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Original Contributions

Sleep quantity and quality as a predictor of injuries in a rural population☆

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Abstract This study aimed to assess the association of sleep disturbance and injuries in a rural population of Iowa. Study participants were 1345 adults who were enrolled in the KCRHS. Sleep problems were assessed based on self-reports at the beginning of the study. Injury information was collected by telephone interviews an average of every 6 months from August 1999 to June 2004. Sleeping for less than 7.5 hours increased the risk for injuries by 61% (rate ratio, 1.61; 95% confidence interval, 1.21-2.15) compared with sleeping for 7.5 to 8.5 hours (reference). Snoring frequency/severity and daytime fatigue/sleepiness were not significant in predicting the risk for injuries. Alcohol consumption of 1 to 2 or more drinks per day increased the risk for injuries among those who had sleep problems. Having adequate hours of sleep is important in preventing injuries. Avoiding alcohol consumption would be especially helpful in reducing injuries among people with sleep disturbance.

1. Introduction

Sleep disturbance has been studied as a risk factor for injuries because it may compromise daytime performance through sleepiness, fatigue, and cognitive impairment. Several dimensions of sleep disturbance may be hypothesized in injury causation. In sleep disordered breathing, which is characterized by heavy snoring, sleep is repeatedly interrupted by short arousals. As a consequence, heavy snoring may lead to poor quality of sleep [1,2]. Reduced sleep hours, which indicate poor quantity of sleep, may result in sleep that is insufficient for the body's needs. Both snoring and reduced sleep hours may be associated with daytime fatigue/sleepiness, which reduces performance capability through slow information processing, delayed response, increased reaction time, and reduced attentiveness. This may lead to human error and could increase the risk for injury [3-6].

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Driver sleepiness has been identified as an important contributor to motor vehicle crashes in a number of earlier studies [7-11]. Patients with clinically diagnosed sleep disordered breathing showed poor performance on driving simulation tests [12-14] and had 2 to 7 times higher rates of motor vehicle crashes than patients without sleep disordered breathing [15-20]. A significant association between sleep-disordered breathing and motor vehicle crashes was also found in a population-based sample of employed adults [21].

Sleep disturbance has been explored as a risk factor for occupational injuries in previous studies. Rotating-shift and night-shift work have both been associated with a higher risk for work-related injuries [22-25]. Six or fewer hours of sleep increased the risk for work-related injuries among veterinarians [26]. Sleep problems, defined as less than 6 hours of sleep per day and/or not sleeping well, and/or regular consumption of sleeping pills, increased the risk for work-related injuries in railway and construction workers [27,28]. Sleep disordered breathing/snoring and daytime sleepiness were associated with an increased risk for occupational injuries [29-32].

The mechanism of sleep disturbance in injury causation may be applied to rural populations beyond drivers and workers. Although a substantial amount of research has been done to investigate the etiology of injuries in rural populations, especially in farmers, few examined the potential impact of sleep disturbance on injury risk. In the only related study, Spengler et al [33] found that sleep apnea symptoms and sleep medication use were related to increased injury incidence among part-time farmers. We conducted this study to evaluate sleep quantity and quality as a risk factor for injuries in a rural population in Iowa. Sleep quantity was measured as the average number of hours slept per night. Sleep quality was measured as snoring frequency and severity. Daytime fatigue and sleepiness were also assessed.

2. Methods

2.1. The KCRHS

This study was conducted as part of the Keokuk County Rural Health Study (KCRHS). The KCRHS is a 20-year prospective cohort study focusing on chronic disease and injury in a rural community in Iowa. The KCRHS is described by Merchant et al [34]. Data for this analysis are from the second round of cohort interviews for the KCRHS, which began in March 1999 and ended in April 2005.

Households were sampled separately from farm, rural nonfarm, and town areas through stratified random sampling. Of the 3749 households invited, 273 were not eligible because of deaths, institutionalizations, and moving out of the county; 1204 cannot be reached by phone; and 1262 declined to participate. One thousand two households participated, which included 311 farm, 128 rural nonfarm, and 563 town households. These 1002 households included 1582 individual participants older than of 18 years. All study subjects signed informed consent forms.

2.2. Assessment of sleep problems

Sleep questions were administered through personal interviews conducted by a trained nurse in the study clinic. The sleep questions analyzed in this study were the frequency and severity of snoring, feeling of fatigue or sleepiness in the daytime, and average hours slept per night. The snoring questions were answered by participants according to what they had been told by others sleeping in the same room. The sleep hours were calculated by averaging sleep hours on weekday/weekend nights and those from naps. The sleep questions are attached in the Appendix.

