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Sleepiness, Sleep Disordered Breathing and Accident Risk Factors in Commercial Vehicle Drivers

Mark E. Howard[1], Anup V. Desai[2], Ronald R. Grunstein[2], Craig Hukins[3], John G. Armstrong[3], David Joffe[2], Philip Swann [4], Donald A. Campbell [5], Robert J. Pierce[1]

[1] Institute of Breathing & Sleep, Austin Health and University of Melbourne, Victoria, Australia

[2] Woolcock Institute of Medical Research University of Sydney, Royal Prince Alfred Hospital and Royal North Shore Hospitals, New South Wales, Australia

[3] Princess Alexandra Hospital, Queensland, Australia

[4] Department of Road Safety, Vicroads, Victoria, Australia

[5] Monash Institute of Health Services Research, Monash Medical Centre, Victoria, Australia

Reprint address: Dr Mark Howard, Institute of Breathing & Sleep, Bowen Centre, Austin Health, Heidelberg, Victoria, Australia, 3084

Corresponding author: Dr Mark Howard, Institute of Breathing & Sleep, Bowen Centre, Austin Health, Heidelberg, Victoria, Australia, 3084. Phone: 613 93871000, Fax: 613 94965124, Email: mark.howard@austin.org.au

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ABSTRACT

Sleep disordered breathing and excessive sleepiness may be more common in commercial vehicle drivers than the general population. The relative importance of factors causing excessive sleepiness and accidents in this population remains unclear. We measured the prevalence of excessive sleepiness and sleep disordered breathing and assessed accident risk factors in 2342 respondents to a questionnaire distributed to a random sample of 3268 Australian commercial vehicle drivers and another 161 drivers among 244 invited to undergo polysomnography. 59.6% of drivers had sleep disordered breathing and 15.8% had obstructive sleep apnea syndrome. 24% of drivers had excessive sleepiness. Increasing sleepiness was related to an increased accident risk. The sleepiest 5% of drivers on the Epworth Sleepiness Scale and Functional Outcomes of Sleep Questionnaire had an increased risk of an accident (odds ratio 1.91, $p=0.02$ and 2.23, $p<0.01$ respectively) and multiple accidents (odds ratio 2.67, $p<0.01$ and 2.39, $p=0.01$), adjusted for established risk factors. There was an increased accident risk with narcotic analgesic use (odds ratio 2.40, $p<0.01$) and antihistamine use (odds ratio 3.44, $p=0.04$). Chronic excessive sleepiness and sleep disordered breathing are common in Australian commercial vehicle drivers. Accident risk was related to increasing chronic sleepiness and antihistamine and narcotic analgesic use.

Key Words: accidents traffic, antihistamines, narcotic analgesics, obesity

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INTRODUCTION

Motor vehicle accidents remain a common cause of injury and premature death (1). Between 20 and 30 percent of accidents involving commercial vehicle drivers are sleep related (2, 3). Sleep restriction, circadian rhythm effects and sleep disordered breathing have been implicated as factors contributing to sleep related accidents, but their relative contribution to sleepiness and accidents in the road transport industry is unclear. Several studies have suggested that chronic excessive sleepiness is no more common amongst commercial vehicle drivers than the general population (4-6). Studies assessing the relationship between chronic excessive sleepiness and accidents have found conflicting results for both subjective and objective tests of sleepiness and have not quantified the degree of sleepiness that confers a high accident risk. (4, 7-10). Sleep disordered breathing is associated with an increased crash risk in the general population (10-13). Twenty-four percent of adult males of working age have sleep disordered breathing (14, 15). Although some studies have suggested that there may be a higher prevalence of sleep disordered breathing amongst heavy vehicle drivers (6, 16) this is controversial. These prevalence estimates have varied between different countries, which may be due, at least in part, to varying frequencies of obesity (17).

Alcohol and cannabis contribute to road accidents in both the general community and commercial vehicle drivers, with amphetamines also contributing to accidents in the latter group (18, 19). Commonly used drugs, such as benzodiazepines, tricyclic antidepressants and narcotic analgesics, have also been implicated as contributing factors to accidents in the general community (20, 21). Their role in causing accidents in commercial vehicle drivers has not been described.

We have undertaken a study to assess the prevalence of excessive sleepiness, sleep disordered breathing and obesity amongst commercial vehicle drivers in Australia and to evaluate which individual factors and work habits are associated with accident risk. Some of the results of this study have been previously reported in the form of abstracts (22, 23).

METHODS

The study comprised two samples of commercial vehicle drivers. 3268 drivers were invited to complete a questionnaire and anthropormorphic measurements. Another 244 drivers were also invited to attend in-laboratory polysomnography.

Questionnaire Sample

A simple random sample of 98 workplaces was selected from 395 workplaces on the database of the Transport Workers Union in Australia. The workplaces were visited by study investigators and questionnaires distributed to the drivers. Questionnaires were completed without assistance and returned anonymously. The questionnaire included demographics, sleep and work habits and self reported accidents from the preceding three years (Appendix E1, online supplement). The Multivariable Apnea Prediction questionnaire was used to assess the probability of having sleep disordered breathing (24). Sleepiness was measured using the Epworth Sleepiness Scale (25). A score of 11 or more was used to indicate excessive sleepiness (5). The Functional Outcomes of Sleep Questionnaire was included to measure sleep related quality of life (26). Height and weight were measured by the investigators.

Polysomnography Sample

For the *polysomnography sample* we randomly selected 244 drivers from the databases of the Transport Workers Union. We collected data on age, gender, height and weight from drivers who declined to participate. Drivers who agreed to participate underwent full in laboratory polysomnography (Compumedics S series, Compumedics Melbourne, Australia) in addition to completing the questionnaire described above. Sleep staging and scoring of respiratory events was performed according to standard criteria (27, 28). A respiratory disturbance index (RDI) of five events per hour or above was considered consistent with sleep disordered breathing. Obstructive sleep apnea syndrome was defined as an RDI of at least five together with an Epworth Sleepiness Scale Score of 11 or more.

Statistical Methods

Adjustments were made for analyses of the *questionnaire sample* to account for cluster sampling (see online supplement). Demographic variables, which were normally distributed, are described as mean and standard deviation with comparison between groups made with the student T-test. Categorical variables are reported as proportions with 95% confidence intervals. We used the Multivariable Apnea Prediction Score to estimate the prevalence of sleep disordered breathing in the *questionnaire* sample (see online supplement(29)).

