Sleepy Driver Near-Misses May Predict Accident Risks

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Study Objectives: To quantify the prevalence of self-reported near-miss sleepy driving accidents and their association with self-reported actual driving accidents.

Design: A prospective cross-sectional internet-linked survey on driving behaviors.

Setting: Dateline NBC News website.

Results: Results are given on 35,217 (88% of sample) individuals with a mean age of 37.2±13 years, 54.8% women, and 87% white. The risk of at least one accident increased monotonically from 23.2% if there were no near-miss sleepy accidents to 44.5% if there were ≥4 near-miss sleepy accidents ($P<0.0001$). After covariate adjustments, subjects who reported at least one near-miss sleepy accident were 1.13 (95% CI, 1.10 to 1.16) times as likely to have reported at least one actual accident as subjects reporting no near-miss sleepy accidents ($P<0.0001$). The odds of reporting at least one actual accident in those reporting ≥4 near-miss sleepy accidents as compared to those reporting no near-miss sleepy accidents was 1.87 (95% CI, 1.64 to 2.14). Furthermore, after adjustments, the summary Epworth Sleepiness Scale (ESS) score had an independent association with having a near-miss or actual accident. An increase of 1 unit of ESS was associated with a covariate adjusted 4.4% increase of having at least one accident ($P< 0.0001$).

Conclusion: A statistically significant dose-response was seen between the numbers of self-reported sleepy near-miss accidents and an actual accident. These findings suggest that sleepy near-misses may be dangerous precursors to an actual accident.

Keywords: Sleepy driving, sleep disorders, sleepy near-miss accidents, driving accidents, driving risks, Epworth Sleepiness Scale.

Citation: Powell NB; Schechtman KB; Riley RW et al. Sleepy driver near-misses may predict accident risks. *SLEEP* 2007;30(3):331-342

INTRODUCTION

LITTLE ATTENTION HAS BEEN GIVEN TO SLEEPY NEAR-MISS DRIVING ACCIDENTS UP TO NOW DESPITE THEIR LIKELY RELATIONSHIP WITH ACTUAL DRIVING accidents. Although there have been investigations that included near-miss accidents and/or sleepy near-misses, these data were limited and not used to predict a sleepy accident.[1-5] In fact, the focus of these and the following papers were mostly on sleep disorders and driving accidents with near-misses an ancillary part of the data. These papers do not make clear any association between sleepy near-misses leading to an actual sleepy driving accident.

Three investigations that have mentioned near-miss sleepy accidents were reported in the sleep literature. Krieger et al.[6] and Engleman et al.[7] found that treatment of obstructive sleep apnea (OSA) with continuous positive airway pressure (CPAP) devices reduced the number of accidents and near-misses.

Turkington et al[8] used a questionnaire on driving history and a simulator to evaluate OSA performances. They reported that older age, female sex, and self-reported use of alcohol had the greatest influence on driving performance. However, self-reported near-miss accidents (in the previous 3 years) were independently associated with poor performance (odds ratio 2.62, 95% CI 1.00 to 6.88). In addition, the subjective ESS score was independently associated with near-miss accidents (odds ratio 1.21, 95% CI 1.12 to 1.31). Further review of several sophisticated studies on sleepy driving reveals no data or specific focus on sleepy near-miss accidents [9-13]

Contrary to the minimal focus on sleepy driving near-misses in sleep research, industry has used this metric extensively both to predict accidents and to control near-miss precursors as a strategy to limit workplace accidents. Near-miss strategy has been effectively used in a broad spectrum of industries, including airlines, railroads, medicine, petrochemical processing, and nuclear power.[14-17] Use of a near-miss strategy system requires systematic reporting of all near-misses that might be associated with a defined accident outcome. A near-miss may be defined as a detected event that has not caused any harm and therefore has limited immediate impact. The success of using this metric is predicated on sufficient education and knowledge of the incident to recognize and identify a precursor condition that may lead to a serious consequence. Near-miss events when accumulated and evaluated provide insight and early detection of a system's possible weakness. Phimister et al.[14] reviewed adverse incidents in industry and described the use of a Safety Pyramid where near-miss accidents fill most (two-thirds) of the lower pyramid and the actual adverse accident is at the pinnacle. This pyramid can have a ratio as high as 300:1 industrial near-miss–no-harm accidents to accidents with harm.[18]

We are unaware of an adequately powered study with emphasis on near-miss accidents while driving sleepy due to sleep depriva-

Disclosure Statement

This is not an industry supported study. The study was supported in part by the Sleep Education and Research Foundation a registered public non-profit foundation. Drs. Powell, Schechtman, Riley, Guilleminault, Chiang, and Weaver have indicated no conflicts of interest.

Submitted for publication September 22, 2006

Accepted for publication November 5, 2006

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tion and/or sleep disorders. Therefore, we sought to investigate a sleepy near-miss strategy using data extracted from a self-reported web-based survey of a large group of drivers (n = 35,217) to: 1) evaluate the prevalence of near-miss sleepy driving accidents; 2) test the associations of demographic, driving, and sleep disorder variables with both near-miss and actual sleepy accidents; 3) test our hypothesis that near-miss sleepy accidents are associated with actual driving accidents.

