Crash characteristics and causal factors of motorcycle fatalities in Australia

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Abstract

Motorcyclist fatalities contribute significantly to road trauma in Australia and continue to increase over time. Australian motorcyclists are 30 times more likely to be killed than car occupants per distance travelled. Understanding the crash characteristics and contributing causal factors of motorcyclist fatalities will assist motorcycling groups, road safety practitioners and road authorities to address motorcyclist safety, and reduce road trauma related to this group of vulnerable road users.

This paper presents a case series analysis of all motorcyclist fatalities that occurred in Australia between 2001 and 2006 (inclusive). Case data for all 1,323 fatalities that occurred in this period were extracted from the Australian National Coroner's Information System (NCIS). An examination of available police, toxicology and Coronial finding reports enabled essential information to be gathered regarding the characteristics and contributing causal factors associated with each fatal crash. A number of areas in which motorcyclist trauma may potentially be reduced are identified, and are presented within the framework of the Safe Systems approach.

Keywords: Motorcycles; fatality; crash characteristics; causal factors.

1. Introduction

Motorcyclist serious injuries and fatalities contribute significantly to road trauma in Australia. In 2007, Australian motorcyclists were 30 times more likely to be killed and 37 times more likely to be seriously injured than car occupants per distance travelled (Henley and Harrison 2009). A range of factors have been identified as contributing to motorcycle crashes, their severity and the severity of the motorcyclists' injury(s): speed, age, time of year, experience, alcohol, illicit drug use, time of day, conspicuity, risk taking behaviour, road side environment and helmet use (Colburn et al 1994, Harrison and Christie 2005, Jama et al 2010, Grzebieta et al 2009, Lin and Kraus 2009, Quddus et al 2002, Rutledge and Stutts 1993, Savolainen and Mannering 2007, Shankar et al 1992, Shankar and Mannering 1996).

Motorcycle usage rates have been increasing significantly in Australia, with an average annual increase in registrations of 7% between 1998 and 2007 (Johnston et al 2008). This rate of increase was around 2.5 times larger than that for registrations of passenger vehicles. The increase in motorcyclists on the roadways has, in part, led to an average annual increase in motorcyclist fatalities of 3% over this period, while all other road user fatalities decreased. By 2007, motorcyclist fatalities exceeded pedestrian fatalities, and were second in frequency only to passenger vehicles. Motorcycle deaths as a proportion of all road deaths increased from 10% to 15% over this period. These figures indicate that initiatives must be undertaken by motorcycling groups, road safety practitioners and road authorities in order to address motorcyclist safety and attempt to reduce the rising numbers of motorcyclist injuries and fatalities. In order to assist this process, the aim of the present paper is to investigate the characteristics of fatal motorcycle crashes in Australia, and in particular to assess the contributing causal factors of the crashes. Understanding the causes of these crashes will

inform prevention strategies. A number of general areas to which preventions might be directed are presented within the framework of the Safe Systems approach (ATC 2011). Particular attention is paid to 'risky riding behaviour', which in the present paper is defined as the involvement of one or more of the following factors prior to or during the crash; excessive speed, alcohol use, drug use or disobeying a traffic control law.

2. Methods

This study is a retrospective descriptive analysis of motorcyclist fatalities that occurred during the six year period between 2001 and 2006 in Australia. The fatalities were identified using the Australian National Coroner's Information System (NCIS). The NCIS is an internet-based data storage and retrieval system that contains Coronial cases from all Australian states dating from the middle of 2000. The NCIS database includes all reportable deaths, which provides a census of all roadway fatalities. It may take several years for a Coronial case to be closed by the Coroner and made available on the NCIS. Variables coded in the NCIS include demographic information about the person, collision vehicles and objects involved and the place of death. Each death record in the NCIS should also have attached to it a police summary, Coronial finding and toxicology report. Each case usually reports the cause of death as recorded by the investigating Coroner. Further detailed information is typically available where an inquest was held to establish the cause of death.