The categories of snoring frequency were collapsed into 3 categories: (1) never/rarely or a few nights per month, (2) once or several nights per week, and (3) every night. The categories of snoring severity were also collapsed into 3 categories: (1) never/rarely snore or slightly louder than heavy breathing, (2) as loud as talking or louder, and (3) extremely loud or uses a continuous positive airway pressure (CPAP) device. Sleep hours were categorized into 3 levels: less than 7.5, 7.5 to 8.5, and 8.5 or more hours.

2.3. Injury follow-up calls

We conducted follow-up phone calls for the households enrolled in the study to obtain self-reported injury information at regular intervals. Households were eligible for the follow-up phone call interviews once they completed the sleep questionnaire. The follow-up phone call data collected between August 1999 and June 2004 were used in our study. Injury information on 843 households with 1345 participating individuals was available.

Trained interviewers called each household to ask about the injury experiences of all adult cohort participants in the household from the date of the last interview to the present. A single informant, who was an adult member in the household, provided injury information for all family members as well as of himself/herself. Follow-up interviews were conducted at an average of every 6 months.

Injury in this study was defined as an incident that restricted normal activities for at least 4 hours; caused loss of consciousness, loss of awareness, or loss of memory for any length of time; or caused the subject to seek care from a health professional, including doctor, physician assistant, nurse, chiropractor, or dentist.

2.4. Analysis

Injury rates were calculated and compared among levels of sleep variables and potential confounding variables. Potential confounding variables included in the analysis were age, sex, general health status, current alcohol use, and depression status. The selection criteria for confounding

variables required that they had been related in previous literature to both sleep variables and injury outcomes [35-43]. Multivariate Poisson regression models were developed to predict injury rates as the outcome variable, with accrued exposure time as the denominator. Rate ratios (RRs) of injury for sleep variables were calculated while adjusting for other covariates. Clustering of participants within the same household was controlled using the Generalized Estimation Equation method [44,45].

Interactions of sleep variables with sex and with alcohol use were examined. Interactions were evaluated by calculating the RRs of injuries for sleep variables separately in men and women and in each level of current alcohol use (none, <1-2 drinks per day, and ≥1-2 drinks per day).

3. Results

3.1. Demographic characteristics

The proportion of females (56.1%) was slightly higher than that of males (43.9%). Age ranged from 18 to 92 years, with 59.5% of the population between 45 and 74 years. Most subjects (92.1%) were high school graduates or above. More than half of the study subjects (54.0%) lived in towns, and nearly a third lived on a farm (Table 1).

Table 1 Demographic characteristics of study subjects (n = 1345)

Characteristics	n (%)
Sex	
Male	590 (43.9)
Female	755 (56.1)
Age (y)	
18-34	117 (8.7)
35-44	245 (18.2)
45-54	275 (20.5)
55-64	255 (19.0)
65-74	269 (20.0)
75-92	184 (13.7)
Education	
Less than high school graduate	106 (7.9)
High school graduate	609 (45.3)
Some college	392 (29.1)
College/university graduate	114 (8.5)
Some graduate school or above	124 (9.2)
Marital status	
Married or living with a partner	1082 (80.6)
Divorced, separated, or widowed	194 (14.4)
Never married	67 (5.0)
Residence type	
Town	726 (54.0)
Rural nonfarm	177 (13.2)
Rural farm	442 (32.9)

Table 2 Injury rates by levels of sleep and potential confounding variables

Variables	Person-years	Injury frequency	Injury rate
Snoring frequency			
Never/rarely or a few nights per month	1374.8	164	11.9
Once or several nights per week	464.5	41	8.8
Every night	560.1	75	13.4
Snoring severity			
Never/rarely snore or slightly louder than heavy breathing	1111.9	134	12.1
As loud as talking or louder than talking	907.1	98	10.8
Extremely loud or use CPAP	209.4	33	15.8
Daytime fatigue			
No	1784.9	197	11.0
Yes	890.5	118	13.3
Daytime sleepiness			
No	2277.4	264	11.6
Yes	385.5	52	13.5
Sleep hours			
≥7.5, <8.5	932.8	83	8.9
<7.5	1244.0	172	13.8
≥8.5	500.7	61	12.2
Sex			
Female	1496.9	159	10.6
Male	1180.6	157	13.3
Age (y)			
18-44	671.1	81	12.1
45-54	534.0	52	9.7
55-69	763.8	90	11.8
70-92	708.7	93	13.1
General health			
Excellent	401.4	48	12.0
Very good	1067.3	109	10.2
Good	909.5	107	11.8
Fair or poor	293.6	52	17.7
Current alcohol use (drinks per day)			
None	1052.9	141	13.4
<1-2	1379.1	143	10.4
≥1-2	245.6	32	13.0
Depression status (CES-D)			
<8	2317.4	256	11.1
≥8	360.2	60	16.7

CES-D indicates Center for Epidemiologic Studies Depression Scale (11 item).