METHODS

Study Design and Population

We investigated and evaluated data on measures of sleepy driving from a survey on driving behaviors, prevalence of self-reported sleepy near-miss accidents, self-reported actual accidents, and actual sleepy accidents in a large group of drivers. Cross-sectional data were gathered prospectively during an internet-linked survey on distracted and sleepy drivers which included demographic data (age, sex, race, body mass index [BMI kg/m^2], marital status, income, and educational levels) and data specific for distracted and sleepy driving. These data were gathered during and for one week following a Dateline NBC television presentation on "Distracted Driving." A short web-based quiz was given by Dateline NBC News on distracted driving which 254,397 subjects completed. A self-selected convenience sample of 39,825 of the 254,397 subjects accessed our web page via a web link and participated anonymously in a combined distracted driver and sleepy driver questionnaire.

Subjects were asked during the Dateline show to go to their website and respond to a brief series of questions (10-question quiz on distracted driving). Our data were based on a self-reported convenience sample of individuals who responded to the Dateline request and subsequently chose to web-link to our more comprehensive questionnaire. There were no other modes of entry into our study. All data from the original 254,397 subjects of the Dateline NBC News quiz were totally independent and not available to us.

Data

The questionnaire contained 99 questions on distracted and sleepy driving. Since the focus for this report is sleepy driving, only 22 of the 99 total questions were extracted and analyzed for this investigation. These questions can be reviewed in the Appendix. Accident history questions included the number of accidents in the past 3 years, whether any of these accidents were related to being sleepy, and the number of near-miss accidents due to driving sleepy in the past 3 years. Other variables included demographics listed above and questions on professional driving, miles driven yearly, time of day driving, seatbelt use, alcoholic drinks per week, insomnia, sleep apnea, narcolepsy, motor vehicle accidents, sleepy near-miss accidents, and hours of sleep when working or not working. The questionnaire asked about current habits with respect to average alcohol consumption, sleep disturbances, driving habits, and other variables. With the exception of miles driven per year and accident history (previous 3 years), we did not give a specific time frame but, rather, asked about current behaviors/status. Question 8 was from the Epworth Sleepiness Scale (ESS)[19,20] and had a total of 8 answers. Our questionnaire was not previously validated, except for the ESS portion, which has been validated for the propensity of sleep in 8 situations. The questionnaire posed simple, unambiguous questions on sleepiness, measures of sleepy driving, sleepy near-miss accidents, and accidents associated with sleepiness. It was designed, compiled, and reviewed by a group of university sleep researchers at the Stanford Sleep Disorders and Research Center at Stanford University School of Medicine (Stanford) and the Division of Biostatistics at Washington University School of Medicine (St Louis), and the Sleep Disorders Center and Sleep Apnea Research Group at the University of Washington (Seattle).

Inclusion Criteria

Included were subjects who completed the questionnaire, who had driven a motor vehicle 1000 miles yearly and who provided information about accident history.

Exclusion Criteria

We excluded subjects who did not complete the questionnaire, who had driven a motor vehicle less then 1000 miles yearly, or who did not provide information about accident history.

All data were transferred immediately via an internet link to an SAS Institute (Cary, NC) statistical program to be analyzed. Extracted from this large database were demographics and data specifically associated with sleepy driving behaviors.

Statistical Analysis

The prevalence of near-miss sleepy accidents was calculated as the proportion of subjects reporting at least one near-miss sleepy accident. We also calculated the prevalence of 1, 2-3, and ≥4 near-miss sleepy accidents as the proportion of subjects reporting in each of these categories.

T-tests, chi-square tests, and Wilcoxon's test were used to make unadjusted comparisons between subjects with and without self-reported sleepy accidents and between subjects with and without self-reported near-miss sleepy accidents. Logistic regression provided information about the associations of demographic, driving, and sleep disorder variables with near-miss and actual sleepy accidents after adjusting for covariates. The logistic models also provided odds ratios and associated 95% confidence intervals (CI). In all of these analyses, summary values for continuous variables collected in categories (e.g., miles driven per year, income) were computed by assuming that a participant's actual value was at the midpoint of the interval. This permitted us to compute actual estimated values for all continuous variables, even for variables such as miles driven per year and percent time using seat belts that were collected in categories. Using estimated values of continuous variables when necessary, the logistic model was used to produce odds ratios associated with specific prespecified increases in a continuous variable. For example, odds ratios for miles driven per year are presented in units of 5000. This means that if the odds ratio for miles driven is X, the odds of having an accident is X times greater in a subject who drives 15,000 miles as compared to a subject who drives 10,000 miles, or equivalently, 20,000 vs 15,000, 25,000 vs 20,000, etc. Multicategory nominal variables were dichotomized in all analyses, with race being treated as white vs nonwhite, and work schedule being dichotomized as a regular daytime schedule vs an evening, night, or irregular schedule. Odds ratios were reported as unadjusted and

Table 1—Demographic Characteristics of Respondents

Characteristic	Mean + SD or percent
Age (yrs)	37.2 + 13
Female	54.8%
Body mass index (kg/m2)	27.4 + 6.5
Race:	
White	87.0%
Black	3.7%
Hispanic	3.8%
Asian	2.8%
Other	2.7%
Education:	
Less than 12 years	2.8%
HS graduate	13.4%
Some college	40.1%
College graduate	33.0%
Advanced degree	10.7%
Marital status:	
Married	52.6%
Single	35.8%
Separated	1.5%
Divorced	10.1%
Household income:	
0-$5,000	2.0%
$5,000-$10,000	2.0%
$10,000-$20,000	5.4%
$20,000-$30,000	12.0%
$30,000-$50,000	25.8%
$50,000-$75,000	24.2%
$75,000-$100,000	14.6%
>$100,000	14.0%
Drives professionally	6.9%
Miles driven per year	15255 + 9915
% of driving between midnight and 6 AM	5.99 + 9.8
% of time using seatbelts	91.0 + 22
Alcoholic drinks per week	2.63 + 4.7
Insomnia	14.3%
Sleep apnea	6.4%
Narcolepsy	0.94%
At least one sleep disorder	19.0%

adjusted with 95% confidence intervals (CI).