To identify motorcycle crashes in the NCIS database, the initial query was designed as follows: all Australian jurisdictions were selected; employment and time fields were left blank; query object was chosen as a mechanism; the mechanism that caused the death was defined as blunt force; level 2 of the mechanism was defined as a transport injury event; level 3 of the mechanism was defined as a motorcyclist/motorcycle rider; the vehicle details were defined as a two wheeled motor vehicle; and the vehicle was further defined as a motorcycle.

The output from the database contained the particulars of the deceased such as the gender, age, date of birth and date of death. An output of up to three levels of the medical cause of death, location and the crash vehicle counterpart was requested. The case documents (Coronial finding, police summary and toxicology report) were also downloaded from the NCIS (where available). Information pertaining to the following factors was then extracted automatically from the database or, when not available there, manually from the case documents: partner objects and vehicles, presence of alcohol and other drugs, weather and road surface factors, vehicular factors, estimated pre-crash speed, rider demographics, recreational riding status, time of occurrence, helmet use, registration and riding licence status, and medical cause of death.

The contributing causal factors in the crash were determined by the investigating police and/or Coronial inquest, and reported in the police summary and/or Coroner's findings. Motorcyclists that were displaying risky riding behaviour were identified (excessive speed, alcohol, drugs or disobeying a traffic control law). Excessive speed included speed considered excessive for the conditions and/or speed in excess of the speed limit (as determined by the investigating police). Disobeying a traffic control law was reported by terms such as; failed to give way, failed to stop at a red light or stop sign, riding on the wrong side of the road, racing, etc. It is important to note that causal factors such as risky riding behaviours are identified as *contributing* causal factors, since crashes are often caused by a complex combination of factors and may not accurately be attributed to any one factor. It is possible that some factors identified as being contributing causal factors were in fact simply present rather than contributing.

Multi-vehicle collisions were disaggregated by partner vehicle and impact location relative to the partner vehicle ('side' was adopted as when the motorcyclist impacted the side of the partner vehicle; 'head-on' when each vehicle impacted its front with that of the other vehicle;

'front' when the partner vehicle impacted the motorcyclist with its front; and 'rear end' when the rear of the partner vehicle was impacted by the motorcyclist).

The vehicle at fault in multi-vehicle collisions was identified from the police summary, Coronial finding and the risky riding behaviour results. The vehicle deemed to be at fault was that typically described as the vehicle entering/exiting the roadway in front of the other vehicle, performing a turn or U-turn in front of the other vehicle, on the wrong side of the roadway, or disobeying a traffic control law. If both vehicle operators were displaying risky driving behaviour they were both deemed to be at fault (eg a car turned in front of a motorcyclist who was travelling at excessive speed).

Descriptive analyses were performed, and the chi-square independence test was used to determine associations between variables, where statistical significance was measured at the $p<0.05$ level.

Following the analysis of all Australian cases using the information contained in the case documents downloaded from the NCIS, a sample of cases was investigated using the full Coronial case files. Coronial case files are held at the Coroner's courts and contain all the documents pertaining to the inquest, including the full police crash investigation reports, an autopsy report, records of interviews with police and witnesses at the scene, and photos and maps of the scene, where available. The police summary and Coronial finding available on the NCIS are brief summaries of the case, and it is possible that in some cases they do not provide complete information on the characteristics and causal factors of the crash. To test if this has an effect on the interpretation of crash causal factors, a sample of crashes was analysed using the full Coronial case files and compared with the results using the summary documents from the NICS. Additionally, the NCIS provides the medical cause of death, however this provides very limited information on the nature of the injuries sustained. In order to better understand injuries sustained in fatal motorcycle crashes, for the sample of crashes the injuries identified in the autopsy reports were recorded according to the Abbreviated Injury Scale (AIS) (AAAM 2005) and only serious (AIS3+) injuries were recorded. The collection and analysis of Coronial case files and the recording of injuries from the autopsy reports is a very time consuming process, thus a small sample of 35 crashes was selected.

