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Protective clothing and motorcyclists in South Australia

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ABSTRACT

In November, 2010, the South Australian Motor Accident Commission launched its ‘Gear Up’ campaign to promote greater use of protective clothing by motorcyclists. Such clothing may include impact protectors and abrasion resistant materials. This study was conducted to ascertain the extent to which abrasion resistant materials would be expected to be of benefit in motorcycle crashes in urban and rural areas. A literature review and analysis of in-depth crash data revealed that crash-involved riders of motorcycles are likely to slide or tumble on the road surface, regardless of crash type or crash location (urban or rural). It was concluded that protective clothing for motorcyclists would be beneficial for all riders, whether they be urban commuters or weekend recreational riders.

KEYWORDS

Motorcycle, protective clothing, crash analysis, literature review

Summary

Motorcycling in South Australia is growing in popularity, with huge increases in motorcycle registrations in recent years, particularly for scooters. Travel by motorcycle, however, involves a higher risk than other modes of transport and so the South Australian Motor Accident Commission is interested in promoting greater use of protective clothing by motorcyclists.

A review of the literature and analysis of CASR's in-depth crash databases both indicate that protective clothing should be beneficial for riders in both urban and rural areas. The literature review found that, in both urban and rural locations, there are a high proportion of cases in which riders are ejected from their motorcycles and slide or tumble on the road surface, regardless of crash type. The in-depth data revealed that there was little difference between South Australian urban and rural locations in the likelihood of crash-involved riders sliding or tumbling on the road after the initial crash event, with a best estimate of around 50 to 60 percent of cases. Crashes in which riders slide or tumble on the road surface can result in injuries to all body regions but the injuries tend to be minor to moderate in severity. Such injuries could be mitigated by protective clothing.

The MAC campaign, called "Gear Up", uses five time world 500cc motorcycle racing champion, Mick Doohan, as a spokesman to promote the benefits of protective clothing for preventing injury. The campaign uses television advertisements, posters at roadhouses and pubs, and advertisements in motorcycle magazines. There is also an associated website and copies of 'The Good Gear Guide' (de Rome, 2009) have been distributed to South Australian motorcyclists. The campaign began in November, 2010. If successful, it would be expected that there would be increased use of protective clothing by motorcyclists following the campaign.

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1 Introduction

Motorcycles are growing in popularity throughout Australia. In South Australia, there were 30,000 registered motorcycles in 2004 but 45,000 in 2009. The most recent general analysis of registration trends in South Australia (Colmar Brunton Social Research, 2009) revealed that motorcycle registrations have increased since 2004 in all motorcycle categories. The increases have been 230 percent for motorcycles with engine capacities up to 50cc, 10 percent for motorcycles between 51 and 250cc, 100 percent for motorcycles between 251 and 600cc, and 50 percent for motorcycles with capacities above 600cc.

This increased popularity of motorcycling needs to be considered in light of the over-representation of motorcyclists in casualty crashes. Johnson, Brooks and Savage (2008) recently analysed ten years of Australian road crash data. Motorcycles comprised 4.5 percent of registered vehicles and 0.9 percent of vehicle miles travelled but motorcyclists comprised 15 percent of road deaths and a greater proportion of seriously injured road users. Per distance driven, motorcyclists were found to have 30 times the fatality rate and 41 times the serious injury rate of car occupants.

One means by which motorcyclists can reduce their likelihood of injury in a crash is to wear protective clothing (de Rome, 2006). Therefore, any intervention that could increase the rates at which motorcyclists wear protective clothing could have benefits for road safety.

The South Australian Motor Accident Commission has developed an advertising campaign to encourage riders of motorcycles to wear protective clothing. The campaign, called “Gear Up” uses five time world 500cc motorcycle racing champion, Mick Doohan, as a spokesman to promote the benefits of protective clothing for preventing injury. The campaign uses television advertisements, posters at roadhouses and pubs, advertisements in motorcycle magazines, and is supported by a website that features links to Doohan speaking in more detail about the specific components of motorcycle attire that riders should purchase (gloves, helmet, jacket, pants and boots). Additionally, copies of ‘The Good Gear Guide’ (de Rome, 2009) have been distributed to South Australian motorcyclists. The campaign began in November, 2010. It follows MAC’s earlier favourably received “No Place to Race” campaign. If the “Gear Up” campaign were successful, it would be expected that there would be increased use of protective gear by motorcyclists after the completion of the campaign.

