

Three Measures of Sleep, Sleepiness, and Sleep Deprivation and the Risk of Injury: A Case-Control and Case-Crossover Study

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Purpose: Sleepiness and sleep deprivation are associated with injury, but few case-control studies have addressed them. We sought to add to the body of analytic observational studies.

Methods: Case-control and case-crossover study of 2517 injured patients interviewed in person in 3 emergency departments and matched by age, sex, rural versus urban, day of week, and hour of day with 1856 controls. Sleep constructs were measured by the following: (1) self-perceived sleepiness at injury or matched control time using 3 adjectives (tired, sleepy, drowsy); (2) usual sleep quality and quantity, and differences in those in the past 7 days; and (3) hours of sleep in the 24 hours before injury and the 24 hours before that.

Results: Better sleep quality in the past 7 days was associated with a lower risk of injury (odds ratio (OR) 0.88, 95% confidence interval (CI) 0.80 to 0.97). Self-reported sleepiness just before injury compared with control time was associated with a lower risk of injury, with ORs of 0.82 per unit on a 0-to-12 scale (95% CI 0.78 to 0.86) in case-control analysis and 0.76 (0.73 to 0.80) in case-crossover analysis. In case-crossover analysis, additional sleep in the 24 hours before injury compared with the 24 hours before that was associated with an increased risk of injury (OR 1.06 per hour, 95% CI 1.03 to 1.09), but this effect disappeared when we controlled for activity, location, and recent alcohol consumption.

Conclusions: Better recent sleep quality was associated with a lower risk of injury, but surprisingly, feeling sleepy was also. (J Am Board Fam Med 2007;20:16–22.)

Many studies have addressed possible associations between sleep problems and injury risk. Most are case series or cross-sectional studies.^{1–3} Other than laboratory studies,^{4,5} randomized clinical trials are obviously impossible, and analytic studies of injury per se are limited to case-control designs. In their 2001 review, Connor and colleagues¹ found only

one case-control study, but it focused on sleep apnea, not ordinary sleep deprivation or self-perceived sleepiness.⁶

We have identified 9 other case-control studies.^{7–15} Only 3 examined sleepiness or recent hours of sleep in adults. Cummings et al¹⁵ compared 200 drivers in Washington State who crashed (only 50 of whom, though, were injured) with 199 controls matched for driving location, day of week, and time of day. Drivers “who felt like they were falling asleep” were more likely to be injured (OR 14.2), as were those who had slept 9 or fewer hours in the past 48 hours. But the authors also reported an increased risk among drivers who had gotten 21 or more hours of sleep in the past 48 hours, and they found that drivers who reported yawning were less likely to crash (OR 0.4).¹⁵

The other 2 case-control studies were similar. Connor et al¹⁴ compared 571 New Zealand drivers involved in injury crashes with 588 controls. A dichotomized measure of feeling sleepy was strongly associated with injury (OR 8.2, 95% CI 3.4 to 19.7), as was getting 5 hours or less of sleep in the previous 24 hours (OR 2.7, 95% CI 1.4 to

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*Words presented in italics are the words used in the interviews.

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Table 1. Description of Participants

	All Cases (N = 2517) Number (%)	Cases from Covered ED Shifts (N = 2161) Number (%)	Community Controls (N = 1856) Number (%)
Gender			
Women	1085 (43.1)	967 (44.7)	908 (48.9)
Men	1432 (56.9)	1194 (55.3)	948 (51.1)
Age			
18 to 20 years	419 (16.6)	379 (17.5)	201 (10.8)
21 to 29	716 (28.4)	636 (29.4)	560 (30.2)
30 to 44	761 (30.2)	658 (30.4)	616 (33.2)
45 to 64	421 (16.7)	325 (15.0)	329 (17.7)
65 and older	200 (7.9)	163 (7.5)	150 (8.1)

5.4). Liu et al⁷ compared 406 Chinese drivers with 438 controls and found a significant association between chronic sleepiness and crash risk (OR 2.07, 95% CI 1.30 to 3.29), but no significant association with acute sleepiness (OR 0.63, 95% CI 0.22 to 1.82) or with having had 5 or fewer hours of sleep in the previous 24 hours (OR 0.94, 95% CI 0.39 to 2.28). Both studies used the Stanford Sleepiness Scale to measure acute sleepiness, which uses a single question with 7 ordered answer options, and both controlled for time of day statistically.