We tested for the monotonic dose-response relationship between the number of near-miss sleepy accidents and actual accidents using the Mantel-Hantzel test for trend; the hypothesis that near-miss sleepy accidents had an independent association with actual accidents by using multivariate logistic regression, adjusting for age, sex, marital status, the number of miles driven per week, the percent of miles driven at night, and alcoholic drinks per week; and whether daytime sleepiness was associated with near-miss sleepy accidents using a similar analysis.

RESULTS

This report discusses results from a cohort of 35,217 individuals (88% of the sample) who met the inclusion and exclusion criteria. Information on all of the outcome measures and covariates used in this report were available on at least 98% of the 35,217 subjects we evaluated.

Table 1 summarizes the demographic characteristics of the sample and indicates that participants were 37.2 + 13 years old, 55% were women, 87% were white, and 53% were married. Table 2 describes several measures related to sleepiness including accidents and near-misses associated with being sleepy in addition to 3 key sleep measures. A total of 1.3% of all participants reported at least 1 accident associated with being sleepy over the preceding 3 years. Near-miss accidents associated with sleepiness were reported in 18.3% of the sample: 1 sleepy near-miss in 10.6% of the sample, 2 or 3 times in 5.9%, and ≥ 4 times in 1.8% of participants.

Table 2—Summary of Key Sleep Measures

Characteristic	Percent or Mean + SD
At least one accident associated with being sleepy last 3 years	1.3%
# of near-miss accidents because sleepy last 3 years:	
None	81.6%
1	10.6%
2-3	5.9%
4 or more	1.8%
Hours of sleep when working next day	6.86 + 1.0
Hours of sleep when not working next day	7.97 + 1.5
Epworth scale summary score	7.03 + 3.6

Table 3 contains information about the association between demographic variables and both reporting an accident associated with being sleepy (Panel A) and/or reporting at least one near-miss accident associated with being sleepy (Panel B) over the preceding 3 year period. Both panels contain 2 sets of odds ratios and 95% confidence intervals (CI) that compare the odds of a sleepiness-related accident or a near-miss accident in subjects who satisfy a particular criterion with the odds of a sleepiness-related accident or a near-miss accident in subjects without the criterion. The first odds ratio in each panel of Table 3 is unadjusted, while the second panel is adjusted for the number of miles driven per year, the percent of driving done between midnight and 06:00, and the number of alcoholic drinks per week. It should be emphasized that in this and subsequent tables that the large sample size means that small effects are sometimes highly significant, especially for near-miss accidents (Panel B) because of the substantial incidence of such events. Table 3 also indicates that with the exception of sex and education, all tabulated variables were associated with both accidents and near-miss accidents. Of particular note is that the adjusted odds of a sleepiness-related accident in nonwhite subjects was 2.40 (Panel A) times as great as in white subjects, with the adjusted odds ratio associated with near-miss accidents being much lower at 1.26 (Panel B). Being unmarried was associated with a 2.15-fold increase in the sleepy accident rate and a 1.46-fold increase in the near-miss accident rate. The one other demographic variable where the association was substantial was age, with each decade of increased age being associated with a reduction in sleepy accident rates to 0.77 of the rate found in individuals who are 10 years younger (i.e., a 23% reduction per decade). The age effect was similar for near-miss accidents.

The 2 panels of Table 4 are analogous to those of Table 3, except that the accident predictors of interest are driving patterns, alcohol intake, and work schedule. While professional drivers were at higher sleepy accident and near-miss sleepy accident risk than nonprofessionals, the adjusted values were not significant, suggesting that higher rates in professional drivers can be explained by increased amounts of driving and by more driving at night. Covariate-adjusted values for all other tabulated variables were highly significant, with the only odds ratio of note being associ-

Table 3a—Association between Demographics and Outcomes (Having a Sleepy Accident)

Characteristic	Sleepy Accident		Odds Ratio (95% CI)		P Value[1]
	Without	With	Unadjusted	Adjusted[1]	
Age	36.1 + 13	33.7 + 16	0.77 (0.71-0.83)[2]	0.76 (0.70-0.82)[2]	<0.0001
Female	53.2%	46.8%	0.71 (0.59-0.85)	1.03 (0.84-1.25)	0.795
Body mass index	27.4 + 6.4	28.7 + 14	1.02 (1.01-1.03)[3]	1.01(1.00-1.02)[3]	0.044
Race:					
White	86.8%	72.3%	2.56 (2.08-3.15)[4]	2.40 (1.93-2.98)[4]	<0.0001
Black	3.7%	6.4%			
Hispanic	3.8%	8.0%			
Asian	3.0%	5.6%			
Other	2.7%	7.6%			
Education:					
Less than 12 years	2.8%	10.5%	1.31 (1.09-1.59)[5]	1.15 (0.95-1.40)[5]	0.152
HS graduate	12.9%	12.1%			
Some college	40.4%	39.3%			
College graduate	33.3%	26.6%			
Advanced degree	10.6%	11.5%			
Married	51.2%	32.9%	2.32 (1.90-2.82)[6]	2.15 (1.76-2.63)[6]	<0.0001
Household income	59267 ± 34416	52851 ± 36274	0.94 (0.92-0.97)[7]	0.93 (0.96-0.96)[7]	<0.0001

