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Driver Sleepiness and Risk of Car Crashes in Shenyang, a Chinese Northeastern City: Population-based Case-control Study

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Objective To estimate the association of driver sleepiness with the risk of car crashes. **Methods** A population-based case-control study was conducted in Shenyang, a northeastern city in China, between November 2001 and July 2002. The case group comprised 406 car drivers involved in crashes, and 438 car drivers recruited at randomly selected sites, and on the day of week, and the time of day when they were driving on highways in the study region during the study period were used as control groups. Face-to-face interviews with drivers were conducted according to a well-structured questionnaire covering the circumstances of their current trip and their background information. Stanford sleepiness scale and Epworth sleepiness scale were used to quantify acute sleepiness and chronic sleepiness respectively. **Results** There was a strong association between chronic sleepiness and the risk of car crash. Significantly increased risk of crash was associated with drivers who identified themselves as sleepy (Epworth sleepiness score ⩾10 vs <10; adjusted odds ratio 2.07, 95% confidence interval 1.30 to 3.29), but no increased risk was associated with measures of acute sleepiness. **Conclusions** Chronic sleepiness in car drivers significantly increases the risk of car crash. Reductions in road traffic injuries may be achieved if fewer people drive when they are sleepy.

Key words: Driver sleepiness; Car crash; Case-control study

INTRODUCTION

Sleepiness in drivers is widely believed to be an important cause of road traffic injuries. Measures of acute and chronic sleepiness, sleep restriction, sleep disorders, and work patterns that interfere with normal sleep have been associated with decreased performance in psychomotor tests and driving simulators[1-5], and with increased rates of car crashes in selected populations. So, it is important to quantify its contributions to crashes for the development and prioritization of interventions to prevent these injuries. Controlled studies that estimated the prevalence of driver sleepiness and the associated risks have been carried out in motorized countries, such as the United States[6] and New Zealand[7], but the results can not be simply adopted in the motorizing countries because of the great difference in the

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traffic mix and social context[8]. A controlled study was carried out in a local population in Shenyang, a northeastern city in China to estimate the association of sleep related characteristics with the risk of crash, and to identify similarity and difference in such association between the motorizing countries and the motorized countries.

METHODS

A population-based case-control study was conducted in the Huanggu District, Urban Shenyang of northeastern China between November 2001 and July 2002, with a population of about 730 thousand. The source population for study participants comprised drivers of both light and heavy vehicles on highways, excluding all those licensed as emergency ones. Geographical boundaries, time period, eligible vehicles and roads both for the study cases and the controls were defined in an identical manner.

The study was approved by the Shenyang Police Bureau Ethics Committee. Informed consent was obtained from all participants for use of their records.

Selection of Cases

All drivers in eligible vehicles involved in crash with economic loss of at least 30 Yuan (RMB) in the study sites were identified through daily surveillance and case finding in the local traffic accident department, and collaboration from the traffic police ensured comprehensive case finding. In each pair, the driver of vehicle was the key informant, whether injured or not. The drivers injured to death were excluded in the study. If the crash occurred at 0:00-5:00 a.m., the driver was excluded because of difficulty in the control recruitment during this period of time.

Selection of Controls

The control group comprised a sample of representatives of car drivers at all time excluding the time from 0:00 to 5:00 a.m. spent by people driving on the roads in the study areas during the study period. They were identified by sampling drivers at 28 randomly selected sites on the road network. The day of week, the time of day, and direction of driving for each survey site were randomly assigned. Eligible vehicles passing each survey site were randomly sampled in proportion to the traffic volume at the site, which had been determined by earlier measurements. The drivers of randomly selected vehicles were invited to stop on an off-road and to be laid aside with the help of a traffic policeman. Roadside staff gave a brief description of the study to the driver and clearly identified themselves as university researchers independent of the police and other authorities. Surveys were carried out averagely of once a week and recruitment approximately matched accrual of cases.

