



## Review

## Age-related safety in professional heavy vehicle drivers: A literature review

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## ABSTRACT

With Australia facing a looming shortage of heavy vehicle drivers the question is raised as to whether it is desirable or prudent to encourage older professional heavy vehicle drivers to remain in the transport sector for longer, particularly those of heavy vehicles or recruit drivers of a younger age.

**Aim:** To review age-related safety and identify other factors that contribute to accidents experienced by heavy vehicle drivers.

**Methods:** A search was conducted of national and international peer-reviewed literature in the following databases: MedLine, Embase, Cinahl, PsychInfo and the Canadian Centre for Occupational Health & Safety. A manual search was performed to obtain relevant articles within selected journals.

**Results:** A limited number of studies reported age-specific accident rates for heavy vehicles for the spectrum of driver age that included drivers younger than 27 years and those over 60 years of age. Heavy vehicle drivers younger than 27 years of age demonstrated higher rates of accident/fatality involvement which decline and plateau until the age of 63 years where increased rates were again observed. Other contributing factors to heavy vehicle accidents include: long hours and subsequent sleepiness and fatigue, employer safety culture, vehicle configuration particularly multiple trailers, urbanisation and road classification.

**Conclusions:** Drivers of heavy vehicles are over-involved until age 27 years however a characteristic 'U' shaped curve indicates a higher risk of accident involvement for both younger and older drivers. More detailed analyses of "at-fault" involvement and inability to avert an accident and other factors that contribute to accidents across the ages of heavy vehicle drivers may give further clarification to the degree of safety of both younger and older commercial heavy vehicle drivers.

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## 1. Introduction

The transport and storage industry plays a significant role in a nation's economy and in Australia contributes approximately 5.6% to gross domestic product and employs almost 5% of the workforce (National Road Transport Commission, 2003). In Australia it is estimated that heavy vehicles deliver up to 72% of the total freight task and this figure is expected to almost double in the next 20 years; therefore a shortage of drivers becomes a critical economic issue. Developed nations, like Australia are faced with challenges presented by ageing populations and declining birth rates that impact on the workforce. It is expected that across all industries, including the transport industry that recruitment challenges are likely to be faced in the near future (Commonwealth of Australia, 2005).

The natural process of ageing brings with it physical and cognitive differences which perhaps do not equate to the desirability of encouraging older workers to continue their employment as professional heavy vehicle drivers. While there are many individual differences in the ageing process, even relatively healthy older adults are likely to experience some level of functional decline in sensory, physical and cognitive areas (Janke, 1994). These changes would intuitively be expected to affect driving and lead to an over-involvement in crashes as a consequence. However, current evidence of causal relationships between declines in specific abilities and reduced driving performance or increased crash risk is limited (Langford and Koppel, 2006).

In addressing the increasing labour shortage, the question is raised as to whether it is desirable or prudent to encourage older professional heavy vehicle drivers to remain in the transport sector for longer, particularly those of heavy vehicles. While a more feasible solution to the predicted skills shortage in the transport industry is to recruit drivers of a younger age, this may not be viewed as a palatable solution with the public, regulators and insurance companies. Given the extensive media focus on the driving skills and attitudes of young drivers, any organisation suggesting encouraging younger drivers into the transport industry needs to be sure that this would be a viable solution and does not present a risk to public safety and occupational health and safety.

### 1.1. Aim

The primary aim of this paper is to review peer-reviewed literature to assess age-related safety in heavy vehicle drivers, focusing on younger drivers (younger than 27 years) up to and including older drivers (60 years and older); and secondly, to review other factors that contribute to accidents experienced by heavy vehicle drivers.

## 2. Methods

To explore age-related safety in professional drivers an initial search of MedLine with MeSH for the years 1985–2007 was conducted of quantitative studies addressing the accidents and safety in relation to age namely older and younger drivers of heavy vehicle. The following search terms were used: accidents/traffic (mortality; statistics and numerical data; epidemiology; trends); automobile driving (statistics and numerical data); age factors; accidents/occupational. Further searches combined keywords to explore accidents and safety, heavy vehicle driving and age factors. The search was further limited to those published in English. Canadian Centre for Occupational Health & Safety, Embase, Cinahl, and PsychInfo databases were also searched. A manual search was performed to obtain relevant articles within the journals. Studies

were considered for inclusion if age-related accident and safety outcomes for heavy vehicle drivers were reported for ages younger than 27 years, through to and including ages 60 years and older.