Multivariate logistic regression was used to assess the relationship between excessive sleepiness and personal and work related factors, adjusted for age. Similarly, to assess the relationship between potential explanatory variables and accident risk we calculated odds ratios adjusted for age, alcohol intake and hours of driving (established major accident risk factors (30-32)). We performed the same analysis with sleepiness classified as a categorical variable. Forward stepwise logistic regression analysis was performed with sleepiness and accidents as dependant variables. We included explanatory variables with an alpha of less than 0.10 on univariate analysis. Analysis of variance was used to assess the relationship between sleepiness and the different severities of sleep disordered breathing. A two-sided P value (or multisided where appropriate) of less than 0.05 was considered to indicate statistical significance.

Written informed consent was obtained from study participants. The protocol was approved by the Human Research and Ethics Committees at each participating institution.

RESULTS

Response Rate and Demographic Features

There was an average of 33.3 drivers (SD 42.5, median 22.3) at each workplace, with a range of 4 to 318. Of 3268 drivers invited to participate in the *questionnaire sample*, 2342 drivers (72%) returned completed questionnaires. Ninety-nine percent of drivers in the sample were male compared to 97% of drivers on the Transport Workers Union database. Mean age for drivers in the sample was 42.4 years compared to 45.0 years for those on the database. Drivers in the *questionnaire sample* were younger than those in the *polysomnography sample*, but there was no difference in other risk factors for sleep disordered breathing, or the degree of sleepiness (Table 1). They had a lower average Multivariable Apnea Prediction Score.

161 drivers completed overnight polysomnography, 66% of the 244 invited in the *polysomnography sample*. There was no difference in age, height, weight or proportion of males for drivers who completed polysomnography compared to those who declined to participate (Table 2). 84% of drivers were overweight or obese (Table 1).

Prevalence of Excessive Sleepiness and Sleep Disordered Breathing

59.6% (95% confidence interval (CI) 51.6% to 67.3%) of drivers in the *polysomnography sample* had sleep disordered breathing (Table 1). Sixteen percent had obstructive sleep apnea syndrome (excessive sleepiness and sleep disordered breathing). Thirty-six percent of drivers in the *questionnaire sample* had a high Multivariable Apnea Prediction Score ($\geq$ 0.5). A score of 0.5 produced a positive predictive value for at least mild sleep disordered breathing (RDI $\geq$ 5) of 0.74 and a negative predictive value of 0.57. Using these values we estimated a prevalence of 54.0% (95% CI 47.2% to 60.8%) for at least mild sleep disordered breathing in the *questionnaire sample*, compared to 59.6% measured directly in the *polysomnography sample* (29).

Twenty-four percent of drivers in both the *polysomnography and questionnaire* samples had excessive sleepiness (5). The degree of sleepiness increased with increasing severity of sleep disordered breathing on polysomnography. Mean Epworth Sleepiness Scale Score was 6.8 for those with normal polysomnography (RDI <5) and 7.4, 9.0 and 9.9 for those with mild, moderate and severe sleep disordered breathing respectively ($F(3, 154) = 3.3$, $p=0.02$).

Factors Associated with Excessive Sleepiness

Adjusted for age, there was an increased odds of excessive sleepiness with an increase in the Multivariable Apnea Prediction Score, hours worked per week and afternoon or night shift work (Table 3, Table 4). Obtaining more sleep on days off, increasing stimulant use and caffeine intake were also associated with increased sleepiness.

In a forward stepwise logistic regression model for excessive sleepiness the Multivariable Apnea Prediction Score entered first, followed respectively by hours of sleep on work days, past history of sleep apnea or heart disease and hours of sleep on days off. The odds of excessive sleepiness increased by 50 percent (odds ratio 1.56, 95% CI, 1.37 to 1.78) for an increase in the Multivariable Apnea Prediction Score of 1 standard deviation (SD 0.19, range 0 to 1.00). Drivers who averaged less than 7 hours of sleep per night during the working week were more likely to report excessive sleepiness than those who had 7-8 hours of sleep per night. For those who averaged less than 5 hours per night the odds ratio for excessive sleepiness was 2.74 (95% CI, 1.84 to 4.08). The odds of reporting excessive sleepiness actually increased in those who had more than 8 hours of sleep, with an odds ratio of 5.62 for more than 9 hours (95% CI, 1.93 to 16.34).

Factors Associated with Self-reported Accidents in the Preceding three years

2079 of 2342 drivers (88.8%) answered the questions about accidents. 739 drivers (35.5%, 95% CI, 32.1% to 38.9%) had a total of 1407 accidents in the previous three years, with 48.3% of these drivers having had more than one accident (95% CI, 44.3% to 52.3%). Most accidents were work related (81.6%, 95% CI, 78.7% to 84.4%). We assessed the relationship between accident risk over the preceding three years and personal and work related factors using odds ratios adjusted for the established risk factors age, alcohol and hours of driving per week (Tables 3 and 4). We also evaluated the relationship between accident risk adjusted for established risk factors and categories of chronic sleepiness (Epworth Sleepiness Scale) and the functional impact of sleep

(Functional Outcomes of Sleep Questionnaire) (Figures 1 and 2). There was an increased risk of an accident with increasing excessive sleepiness. Those with a very high level of sleepiness (Epworth Sleepiness Scale score of 18 to 24, sleepiest 5% of drivers) had an increased risk of any accident (odds ratio 1.91, 95% CI, 1.09 to 3.35) and of multiple accidents (odds ratio 2.67, 95% CI, 1.29 to 5.52). A similar relationship was evident between the Functional Outcomes of Sleep Questionnaire total score and accident risk (Figure 2). The sleepiest five percent of drivers had an odds ratio of 2.23 for having an accident (95% CI, 1.34 to 3.71) and 2.39 for multiple accidents (95% CI, 1.19 to 4.80). The Multivariable Apnea Prediction Score was weakly related to the risk of a single vehicle accident (odds ratio 1.14, 95% CI, 0.99 to 1.33, P=0.07), but not to total accident history (Table 3). Those with symptoms of obstructive sleep apnea syndrome (Epworth Sleepiness Scale Score ≥11 and Multivariable Apnea Prediction Score ≥0.50) had a higher risk of any accident (Table 3), and of a single vehicle accident (odds ratio 1.63, 95% CI, 1.08-2.48). In the polysomnography group there was no relationship between severity of sleep disordered breathing and accident risk (odds ratio 0.82, 95% CI, 0.15 to3.57 for change in RDI of 1 standard deviation).