[1]All P values computed after adjusting for annual miles driven, percent of driving done between midnight and 6am, alcoholic drinks per week.
[2]odds ratios for age assess the effect of each 10 year increase in age
[3]odds ratios for body mass index reflect the effect of an increase of one unit of BMI
[4]odds ratio for race compares nonwhite with white subjects
[5]odds ratio for education compares college graduates with non college graduates
[6]odds ratio compares single with married individuals
[7]odds ratios for income assess the effect of each additional $10,000 of annual household income

Table 3b—Association between Demographics and Outcomes (Having at Least One Near-Miss Sleepy Accident)

Characteristic	Near-Miss Sleepy Accident		Odds Ratio (95% CI)		P Value[1]
	No	Yes	Unadjusted	Adjusted[1]	
Age	37.8 + 13	33.9 + 12	0.78 (0.76-0.80)[2]	0.77 (0.75-0.79)[2]	<0.0001
Female	55.4%	51.9%	0.87 (0.82-0.92)	1.02 (0.97-1.08)	0.414
Body mass index	27.2 + 6.2	28.1 + 7.9	1.02 (1.01-1.02)[3]	1.01 (1.01-1.02)[3]	<0.0001
Race:					
White	87.4%	85.0%	1.24 (1.14-1.33)[4]	1.26 (1.16-1.36)[4]	<0.0001
Black	3.6%	4.1%			
Hispanic	3.5%	4.8%			
Asian	2.7%	3.1%			
Other	2.6%	3.0%			
Education:					
Less than 12 years	2.7%	2.9%	0.95 (0.90-1.00)[5]	0.93 (0.88-0.98)[5]	0.008
HS graduate	13.9%	11.2%			
Some college	39.8%	41.0%			
College graduate	32.8%	34.4%			
Advanced degree	10.8%	10.4%			
Married	54.2%	45.1%	1.44 (1.36-1.52)[6]	1.46 (1.38-1.54)[6]	<0.0001
Household income	60530 + 34446	56383 + 33795	0.96 (0.96-0.97)[7]	0.95 (0.95-0.96)[7]	<0.0001

[1]All P values computed after adjusting for annual miles driven, percent of driving done at night, alcoholic drinks per week.
[2]odds ratios for age assess the effect of each 10 year increase in age
[3]odds ratios for body mass index reflect the effect of an increase of one unit of BMI
[4]odds ratio for race compares nonwhite with white subjects
[5]odds ratio for education compares college graduates with non college graduates
[6]odds ratio compares single with married individuals
[7]odds ratios for income assess the effect of each additional $10,000 of annual household income

ated with work schedule, with subjects who work in the evening, at night, or on an irregular schedule being at increased risk when compared to subjects who work a regular daytime schedule (odds ratios are 1.51 and 1.33 for accidents and near-miss accidents respectively).

Table 5 evaluates the association between the 2 outcome measures (actual and near-miss sleepy accidents) and the presence of sleep disorders. Panel A indicates that all variables had a highly

Table 4a—Association between Outcome Measures and Driving Patterns, Work Schedule, and Alcohol Intake (Having a Sleepy Accident)

Characteristic	Sleepy Accident		Odds Ratio (95% CI)		P Value[1]
	Without	With	Unadjusted	Adjusted[1]	
Work schedule:					
Day only	74.0%	58.7%	2.34 (1.91-2.86)[2]	1.51 (1.20, 1.89)[2]	0.0004
Evening only	2.6%	4.0%			
Night only	1.9%	5.9%			
Irregular	13.0%	22.3%			
Not working	8.5%	9.1%			
Hours worked per week[3]					
1-20 hours	4.4%	3.8%			<0.0001
21-40 hours	36.8%	32.0%			
41-60 hours	46.6%	43.6%			
> 60 hours	5.1%	11.8%			
Do not work	7.1%	8.8%			
Alcoholic drinks per week	2.60 + 4.6	4.97 + 7.8	1.24 (1.19-1.28)[4]	1.05 (1.04-1.07)[4]	<0.0001
Miles driven per year	15282 + 9868	20496 + 13982	1.25 (1.21-1.29)[5]	1.17 (1.13-1.22)[5]	<0.0001
% of driving between midnight and 6 AM	5.96 + 9.7	14.6 + 21	1.49 (1.42-1.56)[6]	1.35 (1.28-1.42)[6]	<0.0001
Percent of time using seat belt	91.0 + 22	79.5 + 35	0.86 (0.83-0.88)[7]	0.92 (0.90-0.95)[7]	<0.0001
Drive Professionally	6.9%	13.9%	2.23 (1.71-2.90)	1.20 (0.89-1.64)	0.236