In this report, the likely benefits of protective clothing in the two areas (metropolitan Adelaide and the Adelaide Hills) are examined. This is done with a review of the literature (Section 2) and an analysis of actual motorcycle crashes that have been investigated at the scene by CASR (Section 3). Both the literature review and in-depth crash data analysis are principally concerned with comparing urban and rural motorcycle crashes in terms of the degree to which riders impact with, and slide along, the road surface following the initial crash event. The degree to which the riders impact with, and slide along, the road surface will be related to the likely benefits of abrasion resistant clothing for preventing injury.

2 Literature review

2.1 Introduction

Motorcyclists are regarded as vulnerable road users due to the lack of a protective cage when involved in a crash, compared to other road users such as car and truck drivers (ETSC, 2008). Motorcyclist injuries are therefore often more severe than those of other road users. Due to the lack of a protective cage, often the only barrier between the motorcyclist and the surfaces impacted in a crash are the clothes the rider is wearing. Typical everyday clothing provides little to no protection in a crash but helmets and specially designed motorcycle protective clothing, including gloves and boots, can reduce the frequency and severity of injury to the motorcyclist.

Abrasion-resistant clothing is useful in preventing injuries caused by the rider sliding along the road post-impact but is less beneficial for heavy impacts with other vehicles or objects (de Rome, 2006). Specialised leather motorcycle clothing can also include impact protectors (or ‘body armour’) located on high-risk parts of the body, such as the shoulders, elbows, hips, knees and spine. These are expected to offer a degree of protection against fractures and joint damage but there has been little published research on the effectiveness of impact protectors. For this reason, this review will focus more on the abrasion resistance aspect of protective clothing for motorcyclists, with an emphasis on protection against injuries sustained in crashes associated with riders sliding along the road surface.

Of particular interest for this review is whether abrasion resistant clothing is likely to be beneficial for riders in both metropolitan and rural regions. The frequency of different crash types tends to differ in metropolitan and rural regions, with metropolitan regions featuring more crashes involving motorcyclists colliding with other vehicles, while rural regions feature more single vehicle crashes (Pierini, Cappon, Garcia & Lopez-Valdes, 2005). Therefore, if the multi-vehicle crashes typical of metropolitan regions are less likely to lead to the rider sliding on the road, this would have implications for the relative benefit of protective clothing in those regions. This knowledge could provide opportunities for tailoring and marketing of protective clothing.

The aim of this review is to clarify the evidence behind these assumptions by presenting findings from four relevant areas of research. The first involves studies that have recorded the post-impact movements of the motorcycle rider in a crash (Section 2.2). These studies include information on the proportion of riders who experience various movements post impact, such as being carried by another vehicle or sliding to final position. This information can be used to determine the prevalence of sliding post-impact, and therefore the proportion of crashes where protective clothing would be beneficial in preventing sliding-related injuries. Due to the scarcity of this type of research, three other types of studies are also reviewed. Research investigating the injury patterns of motorcyclists often includes an analysis of the cause of the injuries such as the proportion of injuries caused by other vehicles, objects, or the road. As post-impact sliding, and injuries that can be prevented by protective clothing, occur on the road, this information can further provide an estimate of the proportion of crashes in which protective clothing could be of use (Section 2.3). Finally, studies investigating the configuration of motorcycle crashes (e.g., rear-end, side-swipe, head-on, single vehicle loss of control) in different regions (e.g., metropolitan or rural) (Section 2.4), and the injury patterns of motorcyclists associated with these crash configurations (Section 2.5) are also reviewed. These studies provide information on the types of crashes occurring in different regions, and the injuries likely to occur in these crash types. By combining this information it may be possible to demonstrate the benefit of protective clothing in different crash types and locations. This information can provide an indication of the potential for tailoring of marketing of protective clothing in specific locations or for different riding purposes (e.g., rural recreational riding or metropolitan commuting).

2.2 Post-impact rider movements

Detailed crash studies are required for information pertaining to the post-impact movements of riders in crashes. Unfortunately, such detailed studies are rare. The two main studies of this type are reviewed here.