Frequency of use of narcotic analgesics, antihistamines and benzodiazepines was related to accident risk, but stimulant use was not (Table 3). Altogether 4% of drivers used one of these drugs (see table E2, online supplement). Narcotic analgesic use (odds ratio 2.17, 95% CI, 1.31-3.60) and benzodiazepine use (odds ratio 3.21, 95% CI, 1.25-8.24) were also related to the risk of multiple accidents. Having more sleep on days off, working night shift and country or interstate driving were related to a lower accident risk (Table 4).

A forward stepwise selection model identified sleepiness (Epworth Sleepiness Scale Score), time spent driving, interstate and country driving, narcotic analgesic use and age as the strongest independent predictors of accident risk (Table 5). The same variables were included in a model for risk of having multiple accidents, with antihistamine use as an additional factor. Sleepiness followed by age, were the only factors included in a model for single vehicle accidents.

DISCUSSION

We found a high prevalence of excessive sleepiness, sleep disordered breathing and obesity amongst commercial vehicle drivers. Excessive sleepiness was predominantly related to sleep disordered breathing risk and hours of sleep, with increasing sleepiness in those averaging less than 7 hours of sleep. We identified a relationship between narcotic analgesic and antihistamine use and motor vehicle accidents, which was independent from other potentially confounding factors such as age, alcohol intake, driving exposure and sleepiness. To our knowledge this has not been previously identified in this population. We have also quantified a relationship between subjective excessive sleepiness and accident risk using two independent measures of sleepiness.

Sleep Disordered Breathing

Sixty percent of drivers had sleep disordered breathing and sixteen percent had obstructive sleep apnea syndrome, compared respectively with twenty-four percent and four percent of working males in the general community (14, 15). Previous studies identified sleep disordered breathing in between 25 and 78 percent of commercial drivers

(6, 16, 33-35). Some of these studies selected drivers from isolated areas of the transport industry and may not be representative of the whole industry (6, 16). Other studies were limited by a small sample size (6). Some studies used screening devices for diagnosis, which might affect the prevalence estimate (6, 33, 36). Stoohs found the highest prevalence of 78 percent amongst American truck drivers (16). This study was performed at a single company and drivers were not randomly selected, hence the sample may not be representative of the broader population of drivers. The prevalence of obesity varies between countries and this could affect the prevalence of sleep disordered breathing within the different populations (17, 37). A Spanish study found the lowest prevalence of sleep disordered breathing in commercial vehicle drivers at 25% (34). Obesity was less common in this study compared to Stoohs' study and our study, which could explain their relatively low prevalence. In a recent American study, 406 drivers were sampled from 1391 respondents to a questionnaire and studied with full in laboratory polysomnography (35). 28.1% of drivers had sleep disordered breathing and, similar to our study, obesity was common. A low initial response rate to the questionnaire raises the possibility of response bias, although age and gender were similar between respondents and non-respondents. A higher proportion of women and more stringent criteria for scoring respiratory events in this study may explain the lower prevalence compared to our study. The combination of a predominantly male population, obesity, the age distribution and sleep deprivation could account for the high prevalence of sleep disordered breathing in this population. Males are 2.5 times more likely to have sleep disordered breathing and 99 percent of our drivers were male (14). Increasing weight is associated with a higher risk of sleep disordered breathing (17). Forty-two percent of our drivers were obese, compared to 16 percent of subjects in the Australian general population study of sleep disordered breathing and 16 percent of adult Australian males (15, 38). Finally, sleep deprivation may increase the severity of sleep disordered breathing (39). Seventeen percent of our drivers averaged five hours of sleep or less, which might increase the prevalence of sleep disordered breathing.

Excessive Sleepiness

Twenty-four percent of drivers had chronic excessive sleepiness, compared to 10.9 percent of working adults in another Australian study (5). Sleep disordered breathing was associated with increasing sleepiness. Thirty-seven percent of drivers were involved in night shift work, which is associated with excessive sleepiness (40). Chronic sleep restriction was also common. It was associated with excessive sleepiness in those averaging less than 7 hours of sleep per night. This supports laboratory evidence demonstrating that chronic sleep restriction increases sleepiness and impairs psychomotor functions that are important for driving, such as vigilance and reaction time (41).

Accident Risk

We found a relationship between accident risk and chronic sleepiness using both the Epworth Sleepiness Scale and Functional Outcomes of Sleep Questionnaire. There was a twofold increased risk of an accident in the sleepiest 5% of drivers. This relationship was even stronger with multiple accidents. To our knowledge a relationship between the Functional Outcomes of Sleep Questionnaire and accident risk has not previously been reported, although several authors have found an association between the Epworth Sleepiness Scale and accident risk. Powell found an increased average Epworth Sleepiness Scale score in drivers with four or more accidents (8). In a large case control study drivers who had sleep related accidents were much more likely to have excessive sleepiness (9). However, other authors have not found any significant relationship between a high Epworth Sleepiness Scale Score and accident risk (7, 10). Our study, together with others (8, 9, 33, 42-44), suggest that self-report measures of sleepiness could be used to identify drivers with excessive sleepiness who are at increased accident risk. Although treatment of sleep disordered breathing reduces accident risk (12, 45) it has not been proven that other interventions that reduce sleepiness will reduce accident risk.