Data Collection

Face-to-face interviews with case drivers were conducted in traffic accident department if the driver was not injured and the injured drivers were interviewed in the hospital where he or she was admitted. For control drivers a breath test for alcohol was performed at the roadside recruitment sites and face-to-face interviews were conducted immediately. If the driver had no time to receive the interview at that time, contact details, and the time for a suitable interview times would be obtained and such interview were carried out in 48 h after the recruitment. The well-structured interview was based on a questionnaire covering the circumstances of the current trip and a number of usual behaviors and background characteristics of the drivers. The sleep-related questions were not identified as a focus of the interview, which comprised only its small part. Apart from the scales used for assessing sleepiness, several other scales were also included in the interview, such as the SF-36, and assessment of social support. The health-related questions and driving experiences also constituted a part of the interview.

Measures of Driver Sleepiness

The Stanford sleepiness scale (a self-rating scale) was used to quantify progressive steps in acute sleepiness. Respondents chose one of seven hierarchical statements that most closely described their level of alertness immediately before the crash or survey[9], and the Epworth sleepiness scale was used to measure chronic or usual daytime sleepiness. Respondents rated the likelihood (never, slight, moderate, high) that they would fall asleep in each of eight common situations, giving a total Epworth score in the range of 0-24: <10 normal; 10-15 moderate impairment, and 16-24 severe impairment[10].

We obtained how long the driver had slept during the previous 24 h before the crash or survey and the number of full nights of sleep (at least seven hours, mostly between 11:00 p.m. and 7:00 a.m.) in the previous week. We used sleep for 5 h or less of sleep in the previous 24 h as an indicator of acute sleep deprivation as it has been identified as a level at which performance starts to become impaired[5]. We used no full nights of sleep in the previous seven nights as an indicator of chronic partial sleep deprivation. Participants were asked about symptoms of obstructive sleep apnoea (witnessed episodes of regular loud snoring, or breathing pauses) and work patterns including types of shift.

Potential confounders considered in the analysis were age, sex, educational level, alcohol consumption, time spent in driving per week, vehicle speed, usual driving behavior, type of road, vehicle condition, and how long the person had been driving that day. Self-reported data for all confounders were collected except for road type, which were ascertained from environmental surveys. Objective alcohol measurements with breathalyzer tests for control drivers, and results of police blood tests, or police breath-analyzer results for drivers involved in crashes were obtained.

Analysis

SAS for windows 6.12 software was used for all analyses and odds ratios were estimated using unconditional logistic regression. Potential confounders were assessed using the change in model estimates, with a cut-off point of 5%[11]. The confounders included in the analyses are shown in Table 1. Self-reported data on alcohol consumption were used for the statistical modeling rather than measured alcohol concentrations, as they were more complete.

TABLE 1

Distribution of Sleepiness and Confounding Variables in Case and Control Groups

Variables	Control（n=438）		Case (n=406)	
	Number	%	Number	%
Stanford Sleepiness Scale				
1(most alert)	296	67.73	264	65.02
2-3	130	29.75	134	33.00
4-7	11	2.52	8	1.97
Epworth Sleepiness Score				

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Variables	Control (*n*=438)		Case (*n*=406)	
	Number	%	Number	%
<10 (normal)	392	89.50	335	82.51
10-15	39	8.90	62	15.27
16-24	7	1.60	9	2.22
Sleeping Hours in Previous 24 h				
>5	420	95.89	394	97.04
≤5	18	4.11	12	2.96
Sleeping in Previous Week				
At Least 1 Full Night [a]	375	85.62	378	93.10
No Full Night's Sleep	63	14.38	28	6.90
Regular Loud Snoring				
No	287	65.53	303	74.63
Yes	151	34.47	103	25.37
Triad of Sleep Apnoea Symptomes[b]				
No	391	90.09	368	90.64
Yes	23	5.30	19	4.68
Do Not Know	20	4.61	19	4.68
Night Work or Shift Work[c]				
No	351	80.14	268	66.01
Yes	87	19.86	138	33.99
Self-reported Alcohol in Pre 6 h				
No	432	98.63	398	98.03
Yes	6	1.37	8	1.97
Continue Driving Time in the Day				
<3 h	298	68.04	264	65.02
≥3 h	140	31.96	142	34.98
Time Spent Driving per Week				
≤40 h	232	52.97	154	37.93
>40 h	206	47.03	252	62.07
Sex				
Male	420	95.89	391	96.31
Female	18	4.11	15	3.69
Age Group				
18-24	44	10.05	66	16.26
25-34	140	31.96	140	34.48
35-44	166	37.90	158	38.92
45-54	82	18.72	40	9.85
≥55	6	1.37	2	0.49
Education Level				
Primary School	8	1.83	12	2.96
High School/Secondary School : 1-3 years	161	36.76	200	49.26
High School/Secondary School: >3 years	174	39.73	141	34.73
University	94	21.46	53	13.05