In an in-depth study of 900 motorcycle crashes in Los Angeles, which ranged in severity from non-injury to fatal, Hurt, Ouellet and Thom (1981) found that only 12 per cent of crashes did not involve the rider separating from the motorcycle. Of the 900 cases investigated, only nine per cent of the riders stopped near their point of impact. Although only 12 per cent were recorded as sliding to a stop, a further 13 per cent were described as tumbling and rolling from the point of impact. The remaining crashes involved the rider being vaulted or falling from the motorcycle, being trapped either under the other vehicle or the motorcycle, or being struck and dragged by the other vehicle (Hurt, Oullet & Thom, 1981). Although not defined as a 'slide to stop' these movements are also likely to involve some contact with the road surface in which protective clothing may be of benefit in reducing injury.

Another in-depth study (ACEM, 2009) looked at the post-impact movements of powered-two-wheeler (PTW) riders in a sample of 921 crashes. In approximately 22 per cent of crashes, the rider of the PTW either stopped at the point of impact, vaulted into another object, was run over, stayed on the PTW and rode to final position, or was caught by the other vehicle and carried to final position (ACEM, 2009). These scenarios are unlikely to be ones where protective clothing would be of benefit for the mitigation of injury from sliding. In 34 per cent of crashes, the rider either slid from the point of impact to a final position or into another object, slid after being vaulted at the point of impact, or was dragged to final position (ACEM, 2009). Furthermore, another 23 per cent of riders either tumbled and rolled from the point of impact to final position or into another object, or rolled after being vaulted from the PTW from impact (ACEM,2009). These movements are all likely to cause injury for which protective clothing could be beneficial. Together they occur in the majority of PTW rider post-impact movements (56%) (ACEM, 2009). For the remaining 22 per cent of crashes reported in the study, it is difficult to determine how effective protective clothing would be. This group includes crashes where the rider was coded as stopping within two meters of the impact point, hit and run crashes (e.g., rider departed scene), 'other', and unknown crashes (ACEM, 2009).

For the purpose of this review, it is unfortunate that there are few studies examining rider impact points, movements, and associated injuries. Despite this, both of the preceding studies suggest that, in motorcycle crashes, post impact movements of the rider in the form of sliding, tumbling, and rolling are common, occurring in the majority of cases (ACEM, 2009; Hurt, Oullet & Thom, 1981). These findings were not compared in terms of location of crash (e.g., metropolitan or rural areas) or type of crash (single or multiple vehicle) in either of the studies so any potential differences are difficult to determine. Further research in this area is warranted.

2.3 Motorcyclist injury patterns

Studies investigating the injury patterns of crash-involved motorcyclists can provide detailed information on the cause, location and severity of injury in different crash types, and also allow estimates of the benefits of protective clothing to be determined. This section reviews studies of this type.

Hurt, Ouellet and Thom's (1981) in-depth crash database included 3,016 cases of rider injury involving a total of 5,067 injury-related contact surfaces. The researchers divided these injuries into categories: those attributed to the motorcycle, those attributed to the other vehicle, and those attributed to the environment. Thirty-nine per cent of the injuries involved contact with the motorcycle, 28 per cent involved the other vehicle, and 33 per cent involved a surface in the environment (e.g., pavement, embankment, tree, pole, guardrail etc.) (Hurt, Ouellet & Thom, 1981). Eighty-three per cent of the injuries that were caused by contact with a surface in the environment involved the pavement (Hurt, Ouellet & Thom, 1981a). Furthermore, of all severe to fatal injuries from the 900 cases, 12 per cent were caused by contact with the pavement (Hurt et al., 1981a). It is likely that some of these injuries may not have been prevented by protective clothing. For example, most protective clothing would have been insufficient to protect a rider who was vaulted from the motorcycle and then heavily struck the ground causing spinal fractures. Unfortunately, there was no way of determining the proportion of this type of injury from the information provided by Hurt et al. (1981a). Of the riders with injuries to their upper torso, 61 per cent were not wearing heavy cloth or leather upper body protection. Of the riders with lower body injuries, 83 per cent were not wearing heavy cloth or leather lower body protection (Hurt et al., 1981).

Although improvements in the design of, and materials used in, protective clothing are likely to have been made since this study was conducted, its findings do suggest that approximately one-third of injuries sustained in motorcycles crashes involve contact with environmental surfaces, the majority of which are related to contact with the pavement (Hurt et al., 1981), an area in which protective clothing is likely to be effective in reducing injury.