3. Results

3.1. Crash characteristics

A total of 1,323 motorcyclist fatalities were identified in Australia during the study period. In the NCIS, 91% of cases had a police summary, 51% had a toxicology report and 50% had a Coroner's finding report. The national annual average number of fatalities per 10,000 motorcycle registrations was 5.6, and the averages for each of the states/territories are presented in Figure 1 (it is noted that the national average has substantially reduced since 2006). The averages for New South Wales, Victoria, Western Australia and the ACT were less than the national average, while those for Queensland, South Australia, Tasmania and the Northern Territory were greater than the national average.

General characteristics of the fatal motorcycle crashes include: 95% were male; 4% were pillion passengers; the mean age was 33.8 years, and the most frequent age group was 21 to 29 year olds, followed by 31 to 39 year olds (Figure 2); the majority of crashes (56%) occurred between Friday and Sunday (Figure 3); the month in which the crashes occurred was fairly evenly distributed throughout the year, however there were slightly fewer crashes in the cooler months of June to September; the majority of crashes (57% of 828 known cases) occurred between noon and 8pm; the majority of crashes (66% of 273 known cases) occurred in fine and dry conditions on a dry roadway surface; the location of the crashes was fairly evenly distributed between arterial roads (26%), rural or private roads (26%), freeways or highways (25%) and suburban roads (21%); the majority of crashes occurred at bends or

intersections (39% and 38% of 957 known cases, respectively), with the remainder on a straight roadway; 47% of multi-vehicle crashes occurred at an intersection, and 67% of these involved a vehicle turning in front of the motorcyclist (i.e. the vehicle driver did not see the motorcyclist or misjudged the distance or speed of the motorcyclist); 84% of deaths occurred at the crash scene; 15% of fatal crashes occurred while the motorcyclist was on a group ride; 42% of motorcycle engine capacities were less than 500cc, 36% were between 500 and 1000cc and 22% were greater than 1000cc (371 known cases); the motorcycles were predominantly registered (84% of 411 known cases) and in a roadworthy condition (75% of 75 known cases); and a motorcycle helmet was worn in 86% of 299 known cases.

Figure 1: Average annual motorcyclist fatalities per 10,000 registered motorcycles in Australia 2001-2006

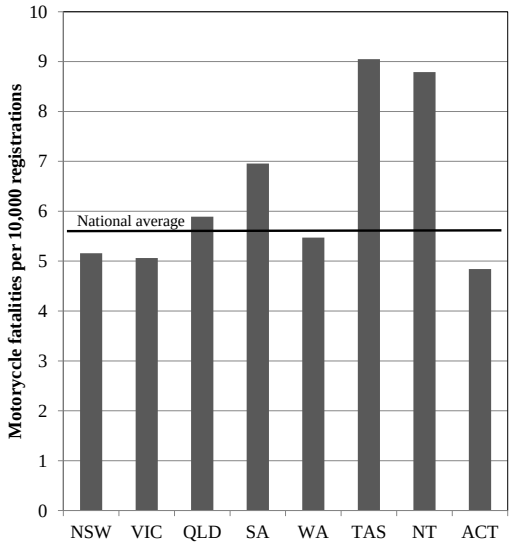


Figure 2: Age of motorcycle fatalities (n=1,323)

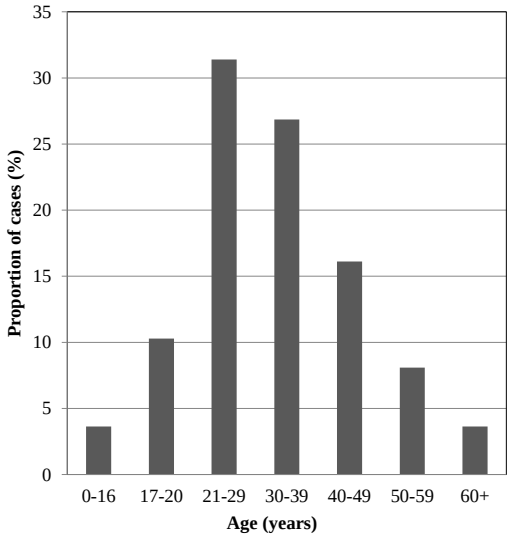
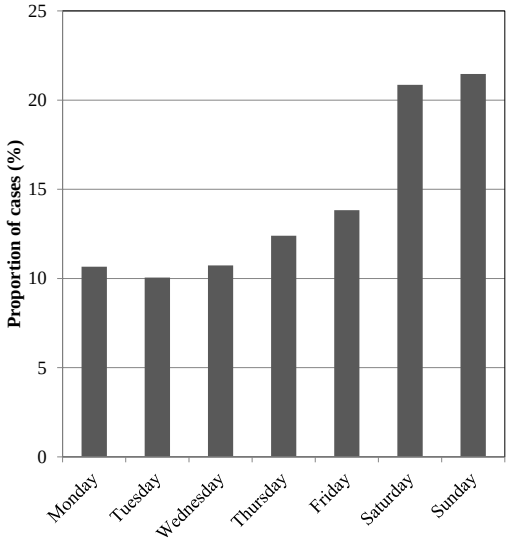