## 3. Results

A large volume of literature is available on fatality and/or crash involvement of commercial vehicle drivers; however a limited number of studies reported outcomes in relation to age for heavy vehicle drivers, and importantly reported on outcomes for young drivers (less than 27 years of age) and older age groups. This review will present findings where age effects could be determined and results will be presented in four parts. Part 1: will focus on papers for which heavy vehicle age-related crash results were available, with Part 2: presenting papers for which fatigue and crash risk in heavy vehicles was the primary focus with age-related results reported. Part 3: will discuss other contributing factors (e.g. heavy vehicle configuration and time of day) that affect crash rates; and Part 4: will discuss age specific associations and crashes in motor vehicle crashes for the general population.

### 3.1. Association between age and fatality and/or crash rates in commercial heavy vehicle drivers

To assess age-related accident involvement for younger heavy vehicle drivers in USA, Campbell (1991) analysed data from the constructed Heavy vehicles Involved in Fatal Accidents (TIFA) database. The TIFA combined data from the National Highway Traffic Safety Administration (NHTSA) Fatal Accident Reporting System (FARS) and accident data from the MCS 50-T report (submitted to FHWA Office of Motor Carriers by interstate carriers). Data were also used from the National Truck Trip Information Survey (NTTIS) to estimate vehicle miles driven. All heavy vehicles with a gross vehicle weight rating greater than 10,000 pounds were included in the study. In 1991 in USA the minimum age for drivers of commercial vehicles engaged in interstate commerce was 21 years, and consideration was being given to lowering this age to 19. The focus of this study was to examine age in relation to accident rate, as well as to other factors associated with increased accident risk (such as time of day, type of heavy vehicle). The results demonstrated that risk estimates of percent accident involvement per percent of travel for drivers of large heavy vehicles continue to be over-involved until the age of 27 years, when the risk generally decreased until the age of 63, after which increases was observed.

When examining fatal accident involvement rates by heavy vehicle driver age groups for days versus night: for driver age group 21–24 years for daytime, relative risk (RR) was 1.52, which declined for age 25–29 years (RR: 0.96), a trend which continued till age over 64 years. For night-time driving a “U” shaped association between risk and age was evident where all the reported RRs were greater than 1, however, were highest for 21–24 years (RR: 4.00), 25–29 years (RR: 3.09) and 30–34 years (RR: 2.36); all other reported RRs for older age categories were below RR of 2 until over 64 years (RR: 2.92). The findings of this study support an elevated risk of fatal involvement for younger drivers of large heavy vehicles.

Increased risk associated with accidents/fatalities for younger drivers of heavy vehicles was also supported by McCall and Horwitz (2005), Häkkinen and Summala (2001), Braver et al. (1992), Stein and Jones (1988) and Hamelin (1987). Analysing workers compensation data in Oregon, USA for truck accidents between 1990 and 1997, McCall and Horwitz (2005) found an over-representation of claims related to accidents for heavy vehicle drivers'  $\leq 25$  years of age: 19.5% of claims for  $\leq 25$  years while for the same period heavy vehicle drivers 25 years or younger represented only 8.5% of heavy vehicle drivers in Oregon. The majority of claimants were for heavy

vehicle drivers'  $\leq 35$  years of age (51.4%) and had less than one year of job tenure (51%).

In the Finnish study of 1357 multiple vehicle accidents where at least one occupant had died (from the Traffic Safety Committee of Insurance Companies data base). Häkkinen and Summala (2001) found that trailer-truck drivers were principally responsible for 16% of all accidents, and compared to drivers over the age of 50 years, the risk of being responsible for an accident increased by a factor of 3.5 for drivers younger than 30 years of age (OR,  $p$ -value: 3.45, 0.04). Likewise, Summala and Mikkola (1994) using in-depth studies of accidents where at least one occupant had died (586 single vehicles; 1357 multiple vehicles) in Finland among car and truck drivers, found that excluding alcohol, trailer-truck drivers who either fell asleep or were tired to the extent that contributed to the accident were younger than those involved in other types of fatalities (31.9 versus 35.7 years;  $p = 0.043$ , Mann Whitney  $U$  test,  $p = 0.043$ ). This result is further supported by survey ( $n = 1000$ ) findings by Hamelin (1987) of French lorry drivers' time habits in work and their involvement in traffic accidents. The relative contribution to the global accident risk was higher for "younger drivers" (18–29 years) than "senior drivers" ( $\geq 30$  years). Risk rates reported: for "all hours" for  $< 30$  years: 1.97,  $\geq 30$  years: 1.32; for work span duration  $< 11$  h:  $< 30$  years: 1.88,  $\geq 30$  years: 1.24; for work span duration  $\geq 11$  h: 30 years: 2.47,  $\geq 30$  years: 1.76. The higher accident risk rate of younger drivers was thought to reflect lack of driving experience.