The degree of risk imparted by severe chronic sleepiness was similar to that of regular cellular phone use while driving (46) or driving just over the legal blood alcohol limit in Australia (0.05 to 0.07%), although higher blood alcohol concentrations convey a much higher accident risk (47). Similarly driving at night, up to about 2 am, doubles the risk of having an accident, whilst driving later at night results in a higher accident risk (48-50). General population studies have shown an increased risk of accidents in those with obstructive sleep apnea, but this has not been demonstrated in commercial vehicle drivers. (10, 12, 13, 42, 51, 52). In our study the Multivariable Apnea Prediction Score was related to an increased risk of single vehicle accidents, but not all accidents. Sleepiness related vehicle accidents are more likely to be single vehicle accidents, which could explain the latter finding (31). It is interesting that sleepiness was predictive of accident risk, whilst the Multivariable Apnea Prediction Score was not strongly predictive. It is possible that there is a survival effect and that those with significant sleep disorders and sleepiness leave the industry because of their symptoms or because they have an accident. Given that both sleepiness and sleep disordered breathing were very common amongst our drivers it seems unlikely that this is a major effect. The moderate accuracy of the Multivariable Apnea Prediction Score for predicting sleep disordered breathing would also tend to reduce the likelihood of finding an association with accident risk. We did not find any relationship between severity of sleep disordered breathing and accident risk in the polysomnography group either. This could be a true finding, but several factors may have resulted in a false negative finding. As described above there could be a survivor bias. The crash data for this group was not anonymous, which would increase the likelihood of reporting bias. Finally this sample was not powered to detect such a relationship. We estimate that a sample of at least 328 drivers would be required to demonstrate a twofold increase in accident risk in those with sleep disordered breathing.

There was an increased accident risk in drivers using antihistamines and narcotic analgesics and a weaker relationship with benzodiazepine use. Benzodiazepines and tricyclic antidepressants have previously been linked to increased accident risk (53, 54). Leveille found an increased risk for crashes of 1.8 in elderly drivers using opiate analgesics, but this has not been demonstrated in younger drivers (55). Kay suggests that sedating antihistamines increase accident risk and our data supports this (56). Antihistamines impair simulated driving performance to a similar degree to alcohol and interestingly this is not associated with sleepiness (57).

We found a lower accident rate in those involved in country and interstate driving and night shift. Our accident definition included minor accidents with property damage only in addition to accidents involving injuries. Traffic density is related to increased accident risk, although accidents in traffic dense urban areas tend to occur at lower speeds and hence are less likely to cause serious injury or result in death (58). Lower traffic density in country, interstate and night driving is the most likely explanation for the lower accident rates we found in these groups.

Current Study

The strengths of our prevalence study include the large randomly selected samples of drivers and high response rate. We used full laboratory polysomnography to diagnose sleep disordered breathing in our *polysomnography sample* and were able to assess the diagnostic accuracy of the Multivariable Apnea Prediction Score for use in our larger *questionnaire sample*. Our *polysomnography sample* appeared to be representative of the population, being similar to the larger *questionnaire sample* for the major risk factors for sleep disordered breathing, apart from being older. We also estimated the prevalence of sleep disordered breathing in the *questionnaire sample,* which at 54 percent was still much higher than the general population.

The use of subjective measures of sleepiness and self report of accidents may lead to underestimation of the degree of sleepiness and accident rates or measurement bias. However we found a higher accident rate (4, 59) and prevalence of sleepiness (4, 5) than previous authors, suggesting that drivers did not tend to underreport these problems. There would still be the potential for a survival bias resulting in fewer serious accidents and no fatal to the driver accidents being included in our study (45). Reporting of accidents in Australia is only mandatory if someone is injured, and it is not possible to link insurance data to individuals who drive for companies. Hence these sources would have underestimated accident rates. Drivers with symptoms of sleepiness or sleep disordered breathing may under-report accidents because of concerns for job security, which would tend to weaken any association between these disorders and accidents.

Whilst a positive bias for reporting of accidents by subjects with sleep disorders is possible this seems unlikely.

Of the established objective and subjective tests for chronic sleepiness only the Epworth Sleepiness Scale, a subjective test, has been shown to correlate with accident risk (4, 10). We used two independent subjective measures of chronic sleepiness, which showed strikingly similar relationships between increasing sleepiness and increased accident risk. Both of the sleepiness measures we used report on stable, trait like characteristics of sleepiness (25, 26). Any individual can reach a severe level of sleepiness as a result of recent sleep deprivation or circadian rhythm effects (sleepiness state rather than trait), without being chronically sleepy. The commonly used objective measures of sleepiness (the multiple sleep latency test and maintenance of wakefulness test) are influenced by these recent sleep habits as well as the chronic level of sleepiness (60, 61). Prior sleep patterns need to be controlled in order to perform these tests optimally, but this is difficult to do in commercial vehicle drivers because of their very irregular sleep and work patterns. The study used a clustered sampling design for the questionnaire sample, selecting truck yards rather than randomly selecting commercial vehicle drivers. Adjustments needed to be made for the design effect in the statistical analysis (see online supplement), resulting in wider confidence intervals. However this design enabled us to obtain a large sample of drivers with a good response rate, which may not have been possible otherwise.

In conclusion we have found a high prevalence of sleep disordered breathing and excessive sleepiness amongst commercial vehicle drivers. Obesity was common, which at least partially explains the high prevalence of sleep disordered breathing. Sleep apnea and sleep duration were the main factors related to excessive sleepiness. There was an increased accident risk in those with excessive sleepiness, and narcotic analgesic or antihistamine use. Interventions to reduce sleepiness amongst professional drivers may reduce accident risk. Physicians and drivers also need to be aware of medications that may increase accident risk.

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Figure Legends

Figure1

Accident risk related to subjective sleepiness (Epworth Sleepiness Scale). ● represents odds ratio for one or more accidents and ▲ the odds ratio for multiple accidents. Error bars represent 95 percent confidence intervals for the odds ratios. Odds ratios are adjusted for age, average daily alcohol intake and hours of driving per week. Definition of abbreviation: ESS = Epworth Sleepiness Scale.

Figure2

Accident risk related to impact of sleepiness (Functional Outcomes of Sleep Questionnaire). ● represents odds ratio for one or more accidents and ▲ the odds ratio for multiple accidents. Error bars represent 95 percent confidence intervals for the odds ratios. Odds ratios are adjusted for age, average daily alcohol intake and hours of driving per week. Definition of abbreviation: FOSQ = Functional Outcomes of Sleep Questionnaire.

Footnotes

Table 1

Definition of abbreviations: ESS = Epworth Sleepiness Scale; MAP = Multivariable Apnea Prediction score; RDI = respiratory disturbance index.

Data expressed as mean (SD) or * proportion (95% CI)

Table 2

Data expressed as mean (SD) or * proportion (95% CI)

Table 3

Definition of abbreviations: ESS = Epworth Sleepiness Scale; MAP = Multivariable Apnea Prediction score; FOSQ = Functional Outcomes of Sleep Questionnaire.

