Fatigue crashes happen in urban areas too: Characteristics of crashes in low speed urban areas

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Abstract

Driver fatigue remains a significant contributory factor in motor-vehicle crashes. Fatigue-attributed crashes most often occur in rural, high speed driving environments with a single vehicle leaving the roadway or crossing the centre line. Previous research has however suggested that fatigue may contribute to a greater number and broader range of crashes, including those in low speed, urban environments. Little research has been conducted towards identifying the salient characteristics associated with fatigue-related crashes occurring in these areas. In order to address this limitation, this investigation examines the characteristics associated with police reported fatigue/fall asleep crashes in urban areas with a speed zone of 60km/h or less, using Queensland crash data from Queensland Transport's Road Crash Database for the period 1 July 2000 to 30 June 2006. The results obtained revealed specific characteristics associated with fatigue/fell asleep crashes, compared to crashes considered to be the result of other circumstances.

Keywords

Fatigue, Fall asleep, Urban, Low speed, Queensland

Introduction

It has been well established nationally and internationally that sleep-related and fatigue-related driving is an important contributory factor in fatal and serious injury crashes [1-5]. For instance, in an Australian Transport Safety Bureau report on fatigue-related crashes, Dobbie [6] reported that 16.6% of all fatal crashes occurring in Australia in 1998 were attributed to sleep-related causes.

The causes of sleepiness while driving and driver fatigue are numerous and interact in complex ways. Diamantopoulou et al.[7] noted in their literature review that the proportion of fatigue-related crashes is greater in rural locations, motorways and other monotonous road environments where speed limits are higher. Linked with this, fatigue-related crashes are often more severe than other crashes as drivers' reaction times are often delayed or drivers have not employed any crash avoidance manoeuvres (see [7]). Thus, there is little doubt that fatigue represents a significant social and economic cost to the community in relation to road crashes, especially fatal road crashes.

Police attribution of fatigue in crash reports is, in some instances, the only data available for most traffic crashes. In some States (including Queensland, New South Wales and Western Australia), police check a box on the crash report form to indicate that fatigue was considered to be a contributing factor in the crash. The figures derived from such coding are considered to be an underestimate of the true number of fatigue-related crashes [8]. In response to this, several jurisdictions have developed proxy measures of fatigue-involvement that can be applied to all of the crashes in their databases. In general, these proxy measures use characteristics that have been shown in research studies to be associated with fatigue to identify crashes that are likely to be fatigue-related; for example, a single vehicle crash occurring during critical times of the day, in a high speed zone that was the result of a head-on collision whilst not overtaking. A limitation of the proxy measures is that they can only incorporate information that is already available on police report forms. Important contributing factors, such as time spent working or amount of sleep in previous 24 or 48 hours, are not included in the police reports. Further, the various Australia jurisdictions use different methods to define a fatigue-related crash, which often reveal very different results. This has resulted in confusion regarding the extent and magnitude of sleepiness and fatigue as a crash factor on the Australian road network, and makes attempts at developing appropriate countermeasures more difficult in terms of targeting at-risk populations and at-risk behaviours.

In addition to investigations based on crash reports or proxy definitions, a number of investigations [9-11] have surveyed drivers regarding their experience of fatigue, and their involvement in fatigue-related crashes. Most of these surveys have used a very narrow definition of fatigue, such as "falling asleep at the wheel" and so their results may be underestimates of the broad range of fatigue effects on crash involvement, because it is well known that sleepiness/fatigue causes performance deficits even without frank sleep episodes. For instance, the Australian Transport Safety Bureau has commissioned a series of surveys entitled the Community Attitudes to Road Safety series. Since 2001, the survey has asked Australian drivers "Have you ever fallen asleep at the wheel while driving a car?" In 2006, approximately 16% of drivers answered in the positive, with 10% of those stating that the most recent episode resulted in a road crash [11]. From this data, the report estimates that about 4% of all current licence holders have fallen asleep while driving in the past two years. Conversely, according to a survey undertaken in 2005 by the National Sleep Foundation in the US [9], 60% of drivers reported to driving whilst fatigued in the previous year, with 37% reporting that they fell asleep at the wheel at least once, perhaps representing a self-reporting bias within the Australian populations sampled by [11].

