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Investigating the role of fatigue, sleep and sleep disorders in commercial vehicle crashes: A systematic review

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Abstract

Commercial vehicle driving is an occupation in which increasing demands are being placed on drivers as a consequence of economic and trade expansion. Crash rates are high, as is the injury risk to all road users where commercial vehicles are involved. Fatigue and sleep deprivation are of increasing concern, and sleep disorders have been shown in car drivers to increase crash risk. Commercial drivers may have higher crash risk due to exposure and high sleep disorder prevalence; however, reviews thus far have not provided sufficient conclusion. The aim of this systematic review was to investigate the evidence of the role of fatigue, sleep and sleep disorders in commercial motor vehicle crashes. Relevant electronic databases and grey literature were searched and 16 peer-reviewed published studies met the study criteria. Factors found to have an association with crashes were daytime sleepiness (Epworth Sleepiness Scale), and sleep debt. While not employed as a search term, obesity was shown to be a risk factor for sleep disorders, daytime sleepiness and incurring a crash or near miss. Most studies suffered from small sample size as well as specific methodological flaws making generalisation difficult and indicating the need for a large, well-designed study with empirical measures of both risk factors and outcomes.

Keywords

Sleep disorder, Commercial driver, Sleepiness, Crash

Introduction

The commercial motor vehicle (CMV) driver faces a challenging work environment. With increasing demands on the heavy vehicle industry, alongside economic and trade expansion, safety concerns are paramount. Crash rates are high [1], as is the injury risk to all road users [2] where heavy vehicles are involved. While fatigue and sleep deprivation have been recognised as factors critical to the safety and performance of commercial motor vehicle drivers [3,4], there is inconclusive evidence for the interplay and strength of associations of other sleep-related risk factors for CMV crashes including sleep disorders such as sleep apnoea and excessive daytime sleepiness, alongside associated factors such as the drivers' health status.

Systematic reviews to date have included some studies of CMV populations; however, there is no current review investigating the crash risk associated with fatigue, sleep or sleep disorders solely among CMV drivers. Connor et al [5] investigated the role of driver sleepiness across studies of car drivers and highlighted a positive association, albeit based on a paucity of well-designed studies. Robb et al [6] conducted a review of risk factors for drivers involved in work-related crashes, concluding fatigue and sleepiness to be consistently associated with an increased risk of crashing and Tregear et al [7] more recently reported increased crash risk for both private motor car and CMV drivers with obstructive sleep apnoea (OSA).

Some studies have focused on sleep hours for CMV drivers, considering also the scheduling contribution to reduced sleep. Studies have shown that, on average, CMV drivers sleep 5-6.5 hours per night/day [4,8]. Further, they have been shown to drive for an average of 14 hours per day when not restricted [9], as such leaving limited time for sleep. Beilock [10] described excessive work hours as well as schedule-driven tendencies to speed among this group of drivers. These factors are expected to contribute not only to insufficient sleep with greater sleepiness during the waking hours, but also increased crash risk. While shift work per se is not the subject of this review, the additional effects of circadian rhythm disruption in those drivers working either predominantly at night, or on rotating shifts, should also be considered as a potentially negative contributor to their sleep health.

Sleep disorders such as obstructive sleep apnoea (OSA) have been shown to increase the crash risk of motor vehicle drivers by two- to seven-fold [11], although this has been demonstrated predominantly in symptomatic sleep clinic populations. Given previous research has found CMV drivers to have a higher prevalence of sleep apnoea than the general population [12,13], it may be expected that the crash risk is greater in a CMV population, yet this has not been empirically demonstrated.

Obesity, most commonly measured as a body mass index (BMI) >30 kg/m^2 is an important risk factor for OSA and has been postulated to contribute to sleepiness. Sufferers of OSA often experience daytime sleepiness, challenging the performance of tasks requiring vigilance and alertness such as motor vehicle driving [14]. Dagan, Doljansky & Green [15] recommended screening all professional drivers, whether or not they report symptoms of OSA, by assessing the drivers' BMI, given their findings that obese drivers are more prone to be sleepy during the day. Few studies have investigated driver performance (of any vehicle, car or truck) and crash outcomes using anthropometric proportions as a covariate measure, and not all studies measuring OSA have concurrently studied the effects of obesity. The replicable estimate of crash risk related to a diagnosis of sleep apnoea, or other measures of or contributors to daytime sleepiness and driver sleep health, has yet to be quantified.