We conducted a case-control and case-crossover study.¹⁶ In the interviews with cases and controls, we gathered data about sleepiness, usual sleep, and recent hours of sleep, and in this study present analyses of those data.

Methods

Cases were patients presenting for care of a recent injury to 1 of the 3 emergency departments in Boone County, MO, from February 1998 through March 2000, and recruited during systematically selected 12-hour shifts ("covered shifts," n = 2199). We added a convenience sample of inpatients who had been admitted because of the severity of their injuries (n = 358). A total of 2517 patients completed the structured interview. Of eligible patients, 86% were approached, and of those 86% responded. All 3 hospitals' Institutional Review Boards approved the study. Further details of the methods are in a previous study.¹⁶ Table 1 shows demographic information about the participants.

Of the 2199 cases from covered shifts, 27% were injured in a fall, 19% were struck by an object, 18% were in a motor vehicle crash, and the rest were

injured by a variety of mechanisms. Of the 358 patients from uncovered shifts, who generally had more serious injuries and had been admitted to the hospital, 61% were injured in a motor vehicle crash and 19% in a fall.

A population-based control group (n = 1856) was recruited by random-digit dialing. The response rate was 47%. They were matched to cases from covered shifts by age (5 strata), sex, and urban versus rural residence. At the time of the control person's interview, each was further matched to a specific case's injury event by day of the week and hour of the day, and time-specific questions then focused on that reference day of the week and hour of the day.

Sleep was examined 3 ways. First, we asked each case how *sleepy*, *tired*, and *drowsy** they felt just before the injury and 24 hours before, and asked controls the same questions referencing the matched time. Each used a 5-point scale from "not at all" to "extremely." These 3 were among 21 items regarding emotional states, most drawn from the Positive Affect Negative Affect Schedule.^{17,18}

Second, we asked each respondent their usual quantity (in hours per night) and quality of sleep (using a 5-point ordinal scale), and the quantity and quality of their sleep in the past 7 days, compared with their usual sleep (also using 5-point ordinal scales).

Third, we asked cases about specific times of going to sleep and waking up during the 48 hours before injury. From these data, we calculated the number of hours the participant had been awake, the total hours of sleep in the immediately preceding 24 hours, and the number of hours of sleep in

Table 2. Measures of Sleepiness, Quality, and Quantity of Recent Sleep and Risk of Injury

	Case-Crossover Analyses	Case-Control Analyses
Self-perceived sleepiness at injury or matched time		
Per unit on a 0-to-12 scale	0.78 (0.75 to 0.81)	0.74 (0.72 to 0.77)
Dichotomous: >0 vs 0	0.47 (0.39 to 0.55)	0.27 (0.23 to 0.33)
Trichotomous: 1 to 3 vs 0	0.60 (0.50 to 0.72)	0.48 (0.39 to 0.59)
4 to 12 vs 0	0.24 (0.18 to 0.30)	0.14 (0.11 to 0.17)
Usual Sleep		
Quality (per point on a 5-point ordinal scale)	Because these variables address longer-term constructs, only case-control analyses are possible.	1.04 (0.98 to 1.10)
Quantity (per hour)		0.98 (0.94 to 1.03)
Quantity in past 7 days compared with your usual (per point on a 5-point ordinal scale)		0.97 (0.90 to 1.05)
Quality in past 7 days compared with your usual (per point on a 5-point ordinal scale)		0.88 (0.80 to 0.97)
Sleep in past 48 hours		
Sleep in past 24 hours compared with the 24 hours before that, per hour	1.06 (1.03 to 1.09)	Data not available from control group.
Last episode of sleep compared with the previous one, per hour	1.01 (0.98 to 1.04)	
Trichotomous, past 24 hours compared with previous 24 hours		
Less than 5 hours compared with 5 to 9 hours	0.88 (0.68 to 1.13)	
10 hours or more compared with 5 to 9 hours	1.28 (1.07 to 1.55)	
Sleep in past 24 hours compared with usual quantity (per hour)	1.29 (1.24 to 1.34)	

ORs (95% CI).

the 24 hours from 25 to 48 hours before injury. Similar data from controls are not available.