Estimates based on broader definitions of self-reported fatigue-related crashes have led to higher approximations. In 1995, the New South Wales Roads and Traffic Authority (NSW RTA) conducted a telephone survey on driver fatigue crashes and near crashes in the Sydney metropolitan area with the aim of identifying characteristics of these incidents which could not be obtained from police accident reports [10]. Interestingly, of the total sample of 301 drivers who responded that they had had a crash, near-crash or moved out of their lane because of being tired or fatigued revealed that 60% of such incidents occurred in a city environment. Further investigation revealed that the issue of driver fatigue in the Sydney metropolitan area was frequently associated with work-related travel and was the result of chronic sleep debt. As such, the authors argued that on the basis of their self-reported survey data, there was no real evidence to suggest that city drivers report less fatigue-related crashes and that driver fatigue is as much a city as a country problem.

In a later report, the NSW RTA [12] revealed that of all fatal crashes where fatigue was identified as a factor, 25% occurred in metropolitan areas, 12% occurred along country urban roads and 63% occurred along country non-urban roads. Thus, while it is clear to see that fatigue-related crashes are overrepresented in rural areas, it is important to note that well over one-third (37%) occurred in a low-speed urban area. This is similar to Harrison's [13] findings which revealed that of 400 young drivers surveyed in Victoria, 27% acknowledged that they had been involved in a near miss and 5% conceded that they had been involved (as a driver) in a crash due to fatigue/sleepiness. This finding was similar for participants in rural and metropolitan areas, regardless of gender.

It is intuitively obvious that sleepiness *per se* is not restricted to just rural populations or high speed environments, or only occurs during critical times. Therefore, as little is currently known about the extent and nature of sleep and fatigue-related crashes in low speed urban crashes, that is those crashes that don't fit the fatigue by proxy definition, the purpose of the current investigation was to create a profile of the characteristics associated with fatigue/fell asleep crashes occurring in low speed, urban, environments of 60km/h or less in Queensland, by identifying who was most likely to be involved, when and where these crashes were most likely to occur, how they occurred, and the severity of injuries that resulted.

Methods

The data used in this study was extracted from Queensland Transport's road crash database for the period 1st July 2000 to 30th June 2006. As this study is interested in examining fatigue crashes in low speed urban areas, only crashes that were recorded as occurring in speed zones of 60 km/h or less were retained. It is important to note that the Queensland road crash database only includes those crashes which occur on a public road and where a person was killed or injured, a vehicle towed, or greater than $2500 to property other than vehicles was incurred. Crashes resulting from medical conditions and deliberate acts are excluded [14].

Six years of crash data was sourced so as to have sufficient scope to identify general trends and permit meaningful comparisons among the different groups of crashes, specifically those where the reporting Queensland Police Services (QPS) officer considered that the attribute 'fatigue/fell asleep' was a contributory factor in the low speed urban crash and those where the reporting QPS officer considered that attributes other than 'fatigue/fell asleep' were contributory factors in the crash.

The data was categorised according to characteristics of interest and cross-tabulated with contributing crash circumstance. This was performed for both driver and crash characteristics. Table 1 displays the categories that comprise each group employed in the analyses.

Table 1. Variables and categories included in the current investigation.