The national freight task in Australia is increasing at approximately 1.21 times economic growth [16]. Projected economic growth in Australia may therefore increase scheduling, payment and delivery pressures on drivers if employers do not adjust their staffing accordingly; it is imperative that the drivers' opportunity for sleep and consequently optimum health is considered equally. The objective of the current review therefore, is to assess the available evidence investigating the role of fatigue, sleep or sleep disorders in drivers of commercial vehicles that crash.

Methods

A systematic review of the international literature was conducted to identify all peer-reviewed published research and relevant grey literature that quantified the relationship between fatigue, sleep or sleep disorders and a CMV crash. The following electronic databases were searched: Medline, EMBASE, Scopus, Transport and the Australian Transport and Road Index (ATRI) database. The search was restricted to English language articles published from 1950 to 2010 inclusive. Studies were included if they specifically investigated the CMV or bus driver population, using the keyword search terms or Medical Subject Heading (MeSH) terms of "Commercial vehicle" OR "Commercial driver" OR "Truck" OR "Truck Driver" OR "Lorry" OR "Bus" OR "Long Distance" AND "Sleep$.tw" OR "Obstructive Sleep Apnoea" OR "Tired" OR "Fatigue" AND "Accident" OR "Crash" OR "Collision". The term 'near miss' was not included as a search term; papers considering 'near miss' were only included if they primarily measured CMV crash. Reference lists of all papers meeting the inclusion criteria (below)were searched and hand searching was conducted of relevant journals, namely Accident Analysis and Prevention, Injury Prevention, Traffic Injury Prevention, Epidemiologic Reviews and Sleep journals for a five year period (2006-2010 inclusive).

Definition of terms

1. *Commercial Motor Vehicle:* includes vehicles defined as 'heavy vehicles' (used for commercial transportation), trucks and buses conducting long haul trips. CMV drivers were considered those who drove long distance trips commercially, in heavy vehicles, and included long distance bus drivers.
2. *Fatigue:* There is ongoing scientific debate about the definition of fatigue. For the purposes of this review, papers were included which employed the terms fatigue and/or sleepiness.

Inclusion criteria

Studies were included if they met the following criteria:

1. Study subjects were CMV drivers or, where both CMV and non CMV drivers were included in the study, a separate analysis using only the CMV drivers was performed and data presented.
2. The study must have enrolled at least 20 subjects.
3. Sleep, fatigue or sleep disorder was measured in CMV drivers as an exposure; either by self-report, validated scale such as the Epworth Sleepiness Scale, formal polysomnography or video evidence such as in naturalistic driving studies.
4. CMV crash was the primary outcome of interest; studies were also included if they measured any near miss as a CMV driver, but only if the study primarily measured crashes.

5. Articles were full-length.
6. If the same study was reported in multiple publications, the most complete publication was used as the primary reference.

Exclusion criteria

Studies that focused entirely on 'short distance CMV' drivers were excluded. This exclusion was considered necessary due to the known differences in scheduling and work environment (including regulatory requirements) of the long distance CMV driver compared with the short distance CMV driver; hence the difference in risk exposures that would influence the outcome of crashing differently.

Literature analysis

The search strategy was applied by one author (LN Sharwood) and repeated after three months in order to verify the number of articles identified as well as to identify new publications. Studies meeting the inclusion/exclusion criteria were appraised independently by two authors according to the STROBE guidelines for reporting observational studies [17]. Studies were appraised on their design with consideration of recruitment bias and reporting, sample size, data sources, statistical methods and data presentation, limitations and external validity. Meta-analysis was not attempted due to the heterogeneity of the populations among the studies that met the inclusion criteria and the lack of robustness of the research designs.

Results

Description of studies

A total of 96 papers were identified using the search terms and databases described above. The 85 articles which had their full text written in English were reviewed by title and abstract to determine relevance for full text extraction. Among the full-text articles extracted, 16 articles (published between 1994 and 2010) met the study inclusion criteria and were critically appraised and their results summarised. These studies comprised one retrospective case-control study, 13 cross sectional studies and two naturalistic driving studies. Of the cross sectional studies, there was only one that used a comparison group.

