables were included in our analysis. The higher rate of crashes was not exclusively due to falling asleep while driving, for only 38% of accidents were said by the driver to be caused by falling asleep at the wheel. The increase of crashes in these subjects may have been a result of poor attentiveness, poor reaction times, poor driving performance, or failure to perceive their excessive sleepiness while driving.

In our study, habitual sleepiness when driving is a kind of sleepiness partially independent of the sleepiness measured in all other activities (Epworth Sleepiness Scale), as only 50% of sleepy drivers have a value $\geqslant 9$ in the Epworth Scale. Driving on a highway can be considered monotonous and boring, provoking sleepiness in subjects with mild to moderate disorders during sleep. These same subjects may be not sleepy during other daily activities.

Our finding of a high prevalence of respiratory disorders during sleep in our habitually sleepy drivers is not unexpected, because these sleep disorders are common causes of unrecognized excessive sleepiness (3) and our habitually sleepy drivers have many clinical characteristics frequently observed in these sleep disorders. The prevalence of sleep apnea in our habitually sleepy drivers was only slightly higher than that obtained by Terán and coworkers (8) in a study evaluating subjects who had highway traffic accidents. The prevalence of sleep apnea in our control group is comparable to previous studies. Terán and coworkers studied healthy subjects and found 3.9% of these subjects had sleep apnea. Our control group had a higher prevalence of sleep apnea because Terán and coworkers' subjects were chosen to be healthy and had a lower incidence of medical illnesses associated with sleep apnea such as hypertension and obesity. Our control group had a lower prevalence of sleep apnea than the study of Young and coworkers (3). Our lower incidence is due to our exclusion of habitually sleepy drivers who have a high prevalence of sleep apnea. Young and coworkers' subjects were from the general population of employed adults with no exclusions for sleepiness. Our study is the first study with a general population base that considers all respiratory-induced arousals (apneas, hypopneas, and all other respiratory effort–related arousals). Therefore, we cannot make comparisons with other studies regarding the frequency of total respiratory events, but the results of our study support the suggestion that all respiratory-induced arousals are important and should be analyzed (29).

Excessive sleepiness during the day as measured by the Epworth Sleepiness Scale did not predict an increased automobile crash rate in our study. Several previous studies have found that excessive sleepiness measured by the Epworth Sleepiness Scale (12) or sleep latency measured by the Multiple Sleep Latency Test (30) does not predict which drivers with sleep apnea will or will not have an automobile crash (4–8, 28). Neither the Epworth Sleepiness Scale nor the Multiple Sleep Latency Test measures sleepiness while driving, which may explain the absence of association of these measures with auto accident risk.

In habitually sleepy drivers (a group recovered from the general population of drivers and with higher automobile crash frequency), we did not find a statistically significant association between automobile crash frequency and sleep apnea. However, this association became statistically significant if we take into account total respiratory disorders during sleep. This finding suggests that respiratory effort–related arousal, which may occur in the increased airway resistance syndrome, may be an additional factor for automobile crash risk. Young and coworkers (5) in a population-based study found that habitual snorers with AHI < 5 have higher accident risk. Likely these snorers could have high respiratory effort–related arousal index. A previous study has suggested that drivers with the increased airway resistance syndrome may have a higher rate of automobile crashes (28). Successful treatment of respiratory disorders during sleep may decrease the number of automobile crashes (6, 31). Therefore, treating respiratory disorders during sleep in habitually sleepy drivers may decrease traffic automobile crash risk.

Comments and Limitations

We recruited our sample from the general population, by telephone. Including only drivers with a telephone would not exclude many drivers, because 88% of households have a telephone in the region of our study. The greater frequency of snoring in our control population sample does not bias our study in favor of the finding that habitually sleepy drivers have a high prevalence of respiratory disorders during sleep. Our accident reporting was retrospective and the subjects could forget those accidents with few repercussions. On the other hand, fatal accidents could not be reported in our subjects. Although this bias is present in both habitually sleepy drivers and control subjects, the impact would be higher in habitually sleepy drivers, with their higher crash rate.