Figure 3: Day of the week on which the motorcycle fatality occurred (n=1,323)



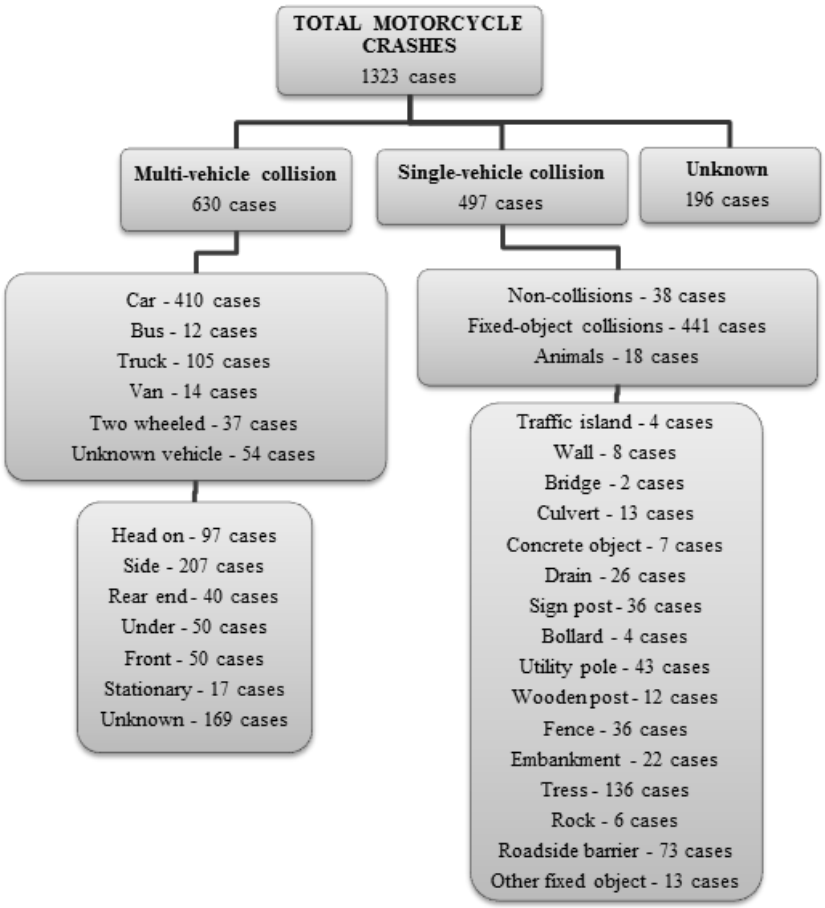
3.2. Crash events

The crash events are summarised for all 1,323 fatal motorcycle crashes in Figure 4. Of 1,127 known cases, 630 were multi-vehicle crashes (56%) and 497 were single-vehicle crashes

(44%). Cars were the most frequent partner vehicle in the collision (65%), and the motorcyclist impacting the side of the partner vehicle was the most frequent crash orientation (45% of known cases). In Figure 4, “Two wheeled” refers to motorcycles.

Single-vehicle motorcyclist fatalities predominantly resulted from collisions with fixed objects (89%). The most frequently impacted fixed objects were trees (31%), utility poles/posts (21%) and roadside barriers (17%).