Study settings included workplaces selected from union databases (n=2) marine ports (n=2), company terminal/depot (n=2), weighing stations (n=1), national occupational safety database (n=2), a roadhouse, a central marketplace, a population database and a police reported crash database. Three studies did not describe study settings. Response rates where they were described, ranged from 25% to 67%, and although many sampling frames may have incorporated significant bias, these concerns were not described nor adjusted for in any study.

Outcome measures

The number of crashes and/or near misses as a CMV driver was the primary outcome in 15 of the 16 studies included in the review, one (a case-control study) [18] examined fatal versus non-fatal crashes. Crash status was self-reported by all studies other than the 2 naturalistic driving studies [8,19] which measured the outcome by observation, plus the case-control study [18] which investigated all crashes in a state police department's collision report database, and compared fatal crashes with injury crashes, determining the influence of driver sleepiness/fatigue and inattention/distraction on the likelihood of fatal outcome compared to non-fatal injury.

Five studies also included the occurrence of a near miss or crash relevant conflict [8,19-22]. The period of time requested for crash history ranged from 6 months to 10 years with one additional study using the drivers' entire driving history. Three studies did not describe the period of crash history requested [23-25].

Measures of sleep disorders and sleepiness

Obstructive Sleep Apnoea as a sleep disorder was empirically measured by three studies [26-28]. Howard et al [26] used a randomly selected subset of their larger questionnaire sample of commercial drivers to conduct 161 polysomnography tests. They found that over half (59.6%) of drivers had sleep disordered breathing (SDB) (five or more respiratory disturbances per hour) and 16% had Obstructive Sleep Apnoea Syndrome (OSAS) - defined as SDB plus an Epworth Sleepiness Score (ESS) of greater than 10. Stoohs et al [27] found 46% of drivers in their study to have SDB, defined as an oxygen desaturations index $\geq$10. Carter et al [28] similarly used a randomly selected subset of participants from their larger questionnaire sample and conducted 161 polysomnography tests; of this sample, 17% were found to have OSAS.

Daytime sleepiness was measured as a covariate in 11 studies using the self-report Epworth Sleepiness Scale (ESS) [29]. Using this scale the respondent is asked to rate their 'likelihood of dozing off' in eight different daily activities (one of which relates to sleepiness while driving), scoring 0 to 3 for each response, a sum total greater than 10 suggesting daytime drowsiness. In these 11 studies, the mean ESS ranged from 4.75 to 9.6 and the proportion of drivers with an ESS score greater than 10 ranged from 10.5% to 46%. The Pittsburgh Sleep Quality Index (PSQI) [measured by 24, 25, 30] can be used to quantify a person's level of daytime functioning although it was primarily designed to measure their sleep quality. A PSQI greater than 5 suggests impaired sleep; however, it has also been shown to identify sleep disorders. Using this criterion (PSQI>5) Sabbagh-Ehrlich et al [25] found 21.3% of their sample to have poor sleep quality, De Pinho et al [24] found 46.3% of drivers to be poor sleepers, and 35.4% of drivers studied by Souza et al [30] reported poor sleep on their PSQI.

Nine studies questioned the drivers directly about their tendency to fall asleep or feel drowsy while driving [8, 19, 21-23, 25, 28, 31, 32], some finding incongruence between these responses and those measured with the self reported ESS or

PSQI. Perez-Chada et al [21] for example, found 56% of CMV drivers in their study to report tiredness while driving, yet only 14% of them had an ESS score over 10. In the study by Sabbagh-Ehrlich et al [25], the drivers seemed to self-report lower levels of fatigue than those suggested by the fatigue component of their PSQI scores.

Sleep quantity was also a measure used by 6 studies [8, 23, 24, 28, 30, 32], with 'insufficient sleep' measured by various methods and showing an association with crashes or critical incidents in the following three studies. Hanowski et al [8] in their naturalistic driving study, compared the sleep in the 24 hours prior to the crash/critical incident to the drivers overall mean sleep. Carter et al [28] attributed a 'sleep debt' to those drivers reporting a difference between the number of hours they actually slept and the number of hours they 'want(ed) to sleep'. Tzamalouka et al [32] measured the number of hours slept in the week prior to the crash as an exposure.