Variable Type	Analysis Groups	Included Categories
Licence Type	Open	Open
	Provisional	Provisional
	Learner	Learner
	Unlicensed	Disqualified, Cancelled, Expired, Inappropriate Class, Never Licensed, Unlicensed (other)
Registration Status	Registered	Registered
	Unregistered	Unregistered, Expired, Cancelled
Vehicle Type	Motorcycle	Motorcycle
	Car	Car/station wagon, 4-wheel drive, utility/panel van
	Heavy vehicle	Articulated vehicle, Road train/B double, Truck
Crash Severity	Fatal/Hospitalisation[a]	Fatal, Hospitalisation
	Medical Treatment	Medical Treatment
	Minor Injury	Minor Injury
	Property Damage	Property Damage

[a] - Only 6 fatalities were recorded for "Fatigue/fell asleep" cases and have thus been combined

The categorical data was analysed using Chi-square (χ^2) tests and where necessary, post-hoc analyses were undertaken within each variable using the adjusted standardised residual statistic (ê). In order to control for the effect of large sample sizes, the results of the Chi-square tests were evaluated against a significance level (α) of .01 and in order to protect against Type 1 errors, a more stringent significance level ($\alpha < .001$)) was used for post-hoc comparisons. However, it is important to note that the simple analysis of using Chi-square tests will not provide any insight into possible confounding variables. All statistical tests were undertaken using the Statistical Package for the Social Science (SPSS) Version 16.

Results

Overall, there were 96,049 drivers involved in a crash in a speed zone of 60 km/or less on Queensland roads between 1 July 2000 and 30 June 2006[*]. Of this, fatigue/fell asleep was recorded as the contributing circumstance in 732 (0.8%) of all crashes, resulting in 431 casualties. The remaining 95,317 (99.2%) recorded circumstances other than fatigue/fell asleep as contributing to the crash, resulting in 57,343 casualties.

Characteristics of the drivers

Examination of drivers' characteristics was undertaken to determine if any significant differences existed between those with the attribute of fatigue/fell asleep as a contributing crash circumstance and those whose crash circumstances were attributed to something other than fatigue/fell asleep. Examination of

[*] For comparison purposes, a total of 143,911 drivers were involved in a crash on Queensland roads during the same time period. Of this, police reported fatigue/fell asleep was recorded as the contributing circumstance in 3,062 (2.1%) of all crashes. Police reported fatigue/fell asleep and 'fatigue by definition' was recorded as the contributing circumstance in 7,685 (5.3%) of all crashes.

Table 2 reveals that compared to other drivers, those drivers whose crash circumstances were attributed to fatigue/fell asleep in a low speed, urban environment were more likely to be male, younger in age, hold a provisional driver's licence and be the sole occupant driving an unregistered car.

Table 2. Characteristics of drivers involved in a crash in a speed zone of 60 km/h or less in an urban environment between 1 July 2000 and 30 June 2006 by contributing circumstance.

Variable	**Contributing Circumstance**		**Significance level**[1]
	Fatigue/Fell Asleep (%)	**Other than Fatigue/Fell Asleep** (%)	
Gender	(n=729)	(n=92,467)	
Males	**77.1**	**65.8**	χ^2 (*df*1) = 41.2, *p* <.0001.
Females	**22.9**	**34.2**	
Age	(n=728)	(n=90,969)	
0-16	0.1	1.0	χ^2 (*df*7) = 55.1, *p* <.0001.
17- 24	**44.5**	**34.5**	
25-29	14.1	11.6	
30-39	16.1	17.8	
40-49	10.7	13.7	
50-59	6.7	9.8	
60 -74	6.0	7.8	
75 and over	1.6	3.8	
Licence Type	(n=732)	(n=95,317)	
Open	**59.7**	**65.7**	χ^2 (*df*3) = 45.2, *p* <.0001.
Provisional	**28.1**	**19.5**	
Learner	4.5	3.2	
Unlicenced	**7.7**	**11.6**	
Vehicle Type	(n=730)	(n=93,821)	
Car	**98.1**	**92.6**	χ^2 (*df*2) = 33.9, *p* <.0001.
Motorcycle	**.3**	**3.9**	
Heavy Vehicle	1.6	3.5	

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Table 2 continued.