3.2. Injury rates

Our study subjects reported 316 injuries during the 2677.6 person-years of follow-up time for an overall injury

rate of 11.8 cases per 100 person-years (Table 2). During the follow-up period, 81.7% of subjects reported no injuries, 14.5% reported 1 injury, and 3.8% reported 2 or more injuries (up to 6). The home was the most frequent location of injury (44.6%), followed by the farm (14.4%) and the street or highway (8.5%). Table 2 shows accrued person-time, injury frequency, and injury rates for sleep and confounding variables.

3.3. Sleep variables and injuries

Sleeping for less than 7.5 hours increased the risk for injuries 1.61 (95% confidence interval [CI], 1.21-2.15) times that of sleeping for 7.5 to 8.5 hours, which was used as a reference (Table 3). Those sleeping 8.5 hours or more had 1.25 times higher risk for injuries compared with the reference, although this was not statistically significant. Other sleep variables, including snoring frequency/severity and daytime fatigue/sleepiness, were not significant in predicting the risk for injuries. Among the covariates included in multivariate models, only sex was consistently associated with the risk for injuries.

We assessed the effect of mutually adjusting sleep variables by incorporating several sleep variables together in the multivariate model. The injury RRs for each sleep variable did not change significantly when mutually adjusted when compared with injury RRs in models including sleep variables separately.

Table 3 Adjusted RRs of injury for sleep variables

Variables	RR	95% CI
Snoring frequency		
Never/rarely or a few nights per month	1.00	
Once or several nights per week	0.74	0.52-1.06
Every night	1.06	0.78-1.46
Snoring severity		
Never/rarely snore or slightly louder than heavy breathing	1.00	
As loud as talking or louder than talking	0.91	0.68-1.23
Extremely loud or use CPAP	1.23	0.77-1.96
Daytime fatigue		
No	1.00	
Yes	1.05	0.77-1.42
Daytime sleepiness		
No	1.00	
Yes	0.98	0.67-1.44
Sleep hours		
≥7.5, <8.5	1.00	
<7.5	1.61	1.21-2.15
≥8.5	1.25	0.82-1.90

The multivariate Poisson regression models adjust for age, sex, general health, current alcohol use, and depression status.

Table 4 Adjusted RRs of injury for sleep variables in male and female

Variables	Male		Female	
	RR	95% CI	RR	95% CI
Snoring frequency				
Never/rarely or a few nights per month	1.00		1.00	
Once or several nights per week	0.71	0.43-1.16	0.79	0.45-1.38
Every night	0.90	0.59-1.39	1.18	0.71-1.95
Snoring severity				
Never/rarely snore or slightly louder than heavy breathing	1.00		1.00	
As loud as talking or louder than talking	0.63	0.41-0.96	1.30	0.88-1.92
Extremely loud or use CPAP	0.82	0.43-1.57	1.78	0.78-4.10
Daytime fatigue				
No	1.00		1.00	
Yes	0.93	0.56-1.54	1.15	0.79-1.66
Daytime sleepiness				
No	1.00		1.00	
Yes	0.62	0.31-1.22	1.39	0.85-2.27
Sleep hours				
≥7.5, <8.5	1.00		1.00	
<7.5	1.82	1.18-2.79	1.38	0.93-2.05
≥8.5	1.70	1.01-2.84	1.02	0.55-1.87

The multivariate Poisson regression models adjust for age, general health, current alcohol use, and depression status.

3.4. Sex and alcohol drinking as an effect modifier

Sex modified the association of sleep and injury risk (Table 4). For the categories of less (<7.5 hours) and more sleep hours (≥8.5 hours), men had a greater risk for injury than women. On the contrary, for severe snoring and daytime sleepiness, women had a higher risk for injury than men. The risk for injury generally increased as the sleep problem worsened in women, whereas this did not occur in men.