Figure 4: Crash events of fatal motorcycle crashes (n=1,323)



3.3. Contributing causal factors and vehicle at fault

Analysis of the 764 available toxicology reports indicated that 233 motorcyclists (30%) had consumed alcohol prior to the crash, of which 167 (72%) had blood alcohol concentrations (BAC) above the legal limit of 0.05g/100mL. The BAC levels are plotted in Figure 5, where it is evident that the majority of alcohol-affected motorcyclists had a BAC above 0.1g/100mL (60%).

Of the 764 known cases, illicit drugs were detected for 207 motorcyclists (27%), where 102 (13%) used more than one type of illicit drug and 81 (11%) used illicit drugs and alcohol. The types of illicit drugs detected are plotted in Figure 6, where the majority was cannabis (68%). Of those motorcyclists that consumed cannabis, 63% had THC concentrations in excess of 5µg/L, which approximates to consumption of one cigarette within 6 hours (of the sample being taken) (Dickson 2011). A total of 359 motorcyclists had consumed alcohol and/or drugs prior to the crash (47%).

There were 355 motorcyclists for whom excessive speed was identified by police and reported in the police summary. There were a further 84 cases for which the police noted that the motorcyclists speed was low or not excessive. However, if speed was not a contributing factor the police may not have deemed it necessary to report that fact, thus it is appropriate to express the incidence of excessive speed as a proportion of all 1,323 cases (27%). There were 146 motorcyclists that were reported to have disobeyed a traffic control law (11%).

Of all 1,323 motorcycle fatalities, there were 663 motorcyclists (50%) for whom risky riding behaviour of any type was identified as a contributing causal factor in the crash (excessive speed, alcohol, drugs, disobeying a traffic control law, or any combination of these). A statistical analysis was performed in order to establish motorcyclist characteristics that were associated with risky riding behaviour, and the results are presented in Table 1. These results indicate that the categories of; males, less than 35 year-olds, riding in the evening on weekends, suburban areas, unregistered motorcycles and single-vehicle crashes, were statistically significantly more likely to have risky riding behaviour identified as a contributing causal factor in the fatal crash. Motorcyclists on a group ride or performing paid work duties were less likely than other riders to have been demonstrating risky riding behaviour.

Figure 5: BAC levels (g/100mL) for motorcyclists where alcohol was present in the toxicology report (n=233)

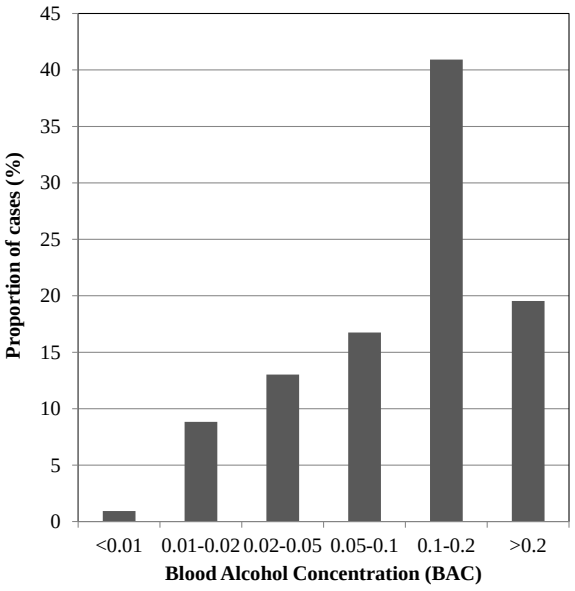


Figure 6: Types of drugs for motorcyclists where drugs were present in the toxicology report (n=207)