[1]All P values except for those associated with alcohol, miles driven, and percent of driving at night are computed after adjusting for all 3 of those variables in addition to age, sex, and family income.
[2]Odds ratio and P value for work schedule based on comparing evening, night only, or irregular hours with a day shift. Subjects not working are excluded.
[3]Odds ratios for hours worked per week are not presented because the categories we used, 21-40 and 41-60, where most subjects lie, do not effectively separate full-time from part-time workers.
[4]Odds ratios for alcohol assess the impact of 3 additional drinks per week. Adjusted odds ratios and P values adjust for miles driven per year and percent of driving at night
[5]Odds ratios for miles driven assess the impact of 5000 additional miles per year. Adjusted odds ratios and P values adjust for alcoholic drinks and percent of driving at night.
[6]Odds ratios for percent of driving at night assess the impact of each additional 10%. Adjusted odds ratios and P values adjust for alcoholic drinks and miles driven per year.
[7]Odds ratios for percent of time using seat belts assess the effect of each 10% increase in use.

significant covariate-adjusted association (P<0.0001 in all cases) with self reported sleepy accidents. Of particular note are the high odds ratios associated with narcolepsy (3.99). Although most odds ratios are lower, the results in Panel A are largely repeated in Panel B of Table 5 which shows the same highly significant associations between tabulated predictors and reporting at least one near-miss sleepy accident.

Table 6 contains data on the association between the number of near-miss accidents due to sleepiness and both the percent of subjects with at least one actual accident and the Epworth Sleepiness Scale (ESS) summary score. The table indicates that there was a substantial ordered relationship between the number of self-reported near-miss sleepy accidents and both tabulated variables, with the number of subjects with at least one actual accident increasing steadily from 23.2% if there were no near-miss sleepy accidents to 44.5% if there were ≥4 near-miss sleepy accidents (P<0.0001). Thus, there is not only an association between near-miss sleepy accidents and actual accidents, but also there is a significant dose-response relationship between the number of near-miss sleepy accidents and the occurrence of an actual accident. The ESS summary score increased from a mean of 6.57 + 3.4 if there were no near-miss sleepy accidents to 12.1 + 5.3 if there were ≥4 such near- miss accidents (P<0.0001). In addition, the driving-related item within the ESS increased from a mean of 0.06 ± 0.31 if there were no near-miss sleepy accidents to 0.79 ± 0.98 if there were ≥4 near-miss accidents (P<0.0001). Thus, there is also a dose-response relationship between subjective sleepiness and near-miss sleepy accidents.

Because of the associations summarized in Table 6, we evaluated the degree to which near-miss sleepy accidents and the ESS summary score had an independent association with reporting an actual accident after adjusting for age, sex, marital status, the number of miles driven per week, the percent of miles driven at night, and alcoholic drinks per week. After covariate adjustment, subjects who reported at least one near-miss sleepy accident were 1.13 (95% CI, 1.10 to 1.16) times as likely to have reported at least one actual accident as subjects reporting no near-miss sleepy accidents (P<0.0001). The odds ratio of at least one actual accident in those reporting ≥4 near-miss sleepy accidents compared with no near-miss sleepy accidents was 1.87 (95% CI, 1.64 to 2.14). An increase of one unit in the ESS summary score was associated with a covariate adjusted 4.4% increase in the likelihood of having at least one accident (P < 0.0001). A difference of 5 units in the ESS is associated with an odds ratio of 1.24 (95% CI, 1.19 to 1.28) in the odds that a subject will have had an accident.

Comments

This is the first scientific study we are aware of that has looked at the important question of near-miss sleepy accidents and their

Table 4b—Association between Outcome Measures and Driving Patterns, Work Schedule, and Alcohol Intake (Having at least One Near-Miss Sleepy Accident)

Characteristic	Near-Miss Sleepy Accident		Odds Ratio (95% CI)		P Value[1]
	No	Yes	Unadjusted	Adjusted[1]	
Work schedule:					
Day only	74.2%	70.3%	1.57 (1.47-1.68)[2]	1.33 (1.23-1.43)[2]	<0.0001
Evening only	2.4%	2.7%			
Night only	1.7%	3.2%			
Irregular	11.7%	17.5%			
Not working	10.1%	6.3%			
Hrs worked per week3					
1-20 hours	4.5%	3.9%			<0.0001
21-40 hours	37.4%	32.8%			
41-60 hours	45.1%	50.5%			
> 60 hours	4.4%	7.7%			
Do not work	8.5%	5.1%			
Alcoholic drinks per week	2.55 + 4.6	2.99 + 5.1	1.06 (1.04-1.07)[4]	1.01 (1.01-1.02)[4]	<0.0001
Miles driven per year	14693 + 9588	17822 + 10936	1.15 (1.14-1.17)[5]	1.15 (1.13-1.16)[5]	<0.0001
% of driving between midnight and 6 AM	5.55 + 9.1	7.84 + 12.4	1.21 (1.19-1.24)[6]	1.14 (1.11-1.17)[6]	<0.0001
Percent of time using seat belt	91.8 + 28	87.6 + 25	0.93 (0.92-0.94)[7]	0.95 (0.94-0.96)[7]	<0.0001
Drive professionally	6.5%	8.2%	1.29 (1.16-1.42)	0.95 (0.85-1.06)	0.378