Variable	Contributing Circumstance		Significance level[1]
	Fatigue/Fell Asleep (%)	Other than Fatigue/Fell Asleep (%)	
Registration Status	(n=680)	(n=86,572)	
Registered	**95.4**	**97.9**	χ^2 (*df1*) = 18.5, p <.0001.
Unregistered	**4.6**	**2.1**	
BAC Reading	(n=546)	(n=55,050)	
0.00	84.8	87.1	χ^2 (*df4*) = 10.8, p = .029.
0.01-0.04	2.4	1.4	(n.s. p >.01)
0.05-0.07	1.8	1.2	
0.08-0.14	6.6	4.8	
0.15 and over	4.4	5.6	
No. of occupants	(n=732)	(n=94,752)	
1	**81.6**	**66.9**	χ^2 (*df1*) = 70.3, p <.0001.
More than 1	**18.4**	**33.1**	

[1] - The cells with significant (p < .001) adjusted standardised residuals are bolded.

It can be seen that over three-quarters (77.1%) of sleepy/fatigued drivers involved in a crash during the period were male, while almost half (44.5%) were aged between 17 and 24. Further, while 59.7% of sleep/fatigued drivers held an open driver's licence at the time of the crash, it is of interest to note that the proportion of sleepy/fatigued drivers holding a provisional licence (28.1%) significantly exceeded the proportion of drivers (19.5%) whose crash circumstances were attributed to something other than fatigue/fell asleep. Not surprisingly, the majority of drivers in either group were driving a registered car at the time of the crash. However, it is interesting to note that heavy vehicle drivers and motorcycle riders were less likely to be involved in a crash attributed to fatigue/fell asleep than drivers involved in a crash attributed to other circumstances, whereas sleepy/fatigued drivers (4.6%) were more likely to be operating an unregistered vehicle at the time of the crash compared to only 1.4% of drivers in the comparison group. Finally, those drivers whose crash was attributed to fatigue/fell asleep were significantly more likely to be the sole occupant of the vehicle when compared to the number of occupants reported for drivers whose crash was attributed to circumstances other than fatigue (81.6% compared to 66.9% respectively).

Characteristics of the crashes

Examination of crash characteristics was undertaken to determine if any significant differences existed between those with the attribute of fatigue/fell asleep as a contributing crash circumstance and those where the crash circumstances were attributed to something other than fatigue/fell asleep. Examination of Table 3 reveals that compared to all other crash circumstances, crashes attributed to fatigue/fell asleep in a low speed, urban environment were more likely to result in a fatality or hospitalisation as a result of hitting an object, a parked car or being involved in a head-on collision. Typically, the crashes occurred on roads without any discernable feature or traffic control and with clear atmospheric conditions. The majority of crashes occurred on the weekend during night-time or dawn/dusk lighting conditions, typically between the hours of midnight and 6am (with a peak time of 5am).

Table 3. Characteristics of crashes occurring in a speed zone of 60 km/h or less in an urban environment between 1 July 2000 and 30 June 2006 by contributing circumstance.

Variable	Contributing Circumstance		Significance level[1]
	Fatigue/Fell Asleep (%)	Other than Fatigue/Fell Asleep (%)	
Crash severity	(n=732)	(n=95,317)	
Fatal/Hospitalisation	**24.7**	**19.2**	χ^2 (*df3*) = 22.5, p <.0001.
Medical Treatment	22.8	25.5	
Minor Injury	11.3	15.5	
PDO	41.1	39.8	
Police region	(n=732)	(n=95,317)	
Central	6.0	7.4	χ^2 (*df7*) = 26.4, p <.0001.
Far Northern	6.0	5.1	* comparisons are not
Metro North	19.5	20.8	significant at p <.001, but
Metro South*	23.1	18.5	are significant at p <.01,
North Coast	15.3	15.5	with trend indicating
Northern*	2.9	5.6	urban fatigue is higher
South Eastern	18.6	16.5	in Metro South
Southern	8.6	10.6	and lower in Northern.
No. of casualties	(n=431)	(n=57,343)	
1	84.2	79.9	χ^2 (*df1*) = 4.9, p = .026.
More than 1	15.8	20.1	(n.s. p >.01)
Crash nature	(n=729)	(n=88,477)	
Angle	**4.1**	**42.7**	χ^2 (*df6*) = 1368.5, p <.0001.
Head-on	**3.3**	**1.6**	
Hit object	**66.0**	**18.8**	
Hit parked vehicle	**15.2**	**5.1**	
Overturned	2.5	1.6	
Rear-end	**6.4**	**25.8**	
Sideswipe	2.5	4.4	
Roadway feature	(n=726)	(n=94,047)	
Bridge/causeway	1.4	.8	χ^2 (*df2*) = 202.2, p <.0001.
Intersection	**29.6**	**55.9**	
No feature	**69.0**	**43.2**	