Related findings

Anthropometric proportions were measured (either by investigators or self-reported) in 13 of the 16 included studies. Mean BMIs reported ranged from 26.9kg/m^2 to 29.29kg/m^2, and the prevalence of obesity (BMI>30) in CMV driver populations ranged from 15% to 53.4%. Where all categories of BMI were presented [19, 21, 25, 26, 30], those drivers with a BMI>25 (overweight and obese) ranged from 52.5 to 81%. High BMI is assessed against the outcome of crash in two studies. These relationships are described below.

Exposure-outcome relationships

Considering first the relationship of a sleep disorder diagnosis to a crash outcome, Howard et al's drivers [26] with SDB did not have significantly increased self-reported crashes compared with drivers not having SDB. However, the study was not powered to detect this. Stoohs et al [27] found drivers with SDB had had twice as many crashes as those drivers without SDB (adjusted for mileage); however, this was not statistically significant. Drivers with OSAS in the study by Carter et al [28] reported no greater crash rate than others in the sample, perhaps because their crash report time frame was very long (10 years prior).

Secondly, the relationship of sleepiness (as measured by an ESS score greater than 10) to self -reported crash was considered by seven studies [21-24, 26,30,31]. In all seven studies positive ESS was related to a significant increase in crash risk; five studies described significance with odds ratios ranging from 1.91 to 2.98 (adjusted) and two studies using chi squared tests. Sleepiness indicated by positive PSQI (score>5) was not found to be significantly associated with self-reported crash by either De Pinho et al [24] or Souza et al [30]. However, all drivers with a history of crash in the study by Souza et al had a positive PSQI.

Thirdly, the findings of all studies which measured the relationship of sleep quantity to crash risk were consistent, despite having measured sleep quantity in different ways. Hanowski et al [8] found reduced sleep to be significantly predictive of critical incidents including crashes; Carter et al [28] combined sleep debt with an ESS>10 and found this variable significantly related to the risk of a work-related crash, with an adjusted OR of 2.1 (95% CI 1.1-3.9). For Tzamalouka et al [32], the number of hours slept the week prior to this incident was a significant independent predictor (adjusted) for drivers both falling asleep at the wheel or having a crash. The majority of drivers reporting sleepiness related crashes in the study by Leechawengwongs et al [31] identified insufficient sleep as the cause although the researchers did not measure sleep quantity.

Finally, crash or near miss was predicted by BMI in the study by Wiegand et al [19] who investigated the relationship of BMI to fatigue and 'safety critical events'. The odds of involvement in a crash or near miss for an obese driver were 1.37 compared with non obese drivers (CI = 1.19–1.59). Sabbagh-Ehrlich [25] revealed a strong association between BMI and sleep quality, assessed by the PSQI, such that increasing BMI predicted poorer sleep quality.

Discussion

Main findings

Regulation of the heavy vehicle industry has been the subject of considerable scrutiny in recent decades with the objective of reducing CMV crashes, in part due to the recognized stresses the CMV environment places on the health and safety of the driver. Obstructive Sleep Apnoea as a crash risk in this population has been empirically measured by three studies, none of which found significant relationships between this disorder and self-reported crash risk. However, sample sizes were too small to establish any effect. In the study by Stoohs et al [27] for example, with sample size of 90 participants, this finding of a non-significant but elevated risk may be due to Type II error; further, all drivers were from one long distance trucking company. One study [28] also reported the incidence of crashes with an exposure time spanning 10 years. Having a significant time lag from exposure to outcome such as this makes determination of any association quite tentative. Tregear et al [7], in a recent systematic review, described OSA as a significant contributor to non-commercial motor vehicle crashes, recognizing the lack of sufficient evidence in the CMV population.

This review also describes seven studies which found positive associations between excessive daytime sleepiness (measured by ESS) and CMV driver crash risk, with adjusted odds ratios ranging from 1.91 to 2.98. Further, three studies presented a relationship between sleep debt experienced by CMV drivers (using varied measurement methods) and their risk of having a crash or near miss, the sleep debt experienced in the days just preceding the incident being the most critical. These are, however, tentative associations given the limitations described below.