The esophageal pressure measurement is an additional disturbance during the polysomnogram and could alter the sleep in those subjects who had an esophageal catheter placed. However, we did not find statistically significant differences between the subjects who had and those who did not have esophageal pressure measurement in the total sleep time, sleep efficiency, percentage of the different sleep periods, arousal per hour of sleep, and sleep latency. Previous researchers have observed minimal changes of sleep with the esophageal catheter (32).

Conclusions

Habitually sleepy drivers are a large group of drivers who are involved in many more automobile crashes than control subjects. In this population-based study the AHI cannot explain the excess automobile crashes of sleepy drivers but the total respiratory event index can (apnea, hypopnea, and other respiratory effort–related arousal). Because these respiratory disorders during sleep are treatable, many automobile crashes in these sleepy drivers may be preventable. Physicians must consider respiratory disorders during sleep when they evaluate subjects complaining of habitual sleepiness while driving.

Overall excessive daytime sleepiness as measured by the Epworth Sleepiness Scale does not predict a higher number of automobile crashes in our studies as well as others studies. Our findings suggest that asking about excessive sleepiness while driving may better predict which subjects with breathing disorders during sleep have crashes than asking about overall sleepiness.

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References

1. Leger, H. 1994. The cost of sleep-related accidents: a report for the National Commission on Sleep Disorders Research. *Sleep* 17:84–93.
2. Webb, W. B. 1995. The cost of sleep-related accidents: a reanalysis. *Sleep* 18:276–280.
3. Young, T., M. Palta, and J. N. Dempsey. 1993. The occurrence of sleep disordered breathing among middle-aged adults. *N. Engl. J. Med.* 328: 1230–1235.
4. Findley, L. J., M. E. Unverzagt, and P. M. Suratt. 1988. Automobile accidents involving patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.* 138:337–340.
5. Young, T., J. Blustein, L. Finn, and M. Palta. 1997. Sleep-disordered breathing and motor vehicle accidents in a population-based sample of employed adults. *Sleep* 20:608–613.
6. Krieger, J., N. Meslier, T. Lebrun, P. Levy, F. Phillip-Joel, J. C. Sailly, J. L. Racineux, and The Working Group ANTADIR, Paris and CRESGE, Lille, France. 1997. Accidents in obstructive sleep apnea patients treated with nasal continuous positive airway pressure. *Chest* 112: 1561–1566.
7. Barbé, F., J. Pericás, A. Muñoz, L. Findley, J. M. Antó, and A. G. N. Agustí. 1998. Automobile accidents in patients with sleep apnea syndrome. *Am. J. Respir. Crit. Care Med.* 158:18–22.
8. Terán, J., A. Jiménez, and J. Cordero. 1999. The association between sleep apnea and the risk of traffic accidents. *N. Engl. J. Med.* 340:847–851.
9. Guilleminault, C., R. Stoohs, A. Clerk, M. Cetel, and P. A. Maistros. 1993. Cause of excessive daytime sleepiness: the upper airway resistance syndrome. *Chest* 104:781–787.
10. McCartt, A. T., S. A. Ribner, A. I. Pack, and M. C. Hammer. 1996. The scope and nature of the drowsy driving problem in New York State. *Accid. Anal. Prev.* 28:511–517.
11. Masa, J. F., J. Sánchez de Cos, J. M. Antó, and L. J. Findley. 1996. The prevalence of drivers who are chronically sleepy while driving (abstract). *Am. J. Respir. Crit. Care Med.* 156:A353.