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Table 3 continued.

Variable	**Contributing Circumstance**		**Significance level**[1]
	Fatigue/Fell Asleep (%)	**Other than Fatigue/Fell Asleep (%)**	
Traffic control	(n=725)	(n=93,940)	
Give-way	**4.3**	**13.9**	χ^2 (*df3*) = 157.1, *p* <.0001.
No traffic control	**85.1**	**62.8**	
Operating traffic lights	**9.6**	**18.5**	
Stop Sign	**1.0**	**4.8**	
Road surface condition	(n=731)	(n=94,871)	
Sealed	98.9	99.0	χ^2 (*df1*) = .059, *p* = .808.
Unsealed	1.1	1.0	(n.s. *p* >.01)
Atmospheric conditions	(n=731)	(n=95,118)	
Clear	**93.6**	**88.8**	χ^2 (*df3*) = 21.5, *p* <.0001.
Fog	.4	.2	
Raining	**5.9**	**11.0**	
Lighting conditions	(n=729)	(n=95,005)	
Darkness	**48.7**	**25.0**	χ^2 (*df2*) = 303, *p* <.0001.
Dawn/Dust	**11.0**	**5.0**	
Daylight	**40.3**	**70.0**	
Day of week	(n=732)	(n=95,317)	
Monday	15.4	13.3	χ^2 (*df6*) = 129.9, *p* <.0001.
Tuesday	**9.0**	**14.1**	
Wednesday	11.9	14.9	
Thursday	**9.6**	**15.8**	
Friday	13.7	17.5	
Saturday	**20.6**	**14.1**	
Sunday	**19.8**	**10.3**	
Number of units	(n=732)	(n=95,317)	
1	**65.7**	**19.1**	χ^2 (*df1*) = 1003.5, *p* <.0001.
More than 1	**34.3**	**80.9**	

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Table 3 continued.

Variable	Contributing Circumstance		Significance level[1]
	Fatigue/Fell Asleep (%)	**Other than Fatigue/Fell Asleep (%)**	
Time of Day	(n=732)	(n=95,317)	
0	**5.6**	**1.7**	χ^2 (*df23*) = 1759.8, p <.0001.
1	**5.2**	**1.5**	
2	**5.5**	**1.2**	
3	**8.1**	**1.0**	
4	**7.9**	**.8**	
5	**10.5**	**1.3**	
6	**7.2**	**2.4**	
7	6.1	4.1	
8	**3.3**	**6.9**	
9	**2.2**	**5.1**	
10	**2.2**	**5.2**	
11	**2.5**	**5.9**	
12	**2.3**	**5.9**	
13	3.7	5.4	
14	**2.9**	**6.0**	
15	**4.4**	**8.9**	
16	**2.3**	**8.8**	
17	**3.0**	**8.1**	
18	**1.4**	**5.3**	
19	**1.4**	**4.0**	
20	1.5	3.2	
21	2.9	2.8	
22	3.4	2.5	
23	**4.6**	**2.2**	
Time of Day by Qld Fatigue Definition	(n=732)	(n=95,317)	
10pm to 6am	**50.8**	**12.1**	χ^2 (*df3*) = 1013.9, p <.0001.
6am to 2pm	**29.5**	**40.9**	
2pm to 4pm	**7.2**	**14.8**	
4pm to 10pm	**12.4**	**32.1**	

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Table 3 continued.