[1]All P values except for those associated with alcohol, miles driven, and percent of driving at night are computed after adjusting for all 3 of those variables in addition to age, sex, and family income.
[2]Odds ratio and P value for work schedule based on comparing evening, night only, or irregular hours with a day shift. Subjects not working are excluded.
[3]Odds ratios for hours worked per week are not presented because the categories we used, 21-40 and 41-60, where most subjects lie, do not effectively separate full-time from part-time workers.
[4]Odds ratios for alcohol assess the impact of 3 additional drinks per week. Adjusted odds ratios and P values adjust for miles driven per year and percent of driving at night
[5]Odds ratios for miles driven assess the impact of 5000 additional miles per year. Adjusted odds ratios and P values adjust for alcoholic drinks and percent of driving at night.
[6]Odds ratios for percent of driving at night assess the impact of each additional 10%. Adjusted odds ratios and P values adjust for alcoholic drinks and miles driven per year.
[7]Odds ratios for percent of time using seat belts assess the effect of each 10% increase in use.

association with actual accidents. Despite the fact that this matrix is often applied in industry to avoid on-the-job accidents, it has not had focused studies during investigation of driving while sleepy. This study indicates that near-miss sleepy accidents are common and dangerous. The near-miss sleepy accidents occur in 14 times more people than actual sleepy accidents, (Table 2, 18.3% vs 1.3%) and the near-misses appear to predict who is at risk for any type of actual accidents in a dose-response fashion.

These preliminary data suggest that near-miss sleepy accidents may be a useful metric for identifying people at risk of accidents and may present an opportunity to develop safety strategies to reduce accidents.[3,13,21-22] This opportunity parallels approaches taken in high-risk industries, such as airline, medicine, and nuclear power industries.[14-18]

This study confirms previous findings that daytime sleepiness, sleep disorders, driving variables, and demographics are associated with actual sleepy accidents. It is important to note that our data demonstrate similar relationships between these predictors and near-miss sleepy accidents. The importance of near-miss sleepy accidents is supported by the consistency of these findings and by the fact that there is a monotonic, independent, dose-response relationship between daytime sleepiness (measured with the Epworth Sleepiness Scale) and near-miss sleepy accidents, and between near-miss sleepy accidents and actual accidents. Furthermore, subjects with 2 to 3 near-miss sleepy accidents had self reported subjective borderline pathological daytime sleepiness (ESS score > 10) and those with ≥4 near-miss sleepy accidents were well into the pathologic range.

The Epworth Sleepiness Scale (ESS)[19,20] was originally designed to assess the propensity of sleep in 8 specific situations. It was used in this study since it has been commonly used in sleep research for motor vehicle accident reporting.[1,2,7,8] Participants were asked to respond to the ESS questions relative to the "present or recent past", whereas the questions about near-miss sleepy accidents were asked relative to the previous 3 years. This could involve a degree of recall bias. In spite of this Maycock[23] used the ESS to evaluate daytime sleepiness in sleepy drivers over a 3-year period and reported ESS scores that under conditions of test-retest showed a high level of internal consistency. It is well known that some controversy exists in the use of the ESS as a metric for subjective sleepiness. For example, while we and others have shown an association between higher ESS scores and accidents[1,8,24] other investigators such as Teran-Santos et al.[25] and Connor et al.[26] have found no such association. Both of these studies were case control studies where cases were defined by injury accidents requiring an emergency room visit (Teran-Santos) or a hospital admission or death (Connor). Our cohort study included any type of accident or near-miss sleepy accident and thus might represent a different population. Furthermore, in these studies of non-anonymous drivers associated with injury accidents, it is

Table 5—Association between Outcome Measures and Sleep Disorders

Medical condition	Sleepy Accident		Odds Ratio (95% CI)		P Value
	Without	With	Unadjusted	Adjusted[1]	
Panel A: Association with Having at Least One Sleepy Accident					
Insomnia	14.2%	24.9%	2.01 (1.63-2.46)	1.77 (1.41-2.22)	<0.0001
Apnea	6.2%	14.3%	2.53 (1.96-3.26)	2.48 (1.86-3.31)	<0.0001
Narcolepsy	0.9%	6.2%	7.31 (4.98-10.7)	3.99 (2.48-6.42)	<0.0001
At least one sleep disorder	18.8%	31.8%	2.01 (1.66-2.43)	1.81 (1.47-2.23)	<0.0001
Panel B: Association with Having at Least One Near-Miss Sleepy Accident.					
Insomnia	13.2%	19.0%	1.53 (1.43-1.65)	1.52 (1.43-1.66)	<0.0001
Apnea	5.7%	9.3%	1.69 (1.53-1.86)	1.83 (1.65-2.04)	<0.0001
Narcolepsy	0.7%	1.8%	2.39 (1.90-3.01)	1.95 (1.53-2.49)	<0.0001
At least one sleep disorder	17.6%	25.2%	1.58 (1.48-1.68)	1.64 (1.53-1.75)	<0.0001

[1]Adjusted analyses adjust for age, sex, family income, miles driven per year, percent driving at night, alcoholic drinks per week.

Table 6—Relationship Between Near-Miss Accidents Associated with Sleepiness and Both Actual Accidents and the Epworth Scale Summary Score

Number of Near-Miss Accidents Due to Sleepiness	Number of Subjects	% of Subjects with at least 1 Actual Accident	Epworth Scale Score	
			Summary Score: Entire Scale	Single item: Doze While in a Car, Stopped for Traffic
0	28479	23.2%	6.57 + 3.4	0.06 + 0.31
1	3705	28.2%	8.41 + 3.5	0.19 + 0.47
2 or 3	2068	31.6%	9.56 + 3.9	0.36 + 0.62
4 or more	631	44.5%	12.1 + 5.3	0.79 + 0.98
P value		<0.0001	<0.0001	<0.0001

Epworth Scale summary score had an independent association with having an actual accident after adjusting for age, sex, marital status, the number of miles driven per week, the percent of miles driven at night, and alcoholic drinks per week.

plausible that the respondents were not fully forthcoming in self-reporting sleepiness for fear of retribution. This type of recall bias was minimized in our cohort because respondents were anonymous. The disparity between reports of the ESS correlating or not correlating with crashes may also lie in the methodology of the individual studies.