12. Johns, M. W. 1993. Daytime sleepiness, snoring, and obstructive sleep apnea. The Epworth Sleepinees Scale. *Chest* 103:30–36.
13. Jennum, P., H. O. Hein, P. Suadicani, and F. Gyntelberg. 1992. Cardiovascular risk factors in snorers: a cross-sectional study of 3,323 men aged 54 to 74 years: the Copenhagen Male Study. *Chest* 102:1371–1376.
14. Findley, L. J., M. J. Fabrizio, H. Knigth, B. B. Norcross, A. J. Laforte, and P. M. Suratt. 1989. Driving simulator performance in patients with sleep apnea. *Am. Rev. Respir. Dis.* 140:529–530.
15. Baydur, A., P. K. Behraks, W. A. Zin, M. Jaeger, and J. Milic-Emili. 1982. A simple method for assessing the validity of the esophageal balloon technique. *Am. Rev. Respir. Dis.* 129:788–791.
16. Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. 1992. EEG arousals: scoring rules and examples. *Sleep* 15: 174–184.
17. Rechtschaffen, A., and A. Kales. 1968. A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages for Human Subjects. University of California at Los Angeles, Brain Information Service/Brain Research Institute.
18. Barbé, F., J. Amilibia, F. Capote, J. Durán, N. G. Mangado, A. Jiménez, J. M. Marín, J. F. Masa, J. M. Montserrat, and J. Terán. 1995. Diagnosis of obstructive sleep apnea syndrome. Consensus Report from the Respiratory Insufficiency and Sleep Disorders Group. *Arch. Bronconeumol.* 31:460–462.
19. Hosmer, D. W. Jr., and S. Lemeshow. 1989. Applied Logistic Regression. John Wiley, New York.
20. Norusis, M. J. 1994. SPSS Advanced Statistics 6.1. SPSS, Chicago.
21. Haraldsson, P. O., C. Carenfelt, and C. Tingvall. 1992. Sleep apnea syndrome symptoms and automobile driving in a general population. *J. Clin. Epidemiol.* 45:821–825.
22. Martikainen, K., H. Urponen, M. Partinen, J. Hasan, and I. Vuori. 1992. Daytime sleepiness: a risk factor in community life. *Acta Neurol. Scand.* 86:337–341.
23. Maycock, G. 1996. Sleepiness and driving: the experience of UK car drivers. *J. Sleep Res.* 5:229–237.
24. Horne, J. A., and L. A. Reyner. 1995. Sleep related vehicle accidents. *B.M.J.* 310:565–567.
25. Pack, A. I., A. M. Pack, E. Rodgman, A. Cucchiara, D. F. Dinges, and C. W. Schwab. 1995. Characteristics of crashes attributed to the driver having fallen asleep. *Accid. Anal. Prev.* 6:769–775.
26. Gislason, T., K. Tómasson, H. Reynisdóttir, J. K. Björnsson, and H. Kristbjarnarson. 1997. Medical risk factors amongst drivers in single-car accidents. *J. Intern. Med.* 241:213–219.
27. Mitler, M. M., J. C. Miller, J. J. Lipsitz, J. K. Walsh, and C. D. Wylie. 1997. The sleep of long-haul truck drivers. *N. Eng. J. Med.* 337:755–761.
28. Stoohs, R. A., L. Bingham, A. Itoi, C. Guilleminault, and W. C. Dement. 1995. Sleep and sleep-disordered breathing in comercial long-haul truck drivers. *Chest* 107:1275–1282.
29. AASM Task Force. 1992. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. *Sleep* 22:667–689.
30. Aldrich, M. S. 1989. Automobile accidents in patients with sleep disorders. *Sleep* 12:487–494.
31. Findley, L. J., C. Smith, J. Hooper, M. Dineen, and P. Suratt. 2000. Treatment with nasal CPAP decreases automobile accidents in patients with sleep apnea. *Am. J. Respir. Crit. Care Med.* 161:857–859.
32. Chervin, R. D., and M. S. Aldrich. 1997. Effects of esophageal pressure monitoring on sleep architecture. *Am. J. Respir. Crit. Care Med.* 156: 881–885.