Drinking alcohol also modified the relationship between sleep and injury risk (Table 5). In general, there was no or little association between sleep variables and injury in those who did not drink or drank only 1 or 2 drinks per day. However, there was an association between sleep and injury risk among those who drank more. The association of fewer sleep hours and injury showed a dose-response relationship across the categories of current alcohol use. Thus, sleeping for less than 7.5 hours increased the risk for injuries by 27%

Table 5 Adjusted RRs of injury for sleep variables by categories of current alcohol use

Variables	None		<1-2 drinks per day		≥1-2 drinks per day	
	RR	95% CI	RR	95% CI	RR	95% CI
Snoring frequency						
Never/rarely or a few nights per month	1.00		1.00		1.00	
Once or several nights per week	0.78	(0.46-1.34)	0.77	(0.46-1.31)	0.61	(0.20-1.86)
Every night	1.13	(0.70-1.81)	0.79	(0.49-1.29)	1.49	(0.55-3.99)
Snoring severity						
Never/rarely snore or slightly louder than heavy breathing	1.00		1.00		1.00	
As loud as talking or louder than talking	1.03	(0.67-1.56)	0.78	(0.50-1.21)	1.25	(0.46-3.36)
Extremely loud or use CPAP	0.96	(0.48-1.93)	0.97	(0.49-1.93)	2.61	(0.62-10.93)
Daytime fatigue						
No	1.00		1.00		1.00	
Yes	0.93	(0.60-1.44)	0.91	(0.62-1.35)	2.82	(0.86-9.23)
Daytime sleepiness						
No	1.00		1.00		1.00	
Yes	0.90	(0.56-1.46)	0.85	(0.50-1.47)	2.65	(0.16-43.87)
Sleep hours						
≥7.5, <8.5	1.00		1.00		1.00	
<7.5	1.27	(0.86-1.87)	1.80	(1.16-2.78)	3.44	(1.21-9.78)
≥8.5	1.25	(0.72-2.17)	1.11	(0.61-2.04)	1.38	(0.33-5.79)

The multivariate Poisson regression models adjust for age, sex, general health, and depression status.

among nondrinkers, 80% in those who drank 1 or 2 drinks per day, and 244% in those who drank more than 2 drinks per day.

4. Discussion

Among the sleep variables tested in our study, sleeping for less than 7.5 hours was the only significant factor in increasing injury risk. Men with both less and more sleep hours were more at risk for injuries than women, whereas women with severe snoring and daytime sleepiness were more at risk for injuries than men. Drinking alcohol aggravated the risk for injuries among those who had sleep problems.

Adequate sleep hours are important in maintaining daytime alertness. In general, most healthy adults need an average of 8 hours of sleep at night [35], whereas the average sleep hours at night in our study participants were lower (7.2 ± 1.1 hours). In our study, sleeping between 7.5 and 8.5 hours was associated with the lowest rate of injuries. The risk for injuries slightly increased as the sleep hours exceeded 8.5 hours. The reason for this increase is not clear but could be due to chance or to certain health conditions associated with more sleep hours (eg, hypersomnolence). In previous studies [26-28], less than 6 hours of sleep was associated with the risk for work-related injuries in veterinarians, railway, and construction workers. In a study by Melamed and Oksenberg [30], more than average sleep hours (≥9 hours) was significantly associated with injury risk. On the contrary, Spengler et al [33] did not find any significant association between sleep hours and injuries in their study of part-time Kentucky farmers.

In this study, snoring frequency/severity and daytime fatigue/sleepiness were not associated with the risk for injuries. This is contradictory to the results of other studies that found that sleep disordered breathing/snoring and daytime sleepiness were significant risk factors for motor vehicle crashes and occupational injuries [7-11,29-32]. The sleep questionnaire used in our study might have been inadequate for properly assessing snoring and daytime sleepiness. Another possible explanation is that the studies showing positive associations between sleep disturbance and injuries were mostly done in a homogenous group of drivers and workers. The heterogeneity of individual characteristics mixed with multiple injury types in our study population might have confounded the association of snoring/daytime sleepiness and specific types of injuries.

The role of sex in modifying the relationship between sleep disturbance and injuries has not been previously identified. In addition, the direction of the association between sleep disturbance and injuries in men and women was not consistent in earlier studies. In a study by Ulfberg et al [32], female workers had a higher risk for occupational

injuries for sleep disordered breathing than male workers. In contrast, Young et al [21] found a significant association of sleep disordered breathing and motor vehicle crashes only among men. Men and women may have different potential for developing injuries given the same level of sleep disturbance [21]. Alternatively, the perception of sleepiness might be different between men and women, which could influence efforts to take preventive actions at different levels of sleepiness [21].