We fully acknowledge that the methodology of this investigation has limitations and that there are unavoidable uncertainties. While these results are new in sleep research the data is persuasive and novel and should be tested in a prospective population-based cohort study to overcome many of the significant and inherent limitations of this first study.

We anticipated and also acknowledge the study limitations of an internet-linked survey of a convenience sample of subjects: those who took this survey required knowledge of computer use and the internet, they needed to have some notification of the impending TV presentation and have an interest in the subject matter.

Since this was a cross-sectional study the data lacks the temporal association between near-miss sleepy accidents and actual accidents, which limits the causal link of the association. This survey was self-reported, so accuracy of the response could be spurious. It is possible but unlikely there was significant deliberate misrepresentation by subjects since the data collected were anonymous.

Self-reporting also introduces biases. Recall bias is an unavoidable reality in any epidemiologic study that asks participants to recall prior events, exposures, or experiences. It is quite possible that subjects who had prior accidents were more likely to recall prior near-misses than subjects who had not had a prior accident thus exaggerating the relationship between near-miss and actual accidents. However, it is unlikely that recall bias completely explains the observed association. This potential recall bias does not explain well: 1) the dose-response relationship between the number of near-miss sleepy accidents and the prevalence of having had an actual accident (Table 6); or 2) the consistency of the relationship of near-miss sleepy accidents with expected predictors (Tables 3–5).

Another possible source of bias relates to our use of current daytime sleepiness as a proxy for past sleepiness. We measured concurrent self-reported sleepiness and tested its association with near-miss sleepy accidents and actual accidents recalled from the prior 3 years. Current sleepiness might not reflect sleepiness in the past at the time of the near-miss sleepy accidents or actual accidents. However, Nabi et al.[13] found the self-reported measure of driving while sleepy to be fairly stable over a 3-year period in their large, prospective cohort study on sleepy driving and serious road traffic accidents. Therefore, our concurrent measure of daytime sleepiness probably is a reasonable estimate of past daytime sleepiness in assessing the risk it poses for near-miss sleepy accidents and actual accidents.

This was not a population based sample, and the selection process may well have also produced selection bias in a convenience sample of individuals with internet access that were more educated, had a higher income, and were more likely to be female than the general population. In this cohort, 88% met the inclusion criteria so nearly everyone who entered the survey was eligible. Since most of the excluded 12% did complete the survey and were excluded because they drove less than 1000 miles annually, fewer than 4% of the original sample did not complete the questionnaire. We are troubled due to selection bias, yet we suspect, but would not assert, that due to this exceptionally large cohort (35,217) and the high response rate, there could be some attenuation of selection bias.

It is acknowledged that this questionnaire was not validated. To limit this confound, we used simple questions and attempted to make them as unambiguous as possible to maximize clarity.

Furthermore, most of the questions were purely factual and/or descriptive (e.g., demographics and number of accidents). Nabi et al.[13] used a similar approach in their large, prospective cohort study that showed a dose-response relationship between self-reported sleepy driving and self-reported serious road traffic accidents. We note the fact that the generalizability of our results must be interpreted within the context of this limitation.

It is expected that some readers would have preferred a stepwise selection procedure for the covariates in our tables. We understand this quandary and give the following rationale for our alternative selection choice. The process of selecting covariates in multivariate modeling is inherently subjective and can be done using several approaches. In this case, we decided a priori that all models would adjust for miles driven, percent of driving done at night, and alcohol intake because of the likely association between these variables and accidents, and because we prefer when feasible to avoid the arbitrariness and limitations of standard stepwise selection procedures. The selection of use or non-use of covariates to be partially or fully adjusted was based on the focus we wished to maintain for each table. The last set of data presented in the results section discusses the degree to which near-miss sleepy accidents and the ESS summary score have an independent association with an actual accident. Because we are narrowly focused on the adjusted odds ratios and P values associated with these 2 variables, we did not wish to dilute that focus by presenting a table that would contain odds ratios for the covariates, odds ratios that are not pertinent to the discussion at hand.

Strengths of this study include the large sample size of >35,000 subjects and the use of questions that were short and unambiguous. In addition, the strengths and consistency of the observed associations argue for an important relationship between near-miss sleepy accidents and actual accidents. These analyses tested potential confounding variables and adjusted for those which were important.

We did not evaluate commercial sleepy driving in this study but it is likely near-miss accidents are even more important in this group due to the inherent increased exposure risks (miles driven and time of day). This is suggested by the reports of commercial driver fatigue by Adams-Guppy and Guppy[27] in which over 30% of their sample (n = 700) reported at least one near-miss accident in the previous 3 months.

Further support for utilization of near-miss applications in sleep research is taken from industry applications which have successfully used near-miss strategies to limit actual accidents and thus improve health and safety in the workplace. Their data collectively reports a larger ratio of near-misses to actual accidents in these various industries compared to our reported ratios.[13-15] Their greater sensitivity to detecting near-misses may be due to enforcement of a systematic risk management protocol as well as prospective documentation of near-misses. Near-miss management strategy might be considered for evaluation and integration into a comprehensive sleepy driving program with a similar systematic management paradigm.

