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

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Sleep-disordered breathing and excessive sleepiness may be more common in commercial vehicle drivers than in 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 2,342 respondents to a questionnaire distributed to a random sample of 3,268 Australian commercial vehicle drivers and another 161 drivers among 244 invited to undergo polysomnography. More than half (59.6%) of drivers had sleep-disordered breathing and 15.8% had obstructive sleep apnea syndrome. Twenty-four percent 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 [OR] 1.91, p = 0.02 and OR 2.23, p < 0.01, respectively) and multiple accidents (OR 2.67, p < 0.01 and OR 2.39, p = 0.01), adjusted for established risk factors. There was an increased accident risk with narcotic analgesic use (OR 2.40, p < 0.01) and antihistamine use (OR 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.

Keywords: accidents, traffic; antihistamines; narcotic analgesics; obesity

Motor vehicle accidents remain a common cause of injury and premature death (1). Between 20 and 30% 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 among 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 acci-

dent 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 among drivers of heavy vehicles (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 among 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. 3,268 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 were 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 (*see* Appendix E1 in the 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, sex, 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 (ORs) 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 dependent variables. We included explanatory variables with an α of less than 0.10 on univariate analysis. ANOVA 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 3,268 drivers invited to participate in the questionnaire sample, 2,342 drivers (72%) returned completed questionnaires. Ninety-nine percent of drivers in the sample were male, compared with 97% of drivers on the Transport Workers Union database. Mean age for drivers in the sample was 42.4 years compared with 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.

One hundred sixty-one 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 with those who declined to participate (Table 2). Eighty-four percent of drivers were overweight or obese (Table 1).

Prevalence of Excessive Sleepiness and Sleep-Disordered Breathing

More than half (59.6%; 95% confidence interval [CI] 51.6–67.3%) 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 ($\geqslant 0.5$). A score of 0.5 produced a positive predictive value for at least mild sleep-disordered breathing (RDI $\geqslant 5$) of 0.74 and a negative predictive value of 0.57. Using these values, we estimated a prevalence of 54.0% (95% CI, 47.2–60.8%) for at least mild sleep-disordered breathing in the questionnaire sample, compared with 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 (Tables 3 and 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

TABLE 1. CHARACTERISTICS OF POLYSOMNOGRAPHY AND QUESTIONNAIRE SAMPLES

	Polysomnography (n = 161)	Questionnaire (n = 2,342)	p Value
Age, yr	47.8 (9.3)	42.4 (10.0)	< 0.01
Proportion of males	99.4% (96.6–100)	99.1% (98.5–99.7)	0.75
Body mass index, kg/m^2	29.7 (5.1)	29.0 (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 $\geqslant 11$)	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 $\geqslant 30$)	10.6% (6.3–16.4)*		
Sleep apnea syndrome (RDI $\geqslant 5$, ESS $\geqslant 11$)	15.8% (10.5–22.5)*		
Sleep apnea risk (MAP)	0.49 (0.19)	0.40 (0.19)	< 0.01

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

Data expressed as mean (SD).

*Data expressed as proportion (95% CI).

TABLE 2. DEMOGRAPHIC FEATURES OF RESPONDERS AND NONRESPONDERS FOR POLYSOMNOGRAPHY

	Responders (n = 161)	Nonresponders (n = 84)	p Value
Age, yr	47.8 (9.3)	46.0 (9.4)	0.16
Height, cm	176 (6.9)	177 (7.7)	0.30
Weight, kg	92.0 (15.9)	88.9 (14.5)	0.13
Proportion of males	99.4% (96.6–100)*	98.8% (93.5–100)*	0.33

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

days off. The odds of excessive sleepiness increased by 50% (OR 1.56, 95% CI 1.37–1.78) for an increase in the Multivariable Apnea Prediction Score of 1 standard deviation (SD 0.19, range 0–1.00). 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 to 8 hours of sleep per night. For those who averaged less than 5 hours per night, the OR for excessive sleepiness was 2.74 (95% CI, 1.84–4.08). The odds of reporting excessive sleepiness actually increased in those who had more than 8 hours of sleep, with an OR of 5.62 for more than 9 hours (95% CI, 1.93–16.34).