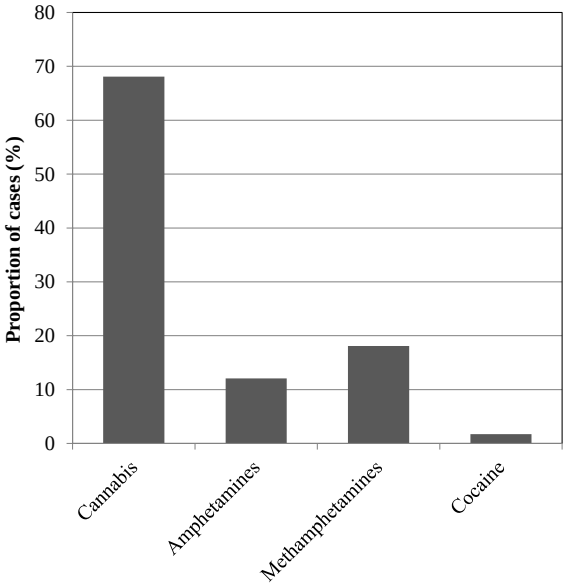


Table 1: Predictors of risky riding behaviour in fatal motorcycle crashes

Group (proportion of the group that were risky riding)	Odds ratio	95% CI lower	95% CI upper	p
Single-vehicle (56%) vs multi-vehicle (50%)	1.302	1.028	1.649	0.0285
Male (51%) vs female (34%)	2.030	1.201	3.434	0.0071
Under 35 years old (56%) vs over 35 (42%)	1.743	1.395	2.178	<0.0001
Not fully licenced (71%) vs full licence (68%)[a]	1.163	0.550	2.458	0.6892
Unregistered (74%) vs registered (56%)	2.244	1.242	4.052	0.0064
Weekend evening (74%) vs not (53%)	2.598	1.694	3.984	<0.0001
Male, <35 years, weekend evening (81%) vs not (48%)	4.525	2.593	7.893	<0.0001
Suburban (65%) vs arterial/rural/freeway/highway (49%)	1.896	1.410	2.548	<0.0001
Group ride (42%) vs not (52%)	0.671	0.493	0.915	0.0113
Riding during paid work (31%) vs not (51%)	0.433	0.245	0.763	0.0030

CI = confidence interval [a] not statistically significant (p>0.05)

The analysis of the vehicle at fault indicated that in the 482 multi-vehicle crashes where fault could be established (77%), the motorcyclist was deemed at fault in 246 cases (51%), the other vehicle operator was at fault in 151 cases (31%) and both were at fault in 85 cases (18%). Most of the dual-fault crashes involved the other vehicle initiating the crash while the motorcyclist demonstrated risky riding behaviour. Considering all 482 multi-vehicle crashes (where fault was established) and the 479 single vehicle crashes (not including collisions with animals) that may be attributed to the motorcyclists' fault, the motorcyclist was at fault or partially at fault in 810 cases (84%) and the other vehicle was at fault or partially at fault in 236 cases (25%). Of the 810 crashes where the motorcyclist was at fault or partially at fault, risky riding behaviour was identified as a contributing causal factor in 569 cases (70%).

In a small number of cases (4%) other factors were identified as contributing to the cause of the crash, including an animal on the roadway, a pothole, loose gravel, high wind, fatigue or a possible medical condition.

3.4. Cause of death and serious injuries sustained

The cause of death (COD) was identified in the Coronial finding report, however in 686 cases specific injuries were not identified (eg died of multiple injuries or injuries sustained in a motor vehicle crash). Of those 637 cases where specific injuries or body regions were identified, the body region most frequently identified as being the cause of death was the head, followed by the thorax (Figure 7). In many cases more than one body region was identified (thus the proportions in Figure 7 sum to more than 100%). In the study of serious (AIS 3+) injuries identified in the sample of autopsy reports (35 cases), the thorax was the most frequently seriously injured body region, followed by the head (Figure 8).