The findings of this investigation suggest that driving near-miss sleepy accidents are dangerous precursors to an actual driving accident. Further studies concerning this possibility will be needed to properly establish the scope of the relationship between near-miss sleepy accidents and actual accidents. However, it is suspected that no preliminary study is likely to be better positioned than ours to provide the kind of suggestive data that will justify the expensive prospective studies of this topic that should be conducted.

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APPENDIX: SLEEPINESS AND DISTRACTED DRIVER QUESTIONNAIRE

You have probably already taken the Dateline NBC Distracted Driving Test. You will find out how you scored on that test by tuning in to Dateline NBC on June 19th.
We now welcome you to this web site and invite you to fill out an important questionnaire. Guidance for this questionnaire came from the Stanford University Sleep and Research Center with assistance from other nationally recognized sleep experts and scientists. The information you contribute could substantially assist in reducing accidents and saving lives on the road and in the workplace. Our questions mainly concern information on sleepy drivers, distracted drivers and the relationship to accidents.
Your answers are completely confidential and will be used for research purposes only. We hope you will complete all questions to the best of your ability.
Please select or enter the appropriate response.
When you are done answering the questions, please press the submit button at the end of the form so your data will be recorded.

1. What is your gender?
   Male
   Female

2. What is your age?

3. What is your height?

4. What is your weight? _____ pounds

5. What is your race?
   White
   African American
   Hispanic
   Asian
   Other

6. How much education have you had?
   Less than 12 years
   High school graduate
   Some college
   College graduate
   Post graduate degree

7. What is your marital status?
   Married
   Single
   Separated
   Divorced

8. In the present or recent past, how likely would it be for you to doze off or fall asleep in the following situations? Even if you have not done some of these things recently, try to estimate how they would have affected you. Use the following scale to choose the most appropriate response for each situation.

SITUATION	**CHANCE OF DOZING**			
	Would never doze	**Slight chance of dozing**	**Moderate chance of dozing**	**High chance of dozing**
a) Sitting and reading	____	____	____	____
b) Watching TV	____	____	____	____
c) Sitting inactive in a public place (e.g., a theater or a meeting)	____	____	____	____
d) As a passenger in a car for an hour without a break	____	____	____	____
e) Lying down to rest in the afternoon when circumstances permit	____	____	____	____
f) Sitting and talking to someone	____	____	____	____
g) Sitting quietly after a lunch without alcohol	____	____	____	____
h) In a car, while stopped for a few minutes in traffic	____	____	____	____

9. Please select that which is closest to describing your work schedule.
    I always work a daytime shift.
    I always work an evening shift
    I always work a nighttime shift
    My shift is irregular but it includes some nighttime or evening work
    I am not currently employed

10. How many hours (to the nearest hour) of sleep do you get:
    A) On an average night when you work the next day______hours of sleep (leave blank if you are not working)
    B) On an average night when you are not working the next day______hours of sleep

11. Do you have any of the following sleep abnormalities?
    A) Insomnia
        No
        Yes
        Do not know what insomnia is
    B) Sleep Apnea
        No
        Yes
        Do not know what sleep apnea is
    C) Narcolepsy
        No
        Yes
        Do not know what narcolepsy is

12. About how many alcoholic drinks do you have in an average week
    None
    1-3
    4-6
    7-9 (i.e. 1-1.5 per day)
    10-13 (i.e. 1.5-2 per day)
    14-20 (i.e. 2-3 per day)
    21 or more (i.e., at least 3 per day)

13. Have you driven a motor vehicle for a total of at least 1000 miles during the last 3 years?
    No
    Yes

If you do drive a motor vehicle, please answer the following questions

14. How many miles a year do you drive?
    less than 5000
    5,000-10,000
    10,000-15,000
    15,000-25,000
    25,000-40,000
    greater than 40,000

15. What percentage of your driving is between midnight and 6 AM?
    0-15%
    16-25%
    26-40%
    41-60%
    more than 60%

16. Do you drive professionally?
    No
    Yes

17. How many motor vehicle accidents have you had during the last 3 years?
    None
    1
    2
    3
    4 or more

18. Were any of these accidents associated with being sleepy?
    No
    Yes

19. Have you experienced a near miss accident due to driving sleepy in the past 3 years?
    No
    once
    2-3 times
    4 or more times

20. How sleepy or unusually tired were you feeling at the time of the most recent accident that was not caused by a distraction?
    Fully awake and refreshed
    Slightly tired, but not enough to affect my driving.
    Tired enough that it might have been a partial cause of the accident
    Very tired. This probably contributed to the accident.
    Exhausted. I either fell asleep at the wheel or am otherwise certain that being tired was the cause of the accident.
    Do not recall

21. What is your annual household income?
    0-$5,000
    $5,000-$10,000
    $10,000-$20,000
    $20,000-$30,000
    $30,000-$50,000
    $50,000-$75,000
    $75,000-$100,000
    Greater than $100,000

22. Do you wear seat belts when you drive?
    Always (100% of the time)
    Most of the time (75-95% of the time)
    More than 50% of the time
    Less than 50% of the time
    Seldom (less that 25% of the time)
    Never
    Bottom of Form

Thank you for completing this questionnaire. Please press the submit button below to submit your responses.