Alcohol drinking in persons with sleep disturbance made them more susceptible to injuries. Alcohol consumption may interact with sleep disturbance to exacerbate daytime sleepiness and performance impairment [43]. In addition, alcohol consumption aggravates primary sleep disturbances such as sleep apnea/hypopnea, thus contributing to excessive daytime sleepiness [46]. Because the number of subjects who reported heavy drinking was relatively small (n = 120, 8.9% of subjects) in this study, the 95% CIs of RRs in that category were wide. However, the point estimates indicated a consistently higher risk for injury among heavy drinkers across all sleep variables.

4.1. Strengths and weaknesses

To the best of our knowledge, this is the first study to examine the relationship between sleep disturbance and injury in the general population including a wide range of ages and occupations. The association of reduced sleep hours and injuries could be generalized to wider populations beyond drivers and workers. The causal association of fewer sleep hours and injury may well be supported through the prospective cohort design, in which sleep information of subjects was collected first, then the subjects were followed for their injuries.

Injury information was collected prospectively by continuously following subjects over a long-term period. The injury rate calculated in this study (11.8 cases per 100 person-years) was comparable to the injury incidence rates reported among agricultural workers (0.5-16.6 injuries per 100 workers) in the review by McCurday and Carroll [47]. The length of recall might have had an impact on the number of injuries reported. Although the length of recall in our study ranged from 80 to 1136 days, 95% were within a year. There was a small difference of injury rates in between longer and shorter recall periods.

Injury information for all household members was obtained through an interview with a single informant representing the household. The informant may have better recall of injury events for himself/herself than for other family members. This differential recall might have lowered the number of injuries reported among other family members in the household, which would lead to an underestimate of the injury rate.

Another potential limitation of this study is that both exposure and outcome information were obtained based on self-report. Consequently, the information was probably susceptible to self-perception and interpretation. Snoring is likely to be especially vulnerable to error from self-report.

Perceptual impairment caused by reduced sleep hours may increase injury risk. Alcohol consumption may worsen this perceptual impairment and further aggravate injury risk. In the future, we need to study specific circumstances of injuries that are associated with sleep disturbance to establish a causal model. For example, we may assume that the risk for injury by sleep disturbance would be higher in physically static conditions rather than physically active conditions. There is a need to use a more organized and validated tool to assess snoring and daytime fatigue/sleepiness. The different association of sleep disturbance and injuries observed in men and women needs to be explored further in future studies.

5. Conclusion

Our study demonstrated that having adequate hours of sleep is important in preventing injuries in a rural population. If the average number of hours slept per night in this sample (7.2 hours) represents that of the general rural population, rural people need more sleep. Reduced sleep hours may be caused by a variety of conditions, including sleep disorders, chronic illnesses, work and lifestyle factors, and substance abuse. Consequently, prevention strategies to increase sleep and reduce resulting injuries should be tailored to the different needs of each individual. Consulting with a physician to diagnose sleep problems may be an important step in injury prevention. Addressing sleep issues among those who drink alcohol may be particularly important. Avoiding alcohol consumption is important to prevent injuries, and this might be a specific prevention message to those who have sleep problems.

Appendix A. Sleep questions

1. Please estimate how often you snore, according to what others sleeping in the same room have told you. Would you say...

    1. Never
    2. Rarely (only once or a few times ever)
    3. Sometimes (a few nights per month; under special circumstances)
    4. At least once a week, but pattern may be irregular
    5. Several nights per week (3 to 5 nights per week)
    6. Every night or almost every night
    8. Don't know
    9. Refuses

2. How loud have others said your snoring is? Would you say...

    1. Only slightly louder than heavy breathing
    2. About as loud as mumbling or talking

3. Louder than talking
4. Extremely loud (can be heard through a closed door)
5. Use CPAP
8. Don't know
9. Refuses

3. Do you feel tired during the day, no matter how many hours of sleep you had?

1. Yes
2. No
8. Don't know
9. Refuses

4. On most days, do you have trouble staying awake during the day?

1. Yes
2. No
8. Don't know
9. Refuses

5. How many hours of sleep do you get in a typical workday/schoolday night? (##.# hours) Weekend/non work/nonschool night? (##.# hours)
6. How many hours of sleep do you get in a typical week from naps in the daytime or evening? (##.# hours).

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