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

A majority of drivers (2,079 of 2,342, 88.8%) answered the questions about accidents. Seven hundred thirty-nine drivers (35.5%, 95% CI 32.1–38.9%) had a total of 1,407 accidents in the previous 3 years, with 48.3% of these drivers having had more than one accident (95% CI, 44.3–52.3%). Most accidents were work-related (81.6%, 95% CI 78.7–84.4%). We assessed the relationship between accident risk over the preceding 3 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 (OR 1.91, 95% CI 1.09–3.35) and of multiple accidents (OR 2.67, 95% CI 1.29–5.52). A similar relationship was evident between the Functional Outcomes of Sleep Questionnaire total score and accident risk (Figure 2). The sleepiest 5% of drivers had an OR of 2.23 for having an accident (95% CI, 1.34–3.71) and 2.39 for multiple accidents (95% CI, 1.19–4.80). The Multivariable Apnea Prediction Score was weakly related to the risk of a single vehicle accident (OR 1.14, 95% CI 0.99–1.33, 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 (OR 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 (OR 0.82, 95% CI 0.15–3.57 for change in RDI of 1 SD).

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 in the online supplement). Narcotic analgesic

TABLE 3. PERSONAL FACTORS ASSOCIATED WITH CHRONIC EXCESSIVE SLEEPINESS AND ACCIDENTS

Variable	Units or Category (Range/SD)	Chronic Excessive Sleepiness (ESS score 11–24) OR‡ (95% CI)	p Value	Accident in Past 3 yr OR§ (95% CI)	p Value
Sex	Female	1		1	
	Male	0.41 (0.17–0.97)	0.04	0.74 (0.29–1.95)	0.54
Age*	yr (16–71 yr/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	(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 ≥ 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/d (0–18 drinks/1.84)	0.98 (0.87–1.11)	0.75	1.09 (0.99–1.19)	0.07
Caffeine*	Cups/d (0–38 cups/3.69)	1.20 (1.08–1.33)	< 0.01	0.96 (0.86–1.04)	0.28

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

* OR 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.
‡ Adjusted for age.
§ Adjusted for age, hours of driving, and alcohol intake.

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 3 yr	
		OR[†] (*95% CI*)	p Value	OR[‡] (*95% CI*)	p Value
Time worked*	h/wk (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, h (work days)	≤ 5	2.61 (1.84–3.71)	< 0.01	1.05 (0.75–1.48)	0.78
	5.1–6	1.87 (1.35–2.61)	< 0.01	1.14 (0.82–1.59)	0.43
	6.1–7	1.49 (1.06–2.08)	0.02	1.20 (0.88–1.64)	0.24
	7.1–8	1		1	
	8.1–9	1.67 (0.78–3.1)	0.15	0.95 (0.49–1.84)	0.89
	> 9	3.92 (1.53–10.05)	< 0.01	0.45 (0.10–2.01)	0.30
Sleep duration* (nonwork days)	h/d (1–24/1.90)	1.13 (1.01–1.27)	0.03	0.88 (0.80–0.98)	0.02

Definition of abbreviations: ESS = Epworth Sleepiness Scale; OR = odds ratio.

* 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.

[†] Adjusted for age.

[‡] Adjusted for age, hours of driving and alcohol intake.

use (OR 2.17, 95% CI 1.31–3.60) and benzodiazepine use (OR 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 among commercial vehicle drivers. Excessive sleepiness was predominantly related to sleep-disordered breathing risk and hours of sleep, with increasing
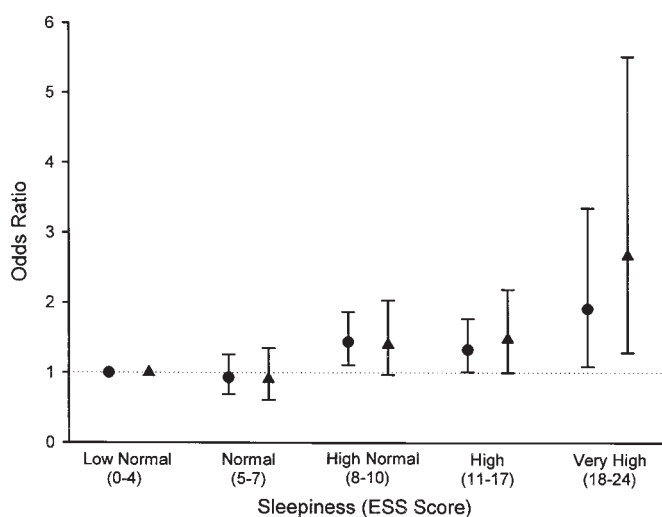