Variable	Contributing Circumstance		Significance level[1]
	Fatigue/Fell Asleep (%)	**Other than Fatigue/Fell Asleep (%)**	
Time of Day by ATSB Fatigue Definition	(n=732)	(n=95,317)	
Midnight to 6am	**42.8**	**7.5**	χ^2 (*df3*) = 1266.9, p <.0001.
6am to 2pm	**29.5**	**40.9**	
2pm to 4pm	**7.2**	**14.8**	
4pm to Midnight	**20.5**	**36.8**	

It can be seen that almost 25% of crashes involving sleepy/fatigued drivers in a low speed, urban area resulted in a fatality or hospitalisation, as a result of hitting an object (66%), hitting a parked vehicle (15.2%) or colliding head-on with another vehicle (3.3%). Just under 70% of crashes involving sleepy/fatigued drivers were single vehicle, occurred on a length of roadway without notable features and without traffic control (85.1%). Further, crashes involving sleepy/fatigued drivers in a low speed, urban area typically occurred in dark lighting (48.7%) but clear atmospheric conditions (93.6%), and on either a Saturday (20.6%) or Sunday (19.8%).

Time of day was of particular interest, which revealed that the majority of crashes attributed to fatigue/fell asleep causes occurred between midnight and 6am, with a peak seen at 5am. Examination of time of day using the ATSB operational definition of critical times revealed a significant peak between the hours of midnight and 6am (42.8%) compared to drivers whose crash circumstances were attributed to something other than fatigue/fell asleep (12.1%). Interestingly, those drivers whose crash circumstances were attributed to something other than fatigue were more likely to crash between the hours of 6am to 2pm, 2pm and 4pm and 4pm to midnight compared to the other group. This same pattern was also observed when the Queensland definition of critical times was examined, revealing a distinct lack of crashes attributed to fatigue/fell asleep between the hours of 2pm and 4pm.

Finally, it was of interest to compare, where possible, drivers with the attribute of fatigue/fell asleep as a contributing crash circumstance by whether the crash occurred in an urban or rural area. In order to perform this, crashes were grouped on the basis of Rural, Remote and Metropolitan Area (RRMA) classifications for the Statistical Local Area (SLA) in which the crash occurred. Those crashes occurring in RRMA 1-2 coded areas were classed as 'urban' while those in RRMA 3-7 coded areas were classed as 'rural'. This revealed that the only difference was for BAC reading at the time of the crash, χ^2 (*df4*) = 14.1, p = .007. Specifically, drivers in low speed zones in rural areas were almost twice as likely to record a positive BAC reading when compared to drivers in urban areas (22.1% vs. 12.9%). Similarly, drivers in low speed zones in rural areas were almost three times more likely to record a high range BAC of equal to or greater than 0.15 when compared to urban drivers (8.8% vs. 2.9% respectively).

Discussion

This investigation involved a retrospective analysis of data drawn from police crash reports in order to create a profile of the characteristics associated with fatigue/fell asleep crashes occurring in low speed, urban environments of 60km/h or less in Queensland. The results obtained reveal that there are a number of characteristics that are associated with fatigue/fell asleep crashes compared to crashes considered to be the result of other circumstances.