With the first and third ways of measuring sleep and sleepiness, we compared each injured patient with him- or herself, comparing how sleepy they felt just before the injury with how sleepy they felt 24 hours before, and comparing the number of hours of sleep in the immediately preceding 24 hours with the number in the 24 hour interval before that. This case-crossover design¹⁹ avoids confounding by any stable within-subject trait, but has obvious potential for recall bias. With the first and second ways of assessing sleep and sleepiness, we compared injured cases with matched community controls.

Activity at specified times (just before injury for cases, reference time for controls) was coded using the biaxial coding system developed by the Nordic Medico-Statistical Committee (NOMESCO), which specifies the purpose or intention of the person's activity (5 categories, eg, work, leisure) and the pattern of movement (7 categories, eg, walking, lifting).²⁰ Location at the time of the injury or, for controls, the matched time was coded using NOMESCO codes.²⁰

The unit of analysis was a single injury event, with controls matched on time and person (the same individual in case-crossover analyses, and a matched control in case-control comparisons). Analyses used conditional logistic regression,²¹ with strata defined by the matching variables (age, sex, rural versus urban, day, and time). Because previous case-control studies have focused on traffic injuries, we also did subgroup analyses of the cases with traffic injuries.

Results

Self-Perceived Sleepiness

Of 2517 cases, 17 were asleep at the time of injury and 332 (13%) were asleep 24 hours before. Of 1856 community controls, 306 (17%) were asleep at the matched time. Cronbach's α for the 3 sleepiness variables (*sleepy, tired, drowsy*) was 0.86 among cases, 0.87 among controls. We summed them, creating a scale scored from 0 ("not at all" on all 3 variables) to 12 ("extremely" on all 3).

In case-crossover analyses, each point on this scale was associated with an OR of 0.78 (Table 2), 0.74 in case-control analyses. OR using dichoto-

mous (0 versus all other values) and trichotomous analyses (with values of 0, 1 to 3, and 4 and above) were lower. The ORs were similar when analyses were limited to cases with traffic injuries.

When activity, location, and drinking in the 6 hours before injury or matched time were entered into the models, the ORs for sleepiness did not change substantially in either case-crossover or case-control analyses and remained statistically significant.

Usual Quantity and Quality of Sleep, and Past-Week Changes (Case-Control Analyses)

The mean number of hours respondents usually slept was 6.9 for both cases and controls (SD 1.4 and median 7 for both; OR 0.98). Usual quality of sleep, reported on a 5-point ordinal scale, was also similar (OR 1.04). Quantity of sleep in the past 7 days compared with the respondent's usual number of hours of sleep did not differ between cases and controls (OR 0.97). None of these ORs were substantially different when we limited the analyses to just those cases with traffic injuries.

Quality of sleep in the past 7 days compared with usual quality differed minimally. Among cases, 19% reported worse sleep than usual, and 8% reported better quality. Among controls the proportions were 17% and 9%, respectively. The OR was 0.88, with better recent sleep quality associated with lower risk of injury. Limiting the analysis to just those cases with traffic injuries, the OR was 0.91 (95% CI 0.77 to 1.07).

We did further analyses using dummy variables to represent those with worse sleep, the same quality, or better sleep than their usual. Analyzing these categorically, the OR for worse sleep was 1.17 (95% CI 0.99 to 1.38), and that for better sleep was 0.86 (95% CI 0.69 to 1.09). Repeating these analyses including only cases with traffic injuries and their matched controls, the OR for relatively worse sleep than usual was 0.92 (95% CI 0.68 to 1.25), and for relatively better sleep quality, 0.74 (95% CI 0.48 to 1.13). Considering all injuries, when drinking in the previous 6 hours, activity, and location were entered into the model, the ORs were closer to 1 (1.13 for worse sleep, 0.86 for better sleep), and neither was statistically significant.