* Adjusted for age.

† Adjusted for age, hours of driving and alcohol intake

‡ Odds ratio for continuous and ordinal variables indicate the change in odds for an increase of one standard deviation or one category for ordinal variables.

§ Categories for frequency of drug use were never, occasional or regular.

Table 4

Definition of abbreviations: ESS = Epworth Sleepiness Scale

* Adjusted for age.

† Adjusted for age, hours of driving and alcohol intake.

‡ Odds ratio for continuous and ordinal variables indicate the change in odds for an increase of one standard deviation or one category for ordinal variables.

Table 5

Definition of abbreviations: ESS = Epworth Sleepiness Scale

* Odds ratio for continuous and ordinal variables indicate the change in odds for an increase of one standard deviation or one category for ordinal variables.

† Categories for frequency of drug use were never, occasional or regular.

Table 1 Characteristics of Polysomnography and Questionnaire Samples

	Polysomnography (n=161)	Questionnaire (n=2342)	P value
Age	47.8 years (9.3)	42.4 years (10.0)	<0.01
Proportion of males	99.4% (96.6-100)	99.1% (98.5-99.7)	0.75
Body mass index	29.7 kg/m^2 (5.1)	29.0 kg/m^2 (5.0)	0.09
Overweight	42.2% (34.5-50.3) *	43.4% (41.3-45.4) *	0.78
Obese	41.6% (33.9-49.6) *	36.4% (33.5-39.2) *	0.19
History of sleep apnea	6.2% (3.0–11.1) *	4.7% (3.9-5.5) *	0.39
ESS score	7.69 (4.34)	7.54 (4.32)	0.68
Chronic excessive sleepiness (ESS score $\geq$ 11)	24.1% (17.6 – 31.5) *	24.1% (21.9-26.3) *	0.99
Sleep disordered breathing			
Normal (RDI < 5)	40.4% (32.7 – 48.4) *		
Mild (RDI 5 – 14.9)	34.8% (27.5 – 42.7) *		
Moderate (RDI 15 – 29.9)	14.3% (9.3 – 20.7) *		
Severe (RDI $\geq$ 30)	10.6% (6.3 – 16.4) *		
Sleep apnea syndrome (RDI $\geq$ 5 & ESS $\geq$ 11)	15.8% (10.5 – 22.5) *		
Sleep apnea risk (MAP score)	0.49 (0.19)	0.40 (0.19)	<0.01

Table 2 Demographic Features of Responders and Non-Responders for Polysomnography

	Responders (n=161)	Non-responders (n=84)	P value
Age	47.8 years (9.3)	46.0 years (9.4)	0.16
Height	176 cm (6.9)	177 cm (7.7)	0.30
Weight	92.0 kg (15.9)	88.9 kg (14.5)	0.13
Proportion of males	99.4% (96.6-100) *	98.8% (93.5-100) *	0.33

Table 3 Personal Factors Associated with Chronic Excessive Sleepiness and Accidents

Variable	Units or category (Range/SD)	Chronic Excessive Sleepiness (ESS score 11-24)		Accident in Past Three Years	
		Odds Ratio * (95% CI)	P value	Odds Ratio † (95% CI)	P value
Gender	Female	1		1	
	Male	0.41 (0.17-0.97)	0.04	0.74 (0.29-1.95)	0.54
Age ‡	Years (16-71 years/10.0)	1.08 (0.99-1.18)	0.08	0.86 (0.78-0.95)	0.03
Sleep disordered breathing risk ‡	MAP Score (0-1.0 unit/0.19)	1.64 (1.45-1.86)	<0.01	1.01 (0.90-1.13)	0.88
Sleepiness ‡	ESS Score (0-24 units/4.32)			1.18 (1.09-1.29)	<0.01
Impact of Sleepiness ‡	FOSQ Score (20-5.6 units/2.08)			1.20 (1.07-1.35)	<0.01
Sleep apnea syndrome (symptom diagnosis)	(MAP score ≥ 0.5 and ESS score 11-24)			1.30 (1.00-1.69)	0.05
Past medical history	Diabetes	1.87 (1.10-3.17)	0.02	0.86 (0.49-1.53)	0.61
	Heart Disease	2.04 (1.21-3.42)	<0.01	0.92 (0.53-1.60)	0.77
	Sleep apnea	2.87 (1.88-4.40)	<0.01	0.82 (0.53-1.26)	0.36
Drug use ‡	Stimulant drugs §	1.79 (1.30-2.08)	<0.01	0.94 (0.86-1.03)	0.20
	Benzodiazepines §	1.27 (0.75-2.15)	0.38	1.91 (0.90-4.07)	0.09
	Antihistamines §	1.66 (0.49-5.65)	0.42	3.44 (1.06-11.16)	0.04
	Narcotic analgesics §	0.96 (0.54-1.70)	0.88	2.40 (1.46-3.92)	<0.01
Alcohol Intake ‡	Standard drinks/day (0-18 drinks/1.84)	0.98 (0.87-1.11)	0.75	1.09 (0.99-1.19)	0.07

Caffeine [‡]	Cups/day (0-38 cups/3.69)	1.20 (1.08-1.33)	<0.01	0.96 (0.86-1.04)	0.28