Approximately 1 in 3 fatigue/fell asleep crashes attributed by a QPS officer as the contributing circumstance to the crash occurred within a low speed, urban area. This figure does not include crashes coded as fatigue by the Queensland proxy definition. As mentioned in the introduction, fewer sleep-related crashes tend to occur on low-speed urban roads as opposed to high-speed highways or rural roads because driving conditions are relatively stimulating and usually, there is more for the driver to see and respond to. Further, crashes attributed to fatigue and sleepy driving tend to occur in among individuals who have had insufficient sleep and/or are driving when their circadian rhythm is at its lowest, rather than just individuals who have an associated sleep disorder [1]. As such, time of day factors have been shown to play an important, contributing role in driver sleepiness and subsequent crash risk. For example, in an investigation of the variations in time of day on driving performance, Lenne et al. [15] found that participants displayed impaired driving performance during the night-time and early morning hours. Sagberg [16] reported that the odds of a crash being fatigue-related increased by a factor of six if the crash occurred between midnight and 6am. In a similar investigation, Åkerstedt and Kecklund [17]found that young adult drivers displayed a dramatic increase in crash risk for late night driving, which was more pronounced for males than for females, and established that the peak was at approximately 5am in the morning. This result is in line with other previous investigations (see [17] for a review). As such, it is clear to see that regardless if a person is driving in a rural or urban environment, driving performance does fluctuate as a function of time of day. As such, it is advisable that individuals minimise late night and early morning driving in order to reduce their associated crash risk.

Specifically, in terms of *who* was most likely to be involved in crash attributed to fatigue/fell asleep in a low speed, urban environments of 60km/h or less in Queensland, this investigation found that males were three times more likely than females to be involved in such a crash. Young persons, that is those aged between 17-24 years, were almost twice as likely to be involved in a fatigue/fell asleep crash when compared to other crash circumstances. Similarly, provisional licence holders were approximately one and a half times more likely to be involved in a fatigue/fell asleep crash when compared to other crash circumstances. Those drivers operating an unregistered vehicle were three times more likely to be involved in a crash attributed to fatigue/fell asleep when compared to other crash circumstances. Comparable to other investigations of fatigue related crashes (see [13]), it was found that drivers who were the sole occupant were also over-represented in low-speed urban fatigue/fell asleep crashes when compared to drivers whose crash was attributed to circumstances other than fatigue.

While the elevated crash risk of young drivers is well known, a number of researchers [1, 18, 19] have reported that young adults are more likely to be involved in sleep/fatigue related crashes than older adults, particularly in the early morning hours. While this may be attributed to an exposure effect, in that young adult drivers are more likely to be using the road network in the early hours of the morning when increased sleepiness is also more likely to occur, it is interesting to note that other research has revealed that the effects of sleep loss and sleepiness is more profound in younger people due to reasons such as social factors [20], developmental changes [21] and sleep deprivation/ disrupted sleep patterns [22, 23]. As such, it is not surprising that the current investigation found young drivers are more involved in fatigue-related crashes. In a longitudinal investigation examining sleep and sleep habits from childhood to young adulthood, Thorleifsdottir et al. [24] found that the length of time spent asleep declined with age through the teenage years, and was less on week nights than on weekends. More recently, research has demonstrated that many young drivers continue to drive when they feel tired and are poorly motivated to change their behaviour in order to reduce the risk of a crash [13, 25]. An apparent misconception among many young drivers that sleepiness or tiredness is manageable [13]. This misunderstanding, combined with the influence of lifestyle/motivational factors are issues that may contribute to the increased risk for young drivers [13].

In terms of *when* and *where* the crashes were most likely to occur, this investigation found that crashes attributed to fatigue/fell asleep in a low speed, urban environments of 60km/h or less in Queensland were more likely to occur in the early hours of the morning (between midnight and 6am). Interestingly there was a distinct lack of crashes attributed to fatigue/fell asleep between the hours of 2pm and 4pm, a time that both the ATSB and Queensland's fatigue by definition' description states as a critical time for a fatigue - related crash to occur. In line with this, crashes involving sleepy/fatigued drivers were almost twice as likely to occur in low-light/dark conditions, on roads without any notable features or traffic control. Fatigue/fell asleep crashes were also over one and a half times more likely to occur on either a Saturday or a Sunday when compared to crashes attributed to other circumstances.