Number of Hours of Sleep in the Past 24 (Case-Crossover Analyses)

Using data from 2505 patients, the mean hours of sleep in the 24 hours before injury was 7.6 (median

8, SD 2.4), and the mean for the 24 hours before that (here, the control time) was 7.4 (median 7, SD 2.4). The OR (per hour of sleep) was 1.06. When we entered activity, location, and alcohol consumption in the 6 hours before injury (or matched time for controls) in the model, the OR was 1.01 and was no longer significant.

We then analyzed the number of hours of sleep using ordinal categories. Compared with 5 to 9 hours of sleep in the past 24 hours, the OR was 0.88 for less than 5 hours, and 1.28 for 10 or more hours (Table 2). Entering activity, location, and past-6-hour drinking in the model, the ORs were 1.14 and 1.01, respectively, and neither was significant (Table 3).

Including only cases with traffic injuries in the analyses, the OR was 1.13 (95% CI 1.06 to 1.20) per hour of sleep. Entering activity, location, and past-6-hour alcohol consumption, the ORs changed little (1.12), but was no longer significant (95% CI 0.94 to 1.32). Using ordinal categories for hours of sleep, the ORs were 0.67 (95% CI 0.41 to 1.11) comparing less than 5 with the reference category of 5 to 9 hours, and 1.49 (95% CI 1.03 to 2.15) comparing 10 or more hours with 5 to 9. With activity, location, and drinking in the model, the ORs were 0.63 (95% CI 0.18 to 2.15) and 1.12 (95% CI 0.39 to 3.27), respectively.

Case-crossover analyses comparing the episode of sleep closest to injury with the episode before that showed no association with injury risk. Whether we included only those with just 2 episodes of sleep in 48 hours or all patients, and whether we included naps as "episodes" or not, the ORs were 0.98 to 1.01 and not significant. Limiting analyses to traffic injuries, the ORs were a little higher (around 1.05), but not statistically significant.

We compared the number of hours the patient had been awake before injury with the number of hours the same person had been awake at the same time the day before. That number varied from 0 (asleep at the time of injury or matched time, and these people were omitted from these analyses) to 24 (truncated at that point). The mean was 9.1 hours for cases on the day of injury (median 9, SD 4.8, interquartile range 5 to 13 hours) and 8.8 for the day before (median 9, SD 4.5, interquartile range 5 to 12 hours). We found no association between the number of hours the person had been awake and injury (OR 1.00, 95% CI 0.97 to 1.04).

Table 3. Measures of Sleepiness, Quality, and Quantity of Recent Sleep and Risk of Injury, Controlling for Activity, Location, and Drinking in the Previous 6 Hours

	Case-Crossover Analyses	Case-Control Analyses
Self-perceived sleepiness at injury or matched time		
Per unit on a 0 to 12 scale	0.82 (0.78 to 0.86)	0.76 (0.73 to 0.80)
Dichotomous: >0 vs 0	0.56 (0.45 to 0.70)	0.29 (0.24 to 0.37)
Trichotomous: 1 to 3 vs 0	0.67 (0.53 to 0.84)	0.49 (0.38 to 0.63)
4 to 12 vs 0	0.30 (0.22 to 0.42)	0.16 (0.12 to 0.21)
Usual sleep		
Quality (per point on a 5-point ordinal scale)		
Quantity (per hour)		
Quantity in past 7 days compared with your usual (per point on a 5-point ordinal scale)		
Quality in past 7 days compared with usual		0.87 (0.76 to 1.01)
Sleep in past 48 hours		
Sleep in past 24 hours compared with the 24 hours before that	1.01 (0.97 to 1.05)	
Last episode of sleep compared with the previous one	1.00 (0.96 to 1.04)	
Trichotomous, past 24 hours compared with previous 24:		
Less than 5 hours compared with 5 to 9 hours	1.14 (0.81 to 1.61)	
10 hours or more compared with 5 to 9 hours	1.01 (0.78 to 1.31)	
Sleep in past 24 hours compared with usual quantity (per hour)	1.01 (0.96 to 1.05)	

OR (95% CI).