Figure 7: Proportion of fatal motorcyclists with a specific body region identified as the cause of death (n=637)

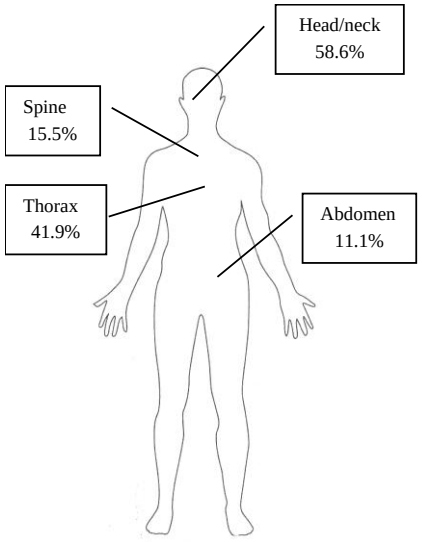
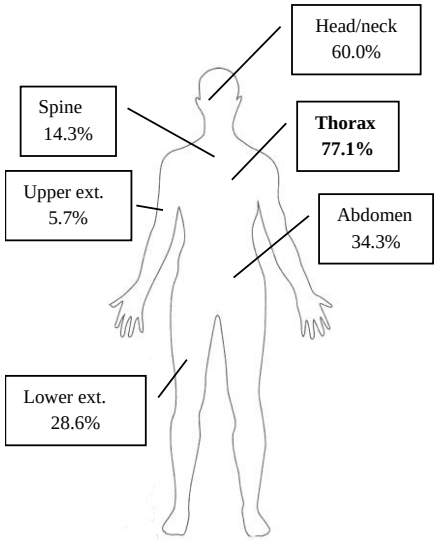


Figure 8: Proportion of fatal motorcyclists with at least one serious injury in a body region from the autopsy reports (n=35)



4. Discussion

The general motorcyclist demographics and crash characteristics identified in the present study for fatal motorcycle crashes in Australia, indicate that motorcyclists were predominantly helmeted males between the ages of 21 and 39, riding on weekends in the afternoons or evenings in fine, dry conditions. These results are generally in agreement with the analysis of fatal motorcycle crashes in Australia by Johnston et al (2008), and those of seriously injured

motorcyclists in Australia by Henley and Harrison (2009), who both identified younger males as being over-represented in motorcycle trauma.

The analysis of crash events indicated that motorcycle fatalities predominantly occur as a result of a collision with another vehicle (56%) or a single-vehicle collision with a fixed roadside object (39%). The most common crash modes were a motorcyclist impacting the side of a car at an intersection for the former, or a tree, utility pole, post or roadside barrier on a bend for the latter. Other studies have also highlighted the injury risk of fixed objects and collisions with vehicles to motorcyclists (Quddus et al 2002, Savolainen and Mannering 2007). These results indicate that intersection design, road user behaviour at intersections and roadside design have a significant influence on motorcyclist safety.

The analysis of liability in fatal motorcycle crashes indicated that while another vehicle was at fault or partially at fault in 49% of multi-vehicle crashes, due to the high number of single-vehicle crashes another vehicle was at fault or partially at fault in only 25% of all crashes. Of all fatal crashes, the motorcyclist was at fault or partially at fault in 84% of crashes, and of these, the motorcyclist was demonstrating risky riding behaviour in 70% of crashes (excessive speed, alcohol, drugs, disobeying a traffic control law, or any combination). These results indicate that while other vehicles are initiating some fatal motorcycle crashes, a large proportion are occurring as a result of motorcyclist riding behaviour. Of particular note was that of cases with known toxicology, 47% of motorcyclists had consumed alcohol and/or drugs prior to the crash. Other authors have also identified alcohol use and speeding as being associated with increased risk of severe injury amongst motorcyclists (Savolainen and Mannering 2007, Shankar and Mannering 1996). Risky riding behaviour was more likely to have been a contributing causal factor for younger males (less than 35 years old), weekend evening crashes, suburban roads and motorcyclists riding unregistered motorcycles. Males under 35 years involved in fatal crashes on weekend evenings were 4.5 times more likely than other riders to be demonstrating risky riding behaviour, and 81% of such individuals were doing so. Significant changes in rider behaviour are required to reduce a majority of motorcyclist fatalities, and this might be assisted with enforcement and education strategies.