In a case-control study of drivers of large heavy vehicles on an interstate system in Washington State USA and crash involvement, data were collected by Commercial Vehicle Enforcement Section (CVES) of the Washington State Patrol (Stein and Jones, 1988). Authors reported that when compared to older drivers, younger drivers of large heavy vehicles were over-involved in crashes, independent of heavy vehicle configuration, with an adjusted odds ratio (OR) and 95% confidence interval (95%CI) for crash involvement for "all truck crashes" for younger drivers  $\leq 30$  years of age of 1.51 (1.20, 1.92) when compared to reference group over drivers over the age of 30 years. An increased risk was also found for "all hours" of driving and younger lorry drivers ( $< 30$  years) of 1.97 compared to lorry drivers 30 years or older with relative risk of 1.32. Braver et al. (1992) in a cross-sectional study of tractor-trailer drivers ( $n = 1249$ ) in the US found that drivers 33 years or younger had a higher risk of violation of "hours of service" and therefore associated higher risk of accident involvement than older drivers; the risk of being an "hours of service" violator decreased with increasing age.

Using fatality data ( $N = 521$  Australia 1989–92;  $N = 210$  in New Zealand (NZ) 1985–98;  $N = 4322$  in USA 1989–92). Driscoll et al. (2005) examined general work-related motor vehicle traffic incidents and fatalities. Drivers of heavy vehicle drivers represented 49% of work-related motor vehicle traffic fatalities in Australia and 37% for NZ and US. While the results pertained to more general work-related traffic fatalities (rate/100,000 person years), the rates for younger workers for 20–24 years and 25–34 years were 1.8 and 2.1, respectively. These rates decreased slightly for ages 35–64 years between 1.1 and 1.7, after which age, the rate increased to 3.3 for 65–69 years and for  $\geq 70$  years, to rate of 6/100,000 person years.

These studies have used accident reports such as accident, fatality or insurance claims data and results support the trend that younger drivers are over-involved in accidents. Kaneko and Jovanis (1992) in a study of driving patterns and motor carrier accident risk reported that driver age did not affect accident risk significantly, however drivers with more than 10 years experience driving with a firm were significantly safer than drivers who had less driving experience. This suggests that number of years of experience driving trucks is the strong predictor with increasing years of experience associated with decrease in accident risk which is also supported by Hamelin (1987).

### 3.2. Heavy vehicle drivers, fatigue and accidents

Driver fatigue has been identified as a leading contributor to roadway crashes among workers as well as the general population. Fatigue affects driving performance by impairing information processing, attention, and at times reaction times; it may also cause a driver to fall asleep. Time of day, duration of wakefulness, inadequate sleep, sleep disorders, and prolonged work hours have all been identified as major causes of fatigue (Akerstedt, 2000). A wide range of estimates of the proportions of crashes attributable to fatigue exist in the literature and is related to the varied spectrum of definitions of fatigue and to the different study methodologies used. Despite these variations, driver drowsiness or fatigue has been implicated in fatal crashes: in USA in 2000, 3.1% of crashes were attributable to fatigue or driver sleepiness. However, fatigue was reported for 7.4% of drivers of large heavy vehicles involved in single-vehicle crashes and implicated in only 1.0% of large-heavy vehicle drivers involved in fatal, multiple-vehicle crashes (Pratt, 2003).

Kanazawa et al. (2006), Howard et al. (2004), Maycock (1997) and Summala and Mikkola (1994) have found that being a younger driver of a heavy commercial vehicle is associated with a higher risk of excessive sleepiness at work with an expected higher risk of accident involvement. Kanazawa et al. (2006) conducted a cross-sectional study of commercial long-haul heavy vehicle drivers in Japan ( $N = 1005$ ) assessed burden of driver characteristics (e.g. age) and work factors (e.g. night shifts) on excessive sleepiness at work and sleep quality disturbance and found that compared to 18–29 year olds, with increasing age there was a decrease risk of excessive sleepiness at work and lower associated risk of accidents; with the reference age group 18–29 years, OR (95%CI) were 0.9 (0.5–1.6), 0.6 (0.3–0.9) and 0.3 (0.2–0.5) for age groups 30–39, 40–49,  $\geq 50$  years, respectively. This trend is further supported by results of an interview study of 996 heavy goods vehicle drivers in the UK, which included administration of the Epworth Sleepiness Scale (ESS) and self-report of accident history (Maycock, 1997) that found the accident frequency was highest for the youngest group of 17–29 years and the accident frequency decreased to less than one third of this for drivers over 55 years of age; this result was considered to be the combined effects of age and driving experience. Likewise, in an Australian survey of commercial drivers ( $N = 1687$ ) aged between 16 and 71 years, of sleepiness and self-reported accidents, Howard et al. (2004) found age to be a strong predictor of accident risk (in the last three years) with increase in age associated with a decrease in risk (OR: 0.86,  $p = 0.03$ ). Results of Summala and Mikkola (1994) research in Finland using in-depth studies of accidents where at least one occupant had died ( $N = 586$  single vehicle; 1357 multiple vehicle) among car and truck drivers found trailer-truck drivers for whom fatigue contributed to the accident were younger than those involved in other types of fatalities (31.9 versus 35.7 years;  $p = 0.043$ , Mann Whitney  $U$  test,  $p = 0.043$ ).