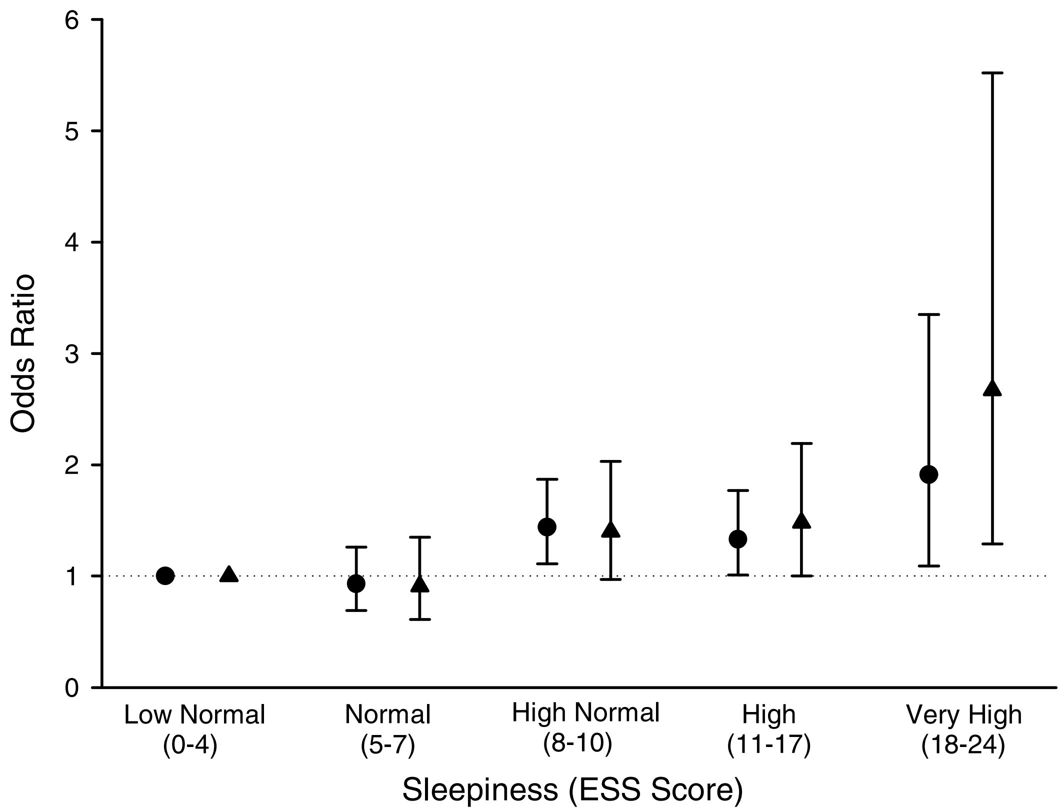
Table 4 Work Factors Associated with Chronic Excessive Sleepiness and Accidents

Variable	Units or category (Range/SD)	Chronic Excessive Sleepiness (ESS score 11-24)		Accident in Past Three Years	
		Odds Ratio * (95% CI)	P value	Odds Ratio † (95% CI)	P value
Time worked ‡	Hours/week (10-144 /15.7)	1.25 (1.12-1.41)	<0.01	0.90 (0.80-1.00)	0.05
Shift types	Day	1		1	
	Afternoon	1.44 (1.14-1.81)	<0.01	0.77 (0.61-0.98)	0.04
	Night	1.57 (1.26-1.95)	<0.01	0.63 (0.49-0.82)	<0.01
Driving location	Metropolitan	1		1	
	Country	0.90 (0.71-1.16)	0.43	0.73 (0.57-0.95)	0.02
	Interstate	1.49 (1.20-1.85)	<0.01	0.56 (0.42-0.76)	<0.01
Sleep duration (Work days)	≤ 5 Hours	2.61 (1.84-3.71)	<0.01	1.05 (0.75-1.48)	0.78
	5.1-6 Hours	1.87 (1.35-2.61)	<0.01	1.14 (0.82-1.59)	0.43
	6.1-7 Hours	1.49 (1.06-2.08)	0.02	1.20 (0.88-1.64)	0.24
	7.1-8 Hours	1		1	
	8.1-9 Hours	1.67 (0.78-3.1)	0.15	0.95 (0.49-1.84)	0.89
	>9 Hours	3.92 (1.53-10.05)	<0.01	0.45 (0.10-2.01)	0.30
Sleep duration ‡ (Non-work days)	Hours/day (1-24 /1.90)	1.13 (1.01-1.27)	0.03	0.88 (0.80-0.98)	0.02

Table 5 Factors Associated with Accidents on Stepwise Logistic Regression Model

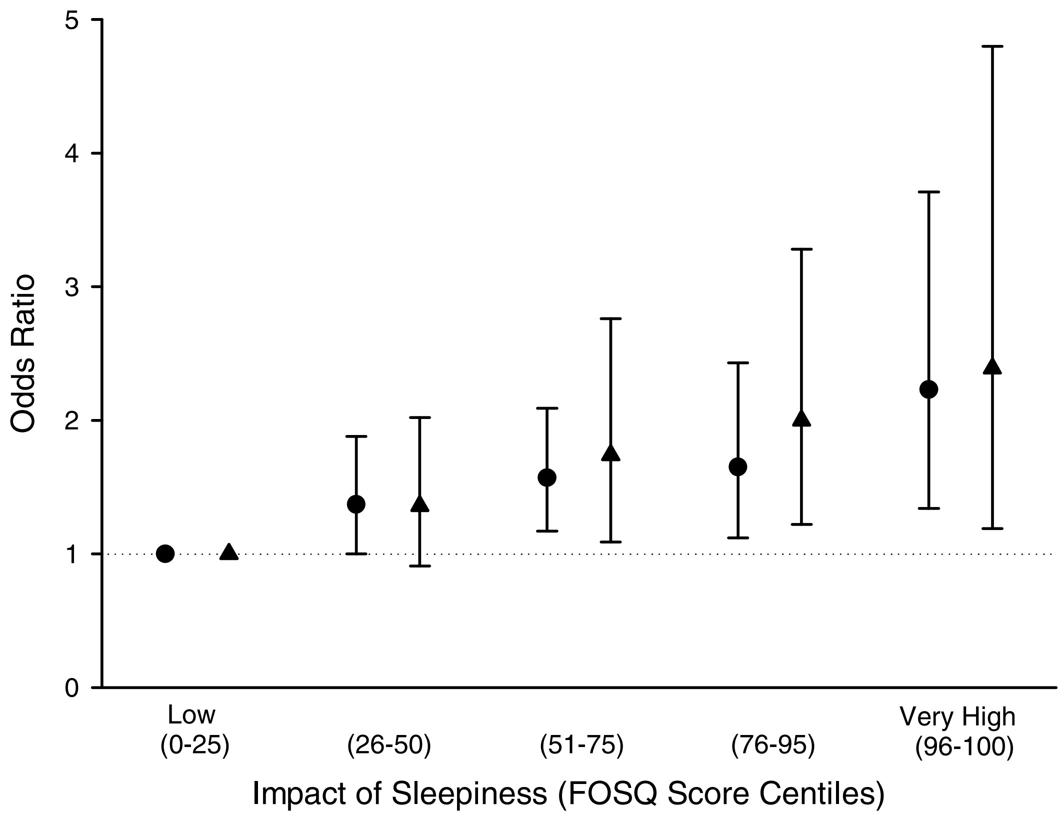
Variable (Range/SD)	All accidents		Multiple accidents		Single vehicle accidents	
	Odds Ratio (95% CI)	P value	Odds Ratio (95% CI)	P value	Odds Ratio (95% CI)	P value
Age - years * (16-71 years /10.0)	0.87 (0.77-0.99)	0.04	0.83 (0.71-0.97)	0.02	0.79 (0.70-0.90)	<0.01
Sleepiness - ESS score * (0-24 units /4.33)	1.24 (1.10-1.34)	<0.01	1.31 (1.14-1.51)	<0.01	1.29 (1.14-1.45)	<0.01
Time driving - hours/week * (10-100 hours /8.21)	1.17 (1.04-1.31)	<0.01	1.20 (1.05-1.36)	<0.01		
Driving location						
Country	0.77 (0.60-0.99)	=0.04	0.59 (0.42-0.83)	<0.01		
Interstate	0.57 (0.40-0.80)	<0.01	0.36 (0.24-0.55)	<0.01		
Drug use *						
Antihistamines †	3.15 (0.97-10.28)	0.06	2.64 (1.19-5.84)	=0.02		
Narcotic analgesics †	2.10 (1.30-3.38)	<0.01	1.84 (1.08-3.12)	=0.03		