It is of particular importance to describe the findings regarding BMI, driver sleepiness and the crash risk of CMV drivers because excess body weight seems common among the CMV drivers studied in developed countries. BMI was measured in 11 out of the 16 studies reviewed, with most studies (n=9) suggesting a prevalence of obesity in CMV drivers that is likely to be considerably higher than in the general population. For example, a recent population-based study of Australian men found a prevalence of overweight and/or obesity of 64% across all ages; this was no different for the age bracket 40-49 years and, at 70%, slightly higher for those aged 50-59 years [33].

Wiegand et al [19] described obese drivers as more likely to be fatigued while driving and involved in a 'safety critical event' compared with non-obese drivers. However, they did not empirically measure OSA. Obesity has been previously described as a contributor to daytime sleepiness and fatigue [34], even in patients without OSA. While it seems likely that a high BMI is a risk factor for daytime drowsiness and sleep disorders, it is not well understood to what degree BMI is an effect modifier on the risk of crashing. There has been sufficient interest in this health concern, however, that the Federal Motor Carrier Safety Administration in the United States recommended in 2008 that CMV drivers with a BMI$\geq$30 should have compulsory testing for OSA. Previous studies have not provided sufficient evidence on the link between lifestyle (health choices, health conditions and work schedules), fatigue and the risk of CMV crashes or critical driving incidents.

Limitations

The overriding limitation relates to the study design adopted for the majority (81%) of the studies, namely, a cross sectional survey. Such a design is limited in its ability to identify causal relationships and the interplay of risk factors of interest and the outcome. The predictor variables have strong collinearity which is difficult to analyse without more rigorous methodology. Further limitations include small sample sizes of as low as 90 (median sample was 308.5) and although all studies described unique hypotheses and related their analyses to these, none of these studies performed any pre or post hoc power calculation.

Self-report data, as used for both predictor and outcome variables in most studies, adds significant limitation to their strength. Most studies (n=13) made use of self-reported crash history which may be subject to considerable recall bias. As is the concern with any self-reported data, trying to obtain accurate estimations of the extent of fatigue in CMV drivers is fraught with difficulty. Most drivers today are heavily regulated with respect to their working hours, so are likely to under-report having been fatigued, falling asleep while driving, or other symptoms of sleep disorder. This has been seen in a USA study [35] where 1443 CMV drivers were screened using a combination of data to identify OSA or related symptoms in which 190 (13%)were identified as having a high risk of OSA and needing further testing. However, none of the 1443 drivers completing the medical form required for licensure reported they had a sleep disorder or, pauses in breathing while asleep, daytime sleepiness or loud snoring. It has also been found that sleepiness is often denied by drivers as a causal factor in their truck crashes [36]. With respect to sleep disorders, many sufferers are unaware of their own symptoms and therefore do not accurately self-report symptoms such as sleepiness. Previous research has suggested that asking for bed partner validation for self-reported sleep disorders can be of significant assistance [37].

Height and weight data, for the purpose of calculating BMI, was also predominantly self- reported, and as such subject to the measurement error previously reported [38]. Given the likelihood of higher BMI being under-reported, it is plausible that in the absence of adjusting for BMI when investigating the association between sleep and commercial vehicle crashes, the reported association would be weakened, thus biased toward the null.

The ESS was originally validated in a Caucasian, symptomatic population and has been since validated for use in several other languages/cultural settings. The limitations of self-reported fatigue have been highlighted through cross validation. This is evident where the self-reported daytime fatigue while driving differs significantly from fatigue levels found by the ESS, highlighting the difficulty of measuring sleepiness. Polysomnography is the gold standard of objective measures to diagnose sleep apnoea. This was used in three studies only and in a smaller sub-sample of drivers - no doubt given the cost and difficulty of application to all drivers.