However, studies by McCart et al. (2000), Bunn et al. (2005) and Häkkinen and Summala (2000) reported older and longer-time drivers to be at higher risk of a fatigue-related accident, while Stoohs et al. (1994) and Adams-Guppy and Guppy (2003) reported no statistically significant association with age. McCart et al. (2000) interviewed long-distance truck drivers using New York state's interstate roadways with ages 21–71 years ( $N = 1005$ ) to identify factors associated with falling asleep while driving. Of the six factors identified tendency toward daytime sleepiness, arduous work schedule and being an older, long-time driver were most highly predictive of falling asleep at the wheel. This result was supported by results of a case-control study by Bunn et al. (2005) comparing commercial motor vehicle collision (CVC) data for drivers who died (cases), with CVC drivers who survived from state police accident electronic files from 1998 to 2002. Results showed that with

18–32 years age group as reference, a significant association was found only for those over the age of 51 years (OR, 95%CI: 2.94, 1.08–7.99). In this study sleepiness and fatigue were assessed by the accident investigating officer. However, this study was based on a small number of cases ( $n=68$ ) although matched to controls 1:4. Häkkinen and Summala (2000) surveyed long haul ( $N=184$ ) and short-haul ( $N=133$ ) truck drivers in Finland to assess self-reported sleep related problems and “near misses”; 11% reported that they had dozed off at least once in their lifetime and had an accident while working as a result. These were more often long-haul drivers ( $p<0.05$ ), somewhat older ( $t_{304}=2.96$ ,  $p<0.01$ ) and had more professional driving experience ( $t_{258}=3.62$ ,  $p<0.001$ ); no statistical significant model was able to be built due to small number of accident cases reported.

Stoohs et al. (1994) investigated possible independent sleep-related breathing disorders on traffic accidents in long-haul commercial drivers in the US ( $N=90$ ) of ages 20–64 years. Drivers completed self-report information on demographics, number of accidents over the previous five years and daytime sleepiness, with accident information also obtained from company records; drivers also underwent sleep monitoring during sleep. No statistically significant result for age was found between those drivers with and without reported accidents ( $37.0\pm 8.8$  years versus  $36.2\pm 8.8$  years), rather results showed that drivers who were obese and those with sleep-disordered breathing had twofold higher accident rates than drivers without these factors. Adams-Guppy and Guppy (2003) in a multi-centre safety study, surveyed commercial goods drivers ( $N=640$ , response rate 53%) and their managers (116, response rate 27%) within a series of related companies across 17 countries. The study used self-reported data on driver characteristics, fatigue and near miss and accident experience; no statistically significant association was found for age of driver and experience of fatigue.

Experimental studies using simulated driving tests to assess effects of sleep found that: younger drivers were more likely to decrease alertness level during the period of driving and, found it more difficult to drive in low traffic conditions than middle-aged drivers (Otmani et al., 2005). When deprived of sleep, the younger were more likely to have increased or slowed reaction times; older drivers already had slower reaction times at baseline, and these remained relatively unchanged (Philip et al., 2004). Other research has been conducted to identify factors implicated in fatigue-related accidents, for which age-related effects have not been reported, such as obesity (Stoohs et al., 1995, 1994), inadequate sleep prior to driving schedule and sleep debt (Arnold et al., 1997; Carter et al., 2003; Mitler et al., 1997; Williamson et al., 1996) and balance of work and rest at appropriate times (Feyer and Williamson, 1995). The majority of cross-sectional studies discussed used self-report measures of sleepiness, fatigue and accidents to predict expected accident risk, with only two studies using accident databases to identify accidents. While an abundance of literature is available on fatigue and accident risk, limited research is available that reports strong evidence of age-related fatigue and accident risk in heavy truck drivers.

### 3.3. Other contributing factors

#### 3.3.1. Safety practices

There is consensus in the literature that fatigue experienced while driving is a common determinant of ‘near misses’ and crashes. Driver fatigue is in turn considered to be a result of a broad spectrum of factors, including some inherent to the function of driving work and others more related to company safety practices. Supportive safety policies in the heavy vehicle industry are needed to ensure the safety of heavy vehicle drivers. Such policies would include limiting unsafe driver behaviour like driving at night, especially

between midnight and 6 am, minimising fatigue-inducing activities such as loading and unloading, and setting reasonable expected delivery times, reducing ‘late’ penalties and providing reasonable pay for duty (Sabbagh-Ehrlich et al., 2005).