Figure 1. Accident risk related to subjective sleepiness (Epworth Sleepiness Scale). *Circles* represent odds ratio (OR) for one or more accidents and *triangles* the OR for multiple accidents. *Error bars* represent 95% confidence intervals for the ORs. ORs are adjusted for age, average daily alcohol intake, and hours of driving per week. ESS = Epworth Sleepiness Scale.
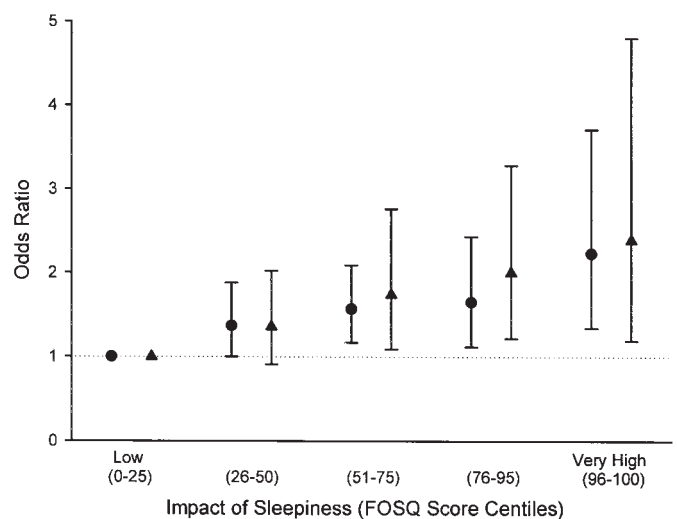

Figure 2. Accident risk related to impact of sleepiness (Functional Outcomes of Sleep Questionnaire). *Circles* represent OR for one or more accidents and *triangles* the OR for multiple accidents. *Error bars* represent 95% confidence intervals for the ORs. ORs are adjusted for age, average daily alcohol intake, and hours of driving per week. FOSQ = Functional Outcomes of Sleep Questionnaire.

TABLE 5. FACTORS ASSOCIATED WITH ACCIDENTS ON STEPWISE LOGISTIC REGRESSION MODEL

Variable (Range/SD)	All Accidents OR (95% CI)	p Value	Multiple Accidents OR (95% CI)	p Value	Single-vehicle Accidents OR (95% CI)	p Value
Age, yr* (16–71 yr/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, h/wk* (10–100 h/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		

For definition of abbreviations, *see* Table 4.

 *OR for continuous and ordinal variables indicate the change in odds for an increase of 1 SD or one category for ordinal variables.

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

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 16% had obstructive sleep apnea syndrome, compared respectively with 24% and 4% of working males in the general community (14, 15). Previous studies identified sleep-disordered breathing in between 25 and 78% 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 and coworkers found the highest prevalence of 78% among 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 with that by Stoohs and colleagues and our study, which could explain their relatively low prevalence. In a recent American study, 406 drivers were sampled from 1,391 respondents to a questionnaire and studied with full in laboratory polysomnography (35). Twenty-eight percent 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 sex were similar between respondents and nonrespondents. A higher proportion of women and more stringent criteria for scoring respiratory

events in this study may explain the lower prevalence compared with 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% 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 with 16% of subjects in the Australian general population study of sleep-disordered breathing and 16% of adult Australian males (15, 38). Finally, sleep deprivation may increase the severity of sleep-disordered breathing (39). Seventeen percent of our drivers averaged 5 hours of sleep per night or less, which might increase the prevalence of sleep-disordered breathing.

Excessive Sleepiness

Twenty-four percent of drivers had chronic excessive sleepiness, compared with 10.9% 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 and coworkers 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), suggests 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 (0.05–0.07%), although higher blood alcohol concentrations convey a much higher accident risk (47). Similarly driving at night, up to about 2:00 A.M., doubles the risk of having an accident, whereas 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, whereas 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 among 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 and colleagues 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 and Quig suggest that sedating antihistamines increase accident risk, and our data support this (56). Antihistamines impair simulated driving performance to a similar degree as 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 those driving on the 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% 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 accidents fatal to the driver 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 underreport accidents because of concerns for job security, which would tend to weaken any association between these disorders and accidents. Although 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 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 among 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 in those who used narcotic analgesics or

antihistamines. Interventions to reduce sleepiness among 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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