In the studies included in this review, participant recruitment methods were either poorly described with respect to sampling frames, or simply suffered from small response rates (some as low as 25%), therefore introducing the possibility of selection bias. While study settings varied, some researchers limited their study populations considerably by using only one transport company [24], or only one recruitment location [21]. Three studies did not describe their sampling methods at all. The key bias in most studies related to how they quantified covariate measures such as sleepiness and similarly the outcome measures of crash or near miss. The ability of the research findings to be generalised beyond the study populations is severely hampered by the significant methodological limitations of the studies.

Conclusion

Commercial motor vehicle drivers spend long hours behind the wheel of the largest vehicles on the road, and therefore particularly need sufficient time for quality sleep, and to eat well to maintain a healthy BMI. The risk of a crash or even drowsiness while driving has significant implications for all road users. This review has highlighted potential associations between the quantity of a CMV driver's sleep, their body weight, levels of sleepiness during the day and their risk of crashing. Most studies thus far, however, have used measures based on self-report or the driver's perception (e.g. of their fatigue); self-report data are known to be limited in comparison to empirical measures. With these and the other limitations described, the current literature to date is restricted in drawing conclusions in relation to sleep and CMV driver crashes. This paper has described the findings and limitations of previous studies of the risk posed by fatigue, sleep and sleep disorders for commercial vehicle crashes. There remains inconclusive evidence as to the direction and strength of associations of risk factors for CMV crashes, particularly for sleep disorders including sleep apnoea, health status and the role of shift scheduling. These factors are limiting the much-needed understanding of how preventive measures can be developed to further reduce the risk of crashing among this group of drivers. In the Australian context, it is clear that policy makers are attempting to manage fatigue-related risk in this population. However, there is a need for empirical pre- and post- intervention research to determine the accuracy of regulatory change. The interplay of sleep, health and work-life factors on the risk profile of the long distance commercial vehicle driver must be incorporated into a well-designed study that can further overcome the limitations of the research to date.

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Safety in the transport industry

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Abstract

Workers compensation statistics show high rates of fatalities, traumatic injuries and musculoskeletal disorders occur in the transport industry, particularly the road transport sub-sector. Safety initiatives and innovation are occurring although they tend not to be shared between operators. The Transport Strategy Group, Workplace Health and Safety Queensland is engaging with the industry, especially the heavy freight road transport sector, using action research to learn more about the health and safety systems in the industry and concurrently to improve health and safety outcomes. Industry networks are being established using concepts of collaborative governance to break down barriers, improve sharing of issues and solutions and to improve work health and safety outcomes.

Keywords

Transport, Road freight, Work health and safety, Collaborative governance, Action research

Introduction

Queensland workers compensation statistics show that the transport industry, and particularly the road transport sub-sector, is a high risk industry with workers compensation claims well above the all-industry wide rate [1]. The Transport and Logistics Industry Skills Council, in their 2010 Environmental Scan [2 p.3], observe '…there are widely held views that the industry is dangerous, fatiguing and has little potential for career development. The high profile of accidents and fatalities involving transport drivers compounds this image.'

It was against this backdrop of higher than average fatality and injury statistics that Workplace Health and Safety Queensland (WHSQ) established the Transport Strategy Group (TSG) in 2010. The aim of the TSG is to provide focus and strategic direction on health and safety issues affecting the transport industry through evidence-based and innovative programs [3].

The TSG is developing an approach which recognises that many of the problems confronting the industry are broader societal issues that defy a single jurisdiction- or government-imposed solution. This approach includes:

- leading relationships between WHSQ and transport industry partners (including other government agencies)
- assisting in the development of information and education strategies to enhance health and safety
- seeking to influence legislation and standards including those in other portfolio areas which have the potential to impact health and safety outcomes within industry
- developing WHSQ's internal capabilities in this area.

The TSG is also addressing the shortcomings or insufficiencies of a formalistic legal paradigm. Over the last two years WHSQ has been improving the impact and effectiveness of inspectorate services through better targeted enforcement activity, a more advisory approach and emphasising interventions with a multiplier effect. Regulatory support and, when required, regulatory compulsion, are critical. However, more is required to move the industry beyond laws and a culture of minimal compliance and avoiding litigation to one which creates new values, norms, practices and culture around health and safety.

One of the priorities of the TSG is an engagement program aimed at identifying and understanding safety management in the industry and, over time, encouraging continuous improvement. This is progressed by facilitating cross-industry