There are often strong economic pressures to minimise the time allotted to loading and unloading heavy vehicles by shippers and receivers. Often drivers will feel an incentive to assist with these duties if it is perceived that they will get back on the road faster. The effects of driver involvement in loading/unloading are mixed: initially alertness may be improved but these effects wear off quickly and contribute to a decreased driving performance, especially after 12 h on duty (Morrow and Crum, 2004). Studies have shown that it is difficult to estimate the extent to which drivers are likely to experience work overload because many drivers frequently exceed the legal driving limits (Braver et al., 1992). Drivers who drive more miles are more likely to violate regulations, drive while drowsy (McCartt et al., 2000), and have an increased risk of crashing (Kaneko and Jovanis, 1992).

Morrow and Crum (2004) surveyed commercial heavy vehicle drivers across 116 trucking firms ( $N=116$  drivers) to explore the relationship between fatigue-inducing factors and company safety practices with ‘near misses’ and crashes. Their findings indicated that the development of a strong company safety culture, company assistance with fatigue-inducing activities such as loading/unloading, had considerable potential to offset fatigue-inducing factors associated with heavy vehicle driving work. Naveh and Marcus (2007) similarly in a study of all U.S. motor carriers with large heavy vehicles to assess safety performance at the system or management level and accidents of large heavy vehicles found that safety performance of certified carriers was significantly better after certification than before, and it also was significantly better than that of non-certified carriers.

#### 3.3.2. Heavy vehicle configuration

Heavy vehicles with multiple trailer combinations have demonstrated certain handling problems more commonly than single-trailer combinations. These handling problems include trailer sway (tendency of the trailers to sway sideways by 4–6 in. or more), rearward amplification (tendency of rapid steering movements to be heightened toward the rear of the vehicle, which can increase risk of roll-over or lane encroachment), off-tracking (movement out of lane of travel that occurs when the rear trailer wheels do not follow the path of the tractor front wheels), and slowed acceleration on grades (Braver et al., 1997; Fancher and Campbell, 1995).

In a case-control conducted by Stein and Jones (1988) in the US, double-trailer heavy vehicles were found to be over-involved in crashes regardless of driver age, hours of driving, cargo weight, or type of fleet. The study was conducted over a two-year period and investigated heavy vehicles, greater than 10,000 pounds weight, involved in crashes occurring on interstate road systems. Heavy vehicle configurations included were: rigid truck, tractor only (bob-tail), tractor with trailer, rigid truck with trailer, heavy vehicle-trailer, Western Double (tractor pulling two 28 foot trailers) and Rocky Mountain double (tractor pulling a 48 foot or longer trailer as well as a 28 foot trailer). While double combinations were over-involved in all crashes, empty doubles were more involved than partially or fully loaded doubles. When examining the effect of daytime/night-time crashes as a function of vehicle configuration, doubles were over-involved in crashes compared to tractor-trailers, however for all configurations, night-time involvement ratios were generally lower than daytime ratios.

In a study of heavy vehicle with trailers in Michigan, USA, by Blower et al. (1993), accident rates for three tractor configurations were examined: a tractor with no trailer, a tractor with a single trailer and a tractor with two trailers (doubles). The acci-



dent data were drawn from Michigan State Police accident files and were not limited to interstate system crashes as in the study by Stein and Jones (1988). Results of this study found that doubles posed an approximate 10% increased risk than singles for a casualty accident. Using a log-linear model, Blower et al., concluded that after adjusting for type of road, doubles had no increased risk of involvement in injury and property damage. However, doubles driving on non-major roads had an injury risk ratio of 1.32 relative to single-trailer configuration. Neither type of carrier, driver variables, weather, nor road surface condition was adjusted for the analysis. The tractor configuration for which there were substantial differences in relative risk was the bob-tail; the bob-tail configuration was found to be much less safe than singles or doubles. Using similar methodology, Campbell et al. (1988) estimated relative risks for fatal crashes of multiple-trailer heavy vehicles using two University of Michigan Transportation Research Unit databases: Trucks involved in Fatal Accidents (TIFA) and the National Truck Trip Information Survey. After adjusting for type of roadway, time of day, and urban/rural location, the fatal crash rates of multiple-trailer configurations during the period 1980–1984 were only 1.1 times those of single-trailer heavy vehicles. The authors expressed a limitation of their study was that fatal crash rates of doubles during 1980–1984 may have been underestimated by using 1985–1986 travel data because miles travelled by doubles increased rapidly after 1982.