Note. Column totals may differ due to missing data. [a]: At least seven hours, mostly between 11 p.m. and 7 a.m.. [b]: Witnessed episodes of choking and breathing pauses during sleep and regular loud snoring. [c]: Included rotating shifts with nights, permanent night shift, and other work patterns that required regularly starting before 6 a.m. or finishing after midnight.

RESULTS

Of the 442 case drivers eligible during the study period, 406 (91.86%) completed interviews and 36 (8.14%) declined to participate. Of the 486 control vehicle drivers selected, 436 completed interviews (89.71%) and 50 declined (10.29%). Table 1 shows the distributions of measures of sleepiness and potential confounders in case drivers and control drivers. There was a strong association between the level of chronic driver sleepiness, as measured by the Epworth score, and the risk of crash (Table 2). After adjustment for effects of age, sex, educational level, ethnicity, and alcohol consumption, drivers with scores of 10 or above (those who were identified as any degree of sleepiness) had a 2.07-fold risk of crash, as compared with the drivers in the group with Epworth score less than 10. Drivers with night work or shift work were at greater risk, as compared to those who worked regularly on daytime with no shifts or night work or shift work, which resulted in a twofold increase in risk. No increase in risk with measures of acute sleepiness was observed (Table 2). Compared to the drivers who identified themselves as alert or relaxed (score<4), the drivers (score≥4) who identified themselves as foggy-headed or sleepy had not increased the risk of crash (*OR*=0.63, 95% CI 0.22-1.82). The direct determinants of acute sleepiness that we measured, sleep deprivation, were neither associated with the risk of crash. The drivers who reported sleep for 5 hours or less in the previous 24 h did not significantly increase the risk, as compared with those who had slept more than 5 h. The driver with high Stanford scores (4-7), less than 5 h sleep in the previous 24 h, usually awake un-refreshed, and triad of sleep apnoea symptoms were not associated with significant increase or decrease in the risk. No major alteration in the effect estimates was found when analyses were restricted to the drivers who had not been drinking (Table 2).

TABLE 2[*]

Estimated Odds Ratios of the Related Factors for Risk of Car Crash

Risk Factor	Total		Alcohol Excluded	
	OR	95% CI	*OR*	95% CI
Night Work or Shift Work[c]				
No	1		1	
Yes	2.14	1.50-3.05	2.03	1.42-2.90
Stanford Sleepiness Score				
1-3	1		1	
4-7	0.63	0.22-1.82	0.50	0.16-1.58
Epworth Sleepiness Score				
<10	1		1	
10-24	2.07	1.30-3.29	2.00	1.26-3.19
Sleeping Hours in Previous 24 h				
>5	1		1	
≤5	0.94	0.39-2.28	0.93	0.38-2.28
Sleeping in Previous Week				
At Least One Night[a]	1		1	
No Full Night's Sleep	0.36	0.21-0.63	0.35	0.20-0.61
Regular Loud Snoring				
No	1		1	

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Risk Factor	Total		Alcohol Excluded	
	OR	95% CI	*OR*	95% CI
Yes	0.71	0.50-1.00	0.72	0.50-1.02
Triad of Sleep Apnoea Symptoms[b]				
No	1		1	
Yes	1.40	0.66-2.97	1.47	0.68-3.16

Note. *Figures listed in the Table are adjusted for other variables by unconditional logistic regression. [a]: At least seven hours, mostly between 11p.m. and 7 a.m.. [b]: Witnessed episodes of choking and breathing pauses during sleep and regular loud snoring. [c]: Included rotating shifts with nights, permanent night shift, and other work patterns that required regularly starting before 6 a.m. or finishing after midnight.