Figure 1



6
5
4
3
2
1
0
Odds Ratio
Low Normal
(0-4)
Normal
(5-7)
High Normal
(8-10)
High
(11-17)
Very High
(18-24)
Sleepiness (ESS Score)

Figure 2



5
4
3
2
1
0
Odds Ratio
Low
(0-25)
(26-50)
(51-75)
(76-95)
Very High
(96-100)
Impact of Sleepiness (FOSQ Score Centiles)

Online data supplement

Sleepiness, Sleep Disordered Breathing and Accident Risk Factors in Commercial Vehicle Drivers

Mark E. Howard, Anup V. Desai, Ron R. Grunstein, Craig Hukins, John G. Armstrong, David Joffe, Philip Swann, Donald A. Campbell, Robert J. Pierce

METHODS

The study comprised two samples of commercial vehicle drivers. 3268 drivers were invited to complete a questionnaire and anthropormorphic measurements. Another 244 drivers were also invited to attend in-laboratory polysomnography.

Questionnaire Sample

For the questionnaire sample a clustered sample was used with truck yards as the primary sampling unit. This enabled us to personally access a large number of drivers. 98 workplaces (including 3268 current commercial vehicle drivers) were selected from 395 workplaces on the databases of the Transport Workers Union branches in the three most populous states in Australia (Victoria, New South Wales and Queensland) using simple random sampling. The workplaces were visited by a study investigator together with a Union official and questionnaires were distributed to the drivers. The drivers completed the questionnaire without assistance and returned them anonymously in order to maximize participation and encourage honesty in their responses. The questionnaire included demographics, sleep and work habits and self reported accidents from the previous three years (Appendix E1). Drivers were asked to "include any accident where someone was injured, the police were called or a vehicle was damaged and required repair". Subjects were asked the following details: type of vehicle driven; driving locality; hours of driving and work; shift types; sleep hours; alcohol and drug intake and medical history. The Multivariable Apnea Prediction questionnaire was included to assess the probability of having sleep disordered breathing (E1). This incorporates age, gender, body mass index and symptom scores into a predictive equation for risk of having sleep disordered breathing. Sleepiness was measured subjectively using the

Epworth Sleepiness Scale (E2) (E3) (E4). This uses eight questions to assess the likelihood of falling asleep in a variety of situations. A score of 11 or more was used as the cut-off for excessive sleepiness (E5). The Functional Outcomes of Sleep Questionnaire was used as an additional measure of sleepiness (E6). This is a quality of life questionnaire assessing the impact of sleepiness on a variety of daily activities.

Polysomnography Sample

For the *polysomnography sample* drivers were selected from the databases of the Transport Workers Union in New South Wales and Victoria using simple random sampling. Drivers were contacted in batches of 20. They were assessed for entry criteria and invited to participate in the study until a sample of 160 drivers had agreed to participate in the study. All subjects were current commercial vehicle drivers driving a minimum of 10 hours per week for work. We collected data on age, gender, height and weight from drivers who declined to participate. Full overnight polysomnography in the laboratory was used to diagnose sleep disordered breathing (Compumedics S series, Compumedics Melbourne, Victoria, Australia). Studies were performed at the Austin Hospital in Victoria and Royal Prince Alfred and Royal North Shore Hospitals in New South Wales. Variables recorded during polysomnography included the following: electroencephalogram activity (standard central lead C_3-A_2); left and right electro-occulogram; submental electromyogram; body position; right and left leg movements (peizoelectric movement sensors); oxygen saturation (OxiRadometer; Radiometer, Copenhagen, Denmark); nasal pressure; thoracic and abdominal movements using respiratory inductance plethysmography; and single lead electrocardiogram. Data were stored on magnetooptical disc for analysis. Sleep was staged according to the criteria of

Rechtschaffen and Kales (E7). Respiratory events during sleep were scored manually according to the recommendations of the American Academy of Sleep Medicine Task Force (E8). Apneas were scored if there was cessation of airflow according to nasal pressure for at least 10 seconds. Hypopneas were scored if there was a reduction in the nasal pressure signal of at least 50% lasting at least 10 seconds or a clear reduction of less than 50% in association with a fall in oxygen saturation of 3% or an arousal on electroencephalogram. Dual channel respiratory inductance plethysmography was used to measure breathing if there was failure of the nasal pressure signal. A single scientist in each state staged the studies for sleep and scored them for respiratory events, calculating the respiratory disturbance index. The scientists were blinded to other study results The intraclass correlation co-efficient between scientists was 0.98 ($P<0.01$) for the respiratory disturbance index.

Written informed consent was obtained from study participants. The protocol was approved by the Human Research and Ethics Committees at the Austin Hospital, Melbourne, Royal Prince Alfred Hospital, Sydney and Princess Alexandra Hospital, Brisbane.

Statistical Methods

We calculated that a sample size of 160 subjects for polysomnography would provide a 95% power for demonstrating a prevalence of sleep disordered breathing or excessive sleepiness of at least double that documented in male working populations, with an alpha of 0.05 (sleep disordered breathing prevalence of 50% or excessive sleepiness prevalence of 22%). Results were entered into a Microsoft Access database and analyzed using Stata 6.0 for windows.