Braver et al. (1997) using a case control design, investigated the role of heavy vehicle configuration in tractor-trailer crashes in Indiana, USA. This study investigated tractor-trailer crashes on interstate highways for the period 1989–1991, using methods similar to that used by Stein and Jones (1988). Controls were obtained for 25% of the crash sites and were all tractor-trailers passing the respective crash sites one to four weeks following the crash on the same day of the week, within 30 min at the same time of day. For all crashes combined, no increased crash risk was observed for doubles however over-involvement was reported for crashes on roads with conditions of snow, ice or slush. The mean age of drivers of tractor-trailers involved in crashes was significantly higher for double-trailers compared with single-trailer heavy vehicles: 45 versus 39 years; incomplete data for age was obtained for control drivers. In this study 1% of double-trailer drivers and 12% of single-trailer drivers in crashes were under the age of 27. Compared with single-trailer drivers, double-trailer drivers were significantly less likely to be given a traffic citation related to the crash (OR: 0.29, 95%CI: 0.11, 0.81). Dissimilarity between this study and that of Stein and Jones (1988) was that the median and mean age of drivers of double-trailers and single-trailer heavy vehicles in Washington crashes were much closer together than that observed in this study. Amongst drivers in crashes, the proportions under 27 years were 15% of Washington double-trailer drivers, 1% of Indiana double-trailer drivers, and 12% of both Washington and Indiana single-trailer drivers. Drivers of doubles in crashes in Washington had the same likelihood as drivers of single-trailer heavy vehicles in crashes of being given a traffic citation for the particular crash. This contrasted the result found by Braver et al. (1997) in Indiana where drivers of single-trailer heavy vehicles were more than three times as likely to be cited for the crash as double-trailer drivers. Importantly, the majority of double-trailer heavy vehicles in crashes were from carriers with fleets greater than 250 in number, the fleet size group that had the lowest risk for crashing in the Washington state study (Stein and Jones, 1988). Carriers with fleets greater than 250 tend to have better safety practices (Braver et al., 1997).

Other than the results found in the Stein and Jones (1988) study, results would tend to suggest no significant increased risk of multiple-trailer heavy vehicles in crashes in USA. Interstate highways are usually road systems of better design. The literature suggests a disproportionate number of tractor-trailer crashes

occur on entrances and exits to highways/freeways (Freedman et al., 1992). Longer heavy vehicle configurations may be at higher risk of crash involvement than single-trailer heavy vehicles when merging into traffic at entrance ramps or when steering to turn onto exit ramps (Fancher and Campbell, 1995). The type and condition of the roads and road systems used are significant factors in accident risk of drivers of heavy trucks. Age is associated with truck configuration: younger drivers tend to drive single-trailer heavy vehicles rather than multiple-trailer heavy vehicles (Braver et al., 1997). In Australia, a driver does not qualify for a licence to drive multiple trailer combinations until he has held a single-trailer licence for at least one year. To qualify for a single-trailer licence a driver must have had a drivers licence for at least three years.

### 3.3.3. Rural or urban routes

Authors of studies of heavy vehicle involvement in crashes conducted in the USA have clearly stated that interstate roadways are safer and better designed road systems (Blower et al., 1993; Braver et al., 1997): two lane, dual carriage road systems, no cross-road intersections. Analyses of traffic accident data from these types of road systems reflect lower accident risk than other intrastate road systems. As stated by Summala and Mikkola (1994), the main highway road systems in Finland have sections where cross-road intersections exist, similar to Australian interstate highway road systems. Urban areas have higher traffic densities, but they generally have lower operating speeds; lower speeds doubtlessly contribute to a lower probability of injury or death given an accident. Urban areas have lower accident rates than rural areas (Blower et al., 1993). The lower speeds may also contribute to fewer accidents overall. Blower et al. (1993) found that the casualty accident risk for heavy vehicle-tractors in rural areas was 1.6 times that of urban areas.

Mitchell et al. (2004) analysing data from the Australian Transport Safety Bureau (ATSB) for 543 workers fatally injured in work-related road fatality incidents for the period 1989–1992, found that fatal incidents occurred on all road types, with smaller roads in urban and rural areas, national highways in rural areas and state highways having the largest numbers of deaths. Prime movers were the most common vehicle involved in work-related fatal deaths on both national (56.7%) and state highways (40.6%) and other rural roads (35.6%). Rigid heavy vehicles were found to be almost equally involved in either non-vehicular collisions on a curve in the roadway (21.3%), crashes with vehicles from an opposing direction (19.7%), or non-vehicular collisions on a straight stretch of road (18.0%). Prime movers were commonly involved in non-vehicular collisions on a curve in the roadway (28.8%), in crashes with vehicle from an opposing direction (20.1%) and in non-vehicular collisions on a straight stretch of roadway (16.8%).