Discussion

In our multifaceted analyses of sleepiness and sleep deprivation, we found little evidence for associations between sleep and injury. We found some surprisingly protective associations, although those associations disappeared in some analyses when we controlled for activity, location, and drinking in the previous 6 hours.

Our study has a number of strengths. We measured sleepiness and sleep deprivation in 3 different ways. We gathered data using a structured interview, comparing cases not only with the population-based control group, but also with themselves, an analysis that controls perfectly for any personal characteristic that does not change from one day to the next. Multiple comparisons increase the risk of a type 1 error; but in this study, despite multiple comparisons, we found little evidence for the expected associations between sleep deprivation or sleepiness and injury risk.

Subjective sleepiness was associated with a significantly lower risk of injury. The association was found in both case-crossover and case-control analyses, and it persisted despite controlling for several potential confounding variables. People who feel sleepy may choose not to engage in activities (eg, sports) or to stop activities (eg, driving) that are associated with injury risk, but controlling for lo-

cation and activity in the models had little effect, suggesting that limiting one's activity may not mediate this apparent protective effect.

In the expected direction, better quality of sleep in the past 7 days was also associated with lower risk, although the magnitude of the association was reduced when we controlled for drinking, activity, and location.

In case-crossover analyses, amount of sleep in the previous 24 hours was minimally but positively associated with injury, but this association essentially disappeared when we controlled for drinking in the previous 6 hours, activity, and location.

Of the 9 case-control studies that we have found, only 3 addressed the same sleep constructs as our study in adults. Connor et al¹⁴ found strong associations of injury risk with self-reported acute sleepiness and past-24-hour sleep deprivation. However, using similar methods, Liu et al⁷ did not, with nonsignificant ORs lower than 1. Both these previous studies were limited to traffic injuries. When we limited our analyses to the 600 patients with traffic injuries (and their matched controls), the ORs for sleepiness were still significantly less than 1. Cummings et al¹⁵ found a strong association between self-reported sleepiness and crash risk, but a protective effect of yawning, which is surprising, given that yawning often accompanies

feeling sleepy. They found increased risk with substantially fewer hours of sleep in the previous 48 hours than the average for the sample, but found similarly increased risk with more than 20 hours of sleep in the previous 48. The inconsistent findings within and among these 3 studies suggest that our findings, although in some aspects surprising, may be valid.

The first major limitation of our study is that all data were retrospective self-reports, and recall and reporting bias were probably different in cases and controls. In case-crossover analyses, for example, we compared sleepiness just before the injury with sleepiness 24 hours before; and recalling the more recent perception of sleepiness would be easier than recalling the more remote. Cases' recall of sleepiness just before the injury might also have been facilitated (or perhaps distorted) by the salience of the event itself, but there was no salient event linked to the matched control time for either cases the day before injury or for community controls. Furthermore, we have some indications that community controls were not as engaged in the interview process as cases, at least in reporting recent alcohol consumption,²² and similar reporting bias may have affected the accuracy of their data regarding sleep.

Second, the response rate in the control group was only 47%. Those who did not answer their phones or chose not to participate when reached may have had sleep patterns different from those who participated. However, findings were similar when we compared cases with themselves, a group in which this kind of selection bias was not present.

Third, our control for potential confounders, especially activity at the injury or matched time, was probably incomplete. When we entered our measure of activity into various models, it sometimes made a significant effect disappear, raising the possibility that more fine-tuned measures of activity might have affected the association more.

In our study of a wide variety of injury mechanisms, better quality of sleep in the past 7 days was associated with a lower risk of injury, as we expected. In contrast, feeling sleepy was associated with decreased injury risk, suggesting that the relationships between various aspects of sleep and injury risk are not always what one might expect. Such surprising findings have been noted only occasionally in previous publications^{7,15} and in our study might be due to confounding or reporting

bias. However, they may be real, although indirect, associations; feeling sleepy, for example, could prompt a change in behavior, which in turn reduces injury risk. Future studies could explore such hypotheses raised by our study.

However, a major conclusion from our study may simply be that sleepiness and sleep deprivation, at least as they are commonly experienced, are weakly and inconsistently associated with injury risk. Future research may more profitably focus on other risk factors that are more strongly associated with injury, such as drinking.¹⁶

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