DISCUSSION

The Difference in Association of Sleep Related Characteristics With the Risk of Crashes Between China and the Motorized Countries.

Our research showed that chronic sleepiness significantly increased the risk of crash, which is consistent with the results in the United States[6] and the UK[12-14]. In Washington, crash risk was greater among drivers who felt they were falling asleep (adjusted relative risk (aRR) 14.2, 95% confidence interval (CI) 1.4 to 147)[6]. A large survey carried out in the UK by Maycock[12-14] found a positive relationship between Epworth score and accident frequency, controlling for age, mileage and trip frequency (no estimate reported, $P<0.05$). Drivers with an Epworth score of 12 were found to have a 3.05-fold risk of crash as compared to the drivers with an Epworth score of 0 ($P<0.05$). But no significant association between chronic sleepiness and injury crash was found in the study on the driver sleepiness and risk of serious injury to car occupants carried out in New Zealand[7]. Connor J., *et al.*[7] reported that there was a strong association between measures of acute sleepiness and the risk of an injury crash. After adjustment for major confounders, significantly increased risk was associated with drivers who identified themselves as sleepy (Stanford sleepiness score 4-7 vs 1-3; *OR* 8.2, 95% confidence interval 3.4 to 19.7), and drivers who reported to have sleep for 5 h or less in the previous 24 h, as compared with those with more than 5 h of sleep (2.7, 1.4 to 5.4). In contrast, in our study no increased risk was shown to be associated with measures of acute sleepiness and the sleep hours in the previous 24 h. Considering the fact that the sleepy drivers may exercise the necessary compensatory effort to stay vigilant while driving even though they experience some level of sleepiness, this result could be possible, which was also reported by a sleep driving research in US drivers[15]. But the compensation has its limit, and when the driver's sleep is disturbed by work patterns, long continuous work spell or sleep-related disorders for a long time, he/she owns chronic sleep debt[16,17]. The sleep debt causes longer reaction time, decreased vigilance and impaired performance while driving, thus increasing the liability of crashes[16,17].

Possible Bias

It is unlikely that our results can be explained by selection bias as we identified nearly all cases and a representative sample of controls from the study region over the study period and obtained higher response rate. We also minimized information bias by using standard interviews and a reference point for acute exposures (crash or survey). Biases could remain, however, particularly unavoidable lying, even though sleepiness was not an identified focus of the study. The risk associated with a Stanford score of four or less is the measure most likely to be affected by lying bias and could, therefore, be somewhat attenuated. Although we spared no effort to ensure the drivers that our study had least impact on the crash judgment, individuals involved in the interview were still under pressure and sensitive to their response. There is little reason to doubt that the measurement of sleep deprivation could be of bias, because it was strictly based on sleep duration, from the beginning to the end. We verified the time of day randomly, which may be correlated with sleepiness[18], though the precision of estimates involving the time of day was reduced by the clustering in time of control recruitment. In this study we lacked information collected from zero to five o'clock in the morning because it was not feasible to interview the subjects during this time period. Chronic sleepiness was measured by self-report Epworth sleepiness scale. Some studies have found that the Epworth sleepiness scale is associated with the risk of crash[19], whereas others have found it to be an insensitive measure[20]. The use of symptoms alone as an indicator of obstructive sleep apnoea may have resulted in misclassification[21] that could have affected the validity and precision of the risk estimate.

The traffic mix and social context between motorized country and motorizing country are different, so it is reasonable that the risk factors of car crash play different roles. This calls for locally generated evidence for crash risk factors, and also calls for in-country capacity and expertise to monitor, evaluate and adapt, and even develop new strategies and approaches to suit the context in motorizing countries. Our study provides the reliable association of driver sleepiness with the risk of car crash in China. Future study and intervention might well be targeted on the specific behavior-driving while sleepy.

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