Analysing 4-year accident data in California, USA (Khorashadi et al., 2005) accidents involving heavy vehicles that occurred at an intersection in a rural area resulted in 725% increase in the likelihood of severe/fatal injury (compared to all other highway locations) whereas accidents in urban areas resulted in a 10.3% decrease in the likelihood of a severe/fatal injury. The presence of concrete median barriers in rural areas reduced the likelihood of severe/fatal injury by 68.7%, and driving in the left lane (equivalent to driving in the right lane in Australia) increased the likelihood of a severe/fatal injury by 268.1% in rural areas. The authors concluded that the significant differences between urban and rural areas exist and that complex interactions between driver behaviour and factors such as environment, geometrics, play a significant role in driver-injury severity. Results of other work by Lee and Mannering (2002) also support that accident severities vary significantly between rural and urban areas.

### 3.4. Age specific associations and motor vehicle accidents in the general population

When general population crash or involvement data are analysed in terms of crashes or involvement rate per distance travelled, a characteristic “U” shaped curve results indicating the higher risk for both younger ( $\leq 25$  years) and older ( $\geq 65$  years) drivers (Baldock and McLean, 2005; Lyman et al., 2002; Massie et al., 1995; McGwin and Brown, 1999; Ryan et al., 1998). When crash rates are examined for crash injury severity, older drivers are over-represented in crashes of high severity; older drivers have a greater susceptibility to injury due to their physical fragility and the nature of the impact/collision they are typically involved (Langford et al., 2005; Li et al., 2003; Lyman et al., 2002; Ryan et al., 1998). With ageing it is normal to have age-related declines in functional (cognitive, physical and sensory) abilities (Janke, 1994) and an increased likelihood of diagnoses of medical conditions that may impair driving skills (Daigneault et al., 2002; Hakamies-Blomqvist, 1998). However, it is important to acknowledge that people “age” at different rates and as it is inappropriate to generalise risk taking behaviours to all young drivers, it is also inappropriate to make generalisations of all drivers over the age of 65 years. However, results do indicate that older drivers ( $\geq 65$  years) in the general population are at a higher risk of crash, particularly in collisions at intersections, crossing traffic and failing to give way.

The extent to which general population statistics of younger and older non-professional drivers are translatable to the younger and older commercial heavy vehicle driver is questionable. The statistics of younger drivers more often reflect driving during leisure time settings and it would be expected that younger commercial drivers may well have a more responsible approach to their work-related driving tasks. Likewise, the literature shows that the non-professional older driver ( $\geq 65$  years) imposes self-restricted distance on driving and it would be expected that significant differences in driving skills set and behaviour would exist between the older non-professional automobile driver and the commercial heavy vehicle driver.

## 4. Discussion

While limited data on age-related accident risk for heavy vehicle drivers are reported in peer-reviewed literature for the spectrum of age from less than 27 years to over 60 years of age, the strongest evidence was provided from studies using accident, fatality or insurance claim data. These studies demonstrated that younger drivers did carry an increased risk of crash involvement as did drivers aged 63–68 years. Results of the study of fatal accident involvement rates by driver age for large trucks by Campbell (1991) showed that younger drivers were over-involved till the age of 27 years; involvement rates for truck configuration, night-time versus daytime driving, and road systems (intrastate versus interstate) demonstrated over-involvement for younger drivers. The night-time driving risk was elevated for drivers till the age of 35 years, at which the risk declined and remained steady till the age of approximately 63 years where risk of involvement increased.

Increased risk of accidents and fatalities for younger drivers of trucks was also supported by McCall and Horwitz (2005), Häkkinen and Summala (2001), Braver et al. (1992), Stein and Jones (1988) and Hamelin (1987) and Summala and Mikkola (1994). McCall and Horwitz (2005) found an over-representation of insurance claims related to accidents for truck drivers'  $\leq 25$  years of age of 19.5% of claims while for the same period truck drivers 25 years or younger represented only 8.5% of truck drivers in Oregon; the majority of claimants were truck drivers under the age of 35 years (51.4%).

Häkkinen and Summala (2001) found that of trailer-truck drivers in Finland the risk of being responsible for an accident increased by a factor of 3.5 for drivers younger than 30 years of age (OR,  $p$ -value: 3.45, 0.04). Likewise, Summala and Mikkola (1994) in a study of accidents where at least one occupant had died, found that for trailer-truck drivers who either fell asleep or were tired to the extent that it contributed to an accident were younger than those involved in other types of fatalities (31.9 versus 35.7 years;  $p = 0.043$ , Mann Whitney  $U$  test,  $p = 0.043$ ).