It is also well known that alcohol impairs driving behaviour for people of all ages. However, it is important to note that even small amounts of alcohol can dramatically increase an individual's risk of crash if they are already tired and or fatigued. For example, investigations employing the use of driving simulators (e.g., [26]) have revealed that low doses of alcohol produced large decrements in performance in sleep-deprived participants. Mills et al. [27] found that impairment was 'severe' when alcohol was combined with pre-existing fatigue compared to a 'modest' effect of alcohol alone. Researchers have argued that this is due to alcohol and sleep loss interacting synergistically to increase levels of sleepiness [28, 29]. This is of interest as this investigation found that when drivers with the attribute of fatigue/fell asleep as a contributing crash circumstance were compared in terms of locality defined by RRMA classification, those in low speed zones in rural areas were almost twice as likely to record a positive BAC reading when compared to drivers in urban areas. Similarly, drivers in low speed zones in rural areas where almost three times more likely to record a high range BAC of equal to or greater than 0.15 when compared to urban drivers. Given that the proportion of the population drinking at 'risky' or 'high risk' levels as defined by the National Health and Medical Research Council (NHMRC) increases gradually moving from major cities (12.6%) to inner regional areas (14.8%) to outer regional areas (16.3%) [30] it is perhaps not surprising that alcohol was a feature in the fatigue/fell asleep low speed zones in rural crashes compared to those occurring in urban areas.

In terms of *how* the crashes occurred, it was interesting to observe that drivers involved in a crash attributed to fatigue/fell asleep were three and a half times more likely to be single vehicle crashes hitting an object, almost three times more likely to hit a parked vehicle and twice as likely to be involved in a head-on collision when compared to drivers involved in crashes attributed to other circumstances. This is in line with previous accounts of fatigue crashes which reveal that the archetypal fatigue-related crash is a single vehicle, fall asleep, run-off-road into a tree or pole on a monotonous country road type and associated head-on, not overtaking crash. Therefore, it is not surprising that in urban areas, similar types of crashes are occurring.

Finally, this investigation found that crashes attributed to fatigue/fell asleep in a low speed, urban environments of 60km/h or less in Queensland were almost one and a half times more likely to result in a fatality/hospitalisation when compared to crashes attributed to other circumstances. It has been well established that late-night and early morning driving increases a driver's crash risk, but only for serious crashes [7, 17, 22]. Thus, while this investigation found that crashes attributed to fatigue/fell asleep was higher for young people when compared to crashes involving circumstances other than fatigue, it is important to acknowledge that fatal and serious crash risk is higher at night-time for all drivers, regardless of age, than it is during daylight hours.

Overall it appears that in Queensland, fatigue/fell asleep crashes are relatively common with 1 in 2.6 occurring in low speed, urban areas. This investigation has revealed that young, male, provisional licence holders, driving between the hours of midnight and 6am at the weekend are more likely to be involved in a serious injury crash attributed to fatigue/fell asleep circumstances compared to any other crash factor being attributed as the cause. However it is important to reiterate that police recording of fatigue crashes is more likely to underestimate fatigue involvement whereas some proxy measures are more likely to overestimate the number of crashes involving fatigue. As such, it is arguable that both approaches can misclassify individual crashes and, as such, are generally better suited to identifying the subset of (largely rural) fatigue-related crashes that involve falling asleep at the wheel than other crashes that may occur at less severe levels of fatigue (particularly in urban areas). Nevertheless, this investigation is important as it may serve as a first step towards the re-calibration of proxy definitions of fatigue used by various Australian jurisdictions. Research conducted by Cercarelli and Haworth [31] in Western Australia has found that police correctly identify fatigue as a contributing circumstance to a crash approximately 75% of the time, where proxy definitions tend to be too broad capture many non fatigue-related crashes. However as the current investigation employed a series of Chi-square tests, it is proposed that future analyses addressing this issue could employ a more sophisticated analysis such as logistic regression in order to partial out the effect of any possible confounding variables.

While the authors acknowledge that further in-depth investigations using a broader methodology are required, it is apparent that crashes attributed to fatigue are not just confined to rural, high speed settings. Thus, any campaigns detailing the risks associated with driving whilst tired and/or fatigued should contain elements relating to both urban and rural driving situations and scenarios in order to educate and inform drivers of the increased risk of driving whilst tired.

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