We calculated the positive and negative predictive value of a Multivariable Apnea Prediction Score of 0.5 or above for detecting sleep disordered breathing using data from the *polysomnography sample*. These values together with the prevalence of a score over 0.5 were used to estimate the prevalence of sleep disordered breathing in the *questionnaire sample* using the method described by Marshall (E9, 10). Using this method an estimate of the true proportion of subjects with a disease can be made from a population using a screening tool (in this case the Multivariable Apnoea Prediction Score) with known error. A validation study can be used to assess the degree of error and calculate positive and negative predictive values (calculated using data from our polysomnography sample). The prevalence estimate is then derived using the following equation:

$P(e) = PPV \,.\, P(x) + (1 - NPV) \,.\, P(x^-)$

P(e) = estimated true proportion with disease

PPV = positive predictive value, NPV = negative predictive value

P(x) = measured proportion with disease (Multivariable Apnoea Prediction Score $\geq$ 0.5)

$P(x^-)$ = measured proportion without disease (Multivariable Apnoea Prediction Score ≤ 0.5)

A cluster sampling design, as used in this study, may result in a marked increase in variance. Adjustments were made for all analyses of the *questionnaire sample* to account for cluster sampling, with truck yard as the sampling unit. We calculated intraclass correlation co-efficients for key variables, and the design effect (deff), which reflects the effect of the study design on variance. The intraclass correlation co-efficients varied between 0.03 and 0.13 (see Table E1) and deff varied between 0.95 and 1.51, indicating a modest effect on variance. In our analysis the cluster sampling scheme was accounted for with the use of a robust variance estimate using the "cluster" option in the Stata commands. This has the effect of increasing the standard errors compared to analysis without adjustment for cluster sampling.

Table E1 Intraclass Correlation Coefficients for Key Variables

Variable	ICC	Design Effect
ESS	0.03	0.99
MAP	0.05	1.51
Body mass index	0.04	0.95
Age	0.13	1.30
Hours of driving	0.06	1.40
Total accidents	0.08	

ICC = intraclass correlation co-efficient, ESS = Epworth Sleepiness Scale and MAP = Multivariable Apnoea Prediction Score.

Multivariate logistic regression was used to assess the relationship between excessive sleepiness and personal and work related factors, adjusted for age. Continuous and ordinal variables were analyzed continuously unless otherwise indicated, with the odds ratio indicating the change in odds for an increase of one standard deviation for continuous variables or one category for ordinal variables (Table 3). The number of hours of sleep on workdays was analyzed as a categorical variable because of a non-linear relationship with sleepiness. Similarly, to assess the relationship between potential explanatory variables and accident risk (risk of one or more accidents compared to no accidents) we calculated odds ratios adjusted for age, alcohol intake (established major accident risk factors (E11-13)) and hours of driving (to adjust for driving exposure). We performed the same analysis with sleepiness (Epworth Sleepiness Scale and Functional Outcomes of Sleep Questionnaire) classified as a categorical variable. The categories were based on the 25th, 50th, 75th and 95th centiles for sleepiness. For these categories the risk of having multiple accidents (two or more compared to no accidents) was also calculated.

Results

Table E2 Prevalence of Drug Use Amongst Drivers

Drug	Proportion of Drivers
Stimulant drugs	18.6% (14.7-22.5)
Benzodiazepines	1.3% (0.6-1.9)
Antihistamines	0.7% (0.4-1.0)
Narcotic analgesics	2.1% (1.4-2.7)

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Appendix E1 Questionnaire

We want to ask you some questions about driving.
The following questions relate to your main occupation.

For The Following Questions Put A Cross In One Or More Boxes

1. What type of vehicle do you drive at work? semitrailer ☐ truck & trailer ☐ B double ☐ forklift ☐ rigid truck ☐ car/van ☐ bus ☐ other ☐
2. At work, do you drive? your own vehicle ☐ a company vehicle ☐
3. Which shifts do you work? days ☐ afternoons ☐ nights ☐
4. Do you rotate shifts? yes ☐ no ☐
5. Where do you drive? metropolitan ☐ country ☐ interstate ☐

For The Following Questions Write The Appropriate Number In The Box

6. How many hours is your longest shift? ☐
7. How many days do you work per week? ☐
8. How many hours do you work per week? ☐
9. How many hours do you drive per week? at work ☐ not work related ☐
10. How many kilometers do you drive each year? at work ☐ 000 km not work related ☐ 000 km
11. How many hours of sleep do you have each night or day? on work days ☐ days off ☐
12. How many glasses of alcohol do you normally have each day? on work days ☐ days off ☐
13. How many cups do you have each day of the following beverages? tea ☐ coffee ☐ cola ☐

Now we would like to ask you about any medical conditions you have and any medications you take.

14. Do you have any illnesses? Please put a cross in the box to indicate that you have any of the following and give details.

heart disease ☐ (details)________
lung disease ☐ (details)________
diabetes ☐
epilepsy ☐
high blood pressure ☐
sleep apnea ☐
other ☐ (details)________

15. Most drivers get tired while driving. Have you ever used tablets to stay awake while driving? (Put a cross in one box)

occasionally ☐ most days ☐ every day ☐ never ☐

16. Please list any medications that you take, including sleeping tablets and pain relievers. Put a cross in one box to indicate whether you take them regularly or occasionally.

	regular	occasional
1)____________________	☐	☐
2)____________________	☐	☐
3)____________________	☐	☐
4)____________________	☐	☐
5)____________________	☐	☐

Only answer the next question if you have sleep apnoea

17. Do you use any of the following treatments for sleep apnea? (put a cross in one or more boxes)

CPAP mask ☐ mandibular splint ☐
none ☐ throat surgery ☐

Most drivers have had an accident at some time. We would like to ask you about any accidents in the last three years.

Include any accident where someone was injured, the police were called or a vehicle was damaged and required repair

18. Have you had any motor vehicle accidents in the last 3 years?

Tick Yes ☐ No ☐
(put a number in each box opposite)

number of accidents involving another vehicle:
at work ☐ non work related ☐

number of accidents with no other vehicle involved:
at work ☐ non work related ☐