These results also supported by Hamelin (1987) where for French lorry drivers' the relative contribution to the global accident risk was higher for “younger drivers” (18–29 years) than “senior drivers” ( $\geq 30$  years) with risk rates reported for driving “all hours” for  $< 30$  years to be 1.97 and for  $\geq 30$  years, 1.32. The high risk rate of younger drivers was suggested to reflect lack of driving experience, which is also supported by Kaneko and Jovanis (1992). Over-involvement in crashes of younger drivers of large heavy vehicles was also reported by Stein and Jones (1988) with risk measure OR and 95%CI for “all truck crashes” for younger drivers  $\leq 30$  years of age of 1.51 (1.20, 1.92) compared to referent group of drivers over the age of 30. Braver et al. (1992) also reported that drivers 33 years or younger had a higher risk of work time violation and therefore associated higher risk of accident involvement than older drivers; the risk of being an “hours of service” violator decreased with increasing age. While Driscoll et al. (2005) examined more general work-related motor vehicle traffic incidents for which truck drivers had a high rate of death (49% death in Australia, and 37% in US and NZ) work-related traffic fatalities (rate/100,000 person years) were recorded for both younger and older age groups: younger workers for 20–24 years and 25–34 years were 1.8 and 2.1, respectively, these rates decreased slightly and tended to plateau until the age of 65 years after which steep inclines were reported (3.3 for 65–69 years, 6.0 for  $\geq 70$  years). While limited information is reported for accident risk of drivers older than 60 years, the evidence supports that younger drivers of heavy vehicles are over-involved in accidents.

Generally there is an association between age and truck configuration whereby younger drivers more predominantly drive single rather than multiple-trailer heavy vehicles (Braver et al., 1992). Given that heavy vehicles with multiple trailer combinations have more commonly demonstrated particular control problems than single-trailer combinations, this would appear to support staging the issue of driver's licences for heavy vehicles whereby drivers are restricted to upgrading their licence to multiple trailer combinations until they have held lower grade licences for a number of years.

Age-related effects of fatigue and predicted accident risk are not consistent. Many studies use self-reported sleep and accident involvement data, and others use level of sleepiness to predict expected level of accident risk; these studies can be prone to recall bias and do not have objective accident data. The evidence from larger fatigue studies supports that younger drivers ( $< 27$  years) are at increased risk of fatigue and accident risk which decreases with increase in age (Howard et al., 2004; Kanazawa et al., 2006; Maycock, 1997; Summala and Mikkola, 1994). Studies presented that did not report an association between fatigue and accident risk and age used small sample sizes and obtained data through self-report. Performance testing suggests that the alertness of younger drivers decreases during the period of driving and that they find it more difficult to drive in low traffic conditions (e.g. low traffic long distance driving); younger drivers may be better suited to shorter urban driving than long distance haulage. A vast number of studies have focused on fatigue and accident risk and have identified other factors such as sleep debt, sleep disorders, work scheduling, company safety practices and obesity that contribute significantly to accident risk, independent of age (Arnold et al., 1997; Carter et

al., 2003; Mitler et al., 1997; Stoohs et al., 1995, 1994; Williamson et al., 1996).

The heavy vehicle industry in Australia plays an important role in the transportation of goods both intra- and interstate. Long distance heavy vehicle drivers face a significant risk of being injured or killed in a single vehicle or multiple-vehicle crash. Further, collisions between articulated heavy vehicles and other vehicles (predominantly cars) as well as incidents involving passengers in heavy vehicles, pedestrians and bystanders mean that heavy vehicle drivers are not the only casualties. Most persons killed in fatal incidents involving heavy vehicles are not heavy vehicle drivers but members of the public, adding a serious public safety dimension for considerations about the safety performance of the long distance road transport industry (Quinlan, 2001). Despite who is at fault, the consequences of a crash involvement with a heavy vehicle are usually grave as a result of the impact with the heavy weight of the heavy vehicle (Evans and Frick, 1993; Pratt, 2003).

## 5. Conclusions

While a vast volume of literature is available on truck accidents and contributing factors such as age, fatigue, truck configuration, urban or rural travel, distance travelled, there is an under-reporting of results for age-specific accident rates that include drivers younger than 27 years of age and those older than 60 years of age. From the limited number of studies for which age-specific accident rates were reported for the spectrum of driver age from younger than 27 up to 60 years of age, younger drivers of heavy vehicles demonstrated higher rates of accident/fatality involvement which tend to steadily decline and plateau until the age of 63 years where increased rates are again observed. More detailed analyses of accident risk, including “at-fault” involvement and inability to avert an accident (indicator of the effect of less driving experience), and other factors that contribute to accidents across the full spectrum of age of heavy vehicle drivers involved in collisions may give further clarification to the degree of safety of both younger and older commercial heavy vehicle drivers.

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