Motorcyclists in fatal crashes while on a group ride were 1.5 times less likely to be demonstrating risky riding behaviour, which indicates that group riding may have a positive influence on discouraging risky riding behaviour. This might result from peer mentoring and increased understanding of risks amongst motorcycle club/group participants discouraging risky riding behaviour, and from scheduled rides offering opportunities for riders to plan ahead and manage alcohol/drug consumption. Motorcyclists that were on paid work duties at the time of the fatal crash were 2.3 times less likely to be demonstrating risky riding behaviour, which is understandable given the professional nature of the motorcycle usage. It is also possible that those people who choose to ride in groups or for work are less likely to engage in risky riding behaviour regardless of the type of riding they undertake. Further research is needed to establish how much influence different types of riding activities actually exert on behaviour.

The injury analysis indicated that the head and thorax were the principal body regions seriously injured and identified as the cause of death. While head injury was identified as the cause of death more frequently, the thorax was more frequently seriously injured. Kraus et al (2002) also found that amongst 548 fatally injured motorcyclists in the United States, the head and thorax were frequently seriously injured, where 73% of motorcyclists received an AIS3+ head injury and 65% received an AIS3+ thoracic injury. Similar to the present study, multiple rib fractures and associated lung injuries were typical serious thoracic injuries. The extensive head injuries in the present study occurred despite 86% of motorcyclists wearing helmets, indicating that the functional limits of current helmets are being exceeded, and improved helmet design may assist in reducing motorcyclist fatalities. Thoracic injury amongst motorcyclists is not well understood, and currently thorax protective devices are rarely used or encouraged for on-road motorcyclists, aside from the usual protective equipment recommended for general abrasion resistance. Thorax protective devices for

impact do exist, however they are typically marketed towards off-road and competition motorcyclists. In Europe there are currently two test Standards for impact protective devices for motorcyclists (EN 1621-1,2), and a Standard for chest impact is currently under development (prEN 1621-3). Given the predominance of serious thoracic injury and the current lack of protective devices, there may be a significant opportunity to reduce motorcyclist fatalities with thoracic protection.

These potential areas for reducing motorcyclist fatalities identified in this study are summarised in Table 2, within the framework of the Safe Systems approach endorsed by Australian governments.

The comparison of characteristics and contributing causal factors between the summary case documents downloaded from the NCIS, and those determined from the full Coronial case files in the sample of 35 cases, did not indicate any substantial differences between the two data sources. This provides evidence of the validity of using case documents from the NCIS for the analysis of Australian motorcyclist fatalities.

Table 2: Potential areas for reducing motorcyclist fatalities, within the Safe Systems approach

Safe roads	Safe road use and Safe speeds	Safe vehicles
Collisions with fixed objects in the roadside occurred in 39% of crashes. *Improve the safety of roadside infrastructure for motorcyclists.*	Risky riding behaviour was a contributing causal factor in 70% of motorcyclist at/partially at fault crashes. *Education and enforcement.*	Protective devices – helmets were worn in 86% of crashes yet 59% had head injury as COD. *Improve helmet designs and standards.*
38% of crashes occurred at intersections. *Improve the safety of intersections for motorcyclists.*	47% of motorcyclists were under the influence of alcohol and/or drugs. *Education and enforcement.*	Protective devices – 42% of cases had thoracic injury as COD. *Investigate/develop standards and promote/educate motorcyclists on the use of thorax protection.*
	Vehicles turning in front of motorcyclists occurred in 67% of multi-vehicle intersection crashes. *Promote motorcycle awareness amongst other road users.*	30% of motorcyclists were under the influence of alcohol and 27% had excessive speed. *Alcohol interlocks, ABS breaking*

5. Conclusions

This study identified 1,323 fatal motorcycle crashes that occurred in Australia between 2001 and 2006. Motorcyclists killed were predominantly younger males involved in collisions with cars at intersections or experienced impacts with fixed roadside objects. While other vehicles initiated some fatal motorcycle crashes, a large proportion occurred as a result of motorcyclist risky riding behaviour, including excessive speed, alcohol and drug use and disobeying traffic control laws. Head injury was the most frequently reported cause of death, and the thorax was the most frequently seriously injured body region. A number of potential areas for reducing motorcyclist fatalities have been identified, including safer roadside and intersection design, enforcement and education related to riding behaviour and the development of thoracic impact protection.

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