A study undertaken by Whitaker (1980) looked at the causes and consequences of motorcycle crashes within regions of the United Kingdom in 1974 and also demonstrated the involvement of the road surface in injury causation. Whitaker found that 53 per cent of all motorcyclist crash-related injuries (from minor to fatal) were caused by the road surface, but most of these road-related injuries were of minor to moderate severity (96%). These injuries are likely to have included those caused by both sliding and heavy impacts, and they occurred on all body regions. In comparison to the road, more severe and fatal injuries were caused by impacts with other vehicles (Whitaker, 1980). These injuries also occurred on all body regions but particularly in the legs. Whitaker found that only a small proportion of injuries to the riders were caused by the motorcycle (12%). It was also suggested that the impact point of the motorcycle does not influence injury severity but does influence the distribution of injuries on the body. For example, severe injury to the legs caused by side impacts (81%) was more common than from frontal or oblique impacts (52% in total). Speed and the presence of other objects in the crash location were more likely to affect injury severity (Whitaker, 1980). Unfortunately, this study did not record protective clothing other than helmet use, and so does not provide any indication of the effectiveness of protective clothing for mitigating injury.

An in-depth study of powered two wheeler (PTW) crashes in France involving both fatally and non-fatally injured riders was conducted from 2003 to 2005 (Phan, Moutreuil, Martin, Feurxer & Hermitte, 2008). The researchers investigated the initial impact of PTW riders, and found that 52 per cent of injuries were related to impacts with the ground, while 42 per cent were due to other vehicles or powered two wheelers. The researchers also found that minor and moderate injuries were more likely to occur at the extremities, while more severe injuries were located at the head, thorax, spine, and abdomen. The study suggested that upper body protection is more effective in reducing injuries than lower body protection (Phan et al., 2008) but this may be due to the legs of riders often impacting heavily with other vehicles in multiple vehicle crashes. These injuries are likely to be substantial and may hide the effective properties of lower leg protection in post-impact sliding motions.

The previously mentioned in-depth study conducted by ACEM (2009) also investigated injuries. This study found that the majority of rider injuries occurred in the lower extremities (32%), followed by the upper extremities (24%) and that these injuries were mainly of minor to moderate severity. Contact surfaces related to the most severe injury of each body region were also recorded. The road caused injuries to all regions of the body but the most severe injury caused by the road to each body region was often only minor. The report also recorded the clothing details of all crash-involved motorcyclists and determined its effectiveness in reducing or preventing minor injuries to the rider. In 65 per cent of all cases, upper body clothing coverage prevented or reduced these injuries, while in 61 per cent of all cases, lower body clothing coverage achieved this task (ACEM, 2009).

Unfortunately, there was no comparison made in terms of the effectiveness of different levels of protection. Prevalence of the use of protective clothing within the sample was reported, with 38 per cent of riders wearing leather or Kevlar upper body protection and 31 per cent wearing leather or Kevlar lower body protection (ACEM, 2009).

A questionnaire study was conducted by Craig, Sleet and Wood (1983) over a four-month period in Southampton, United Kingdom, from 1980 to 1981. Injured motorcyclists who attended the Southampton General Hospital were invited to participate in the study. The researchers were particularly interested in lower limb injuries. They found that 73 per cent of the respondents received an injury to their lower limb and that the majority of these injuries were minor (74%). From information gathered in the questionnaire, the causes of the lower limb injuries were identified. Out of all the injuries, 28 per cent were attributed to the road by the patient, 20 per cent were attributed to another vehicle and 10 per cent to the motorcycle. The patients did not know the cause of their injuries in the remaining cases. Less severe injuries tended to be related to the road or the motorcycle, while more severe injuries were related to another vehicle. The study did not take into account the clothing worn by the motorcyclists or the crash configuration or location, but it was stated that the hospital covered both rural and metropolitan regions (Craig et al., 1983).

Although the studies presented vary in their method of data collection, location and specific focus, there are some trends to be observed which are of importance to this review. The studies together suggest that the road, ground, or pavement, are relatively common sources of injury, and that the majority of the injuries related to this source tend to be of a minor severity. These injuries therefore are likely to be those that protective clothing is most effective in preventing.

2.4 Patterns in motorcycle crashes

Geographical location is related to a number of other factors in motorcycle collisions. This includes the proportion of single and multiple vehicle crashes, and the proportion of different types of crash configuration (e.g., rear-end, head-on etc.). Determining the proportion of different crash types in various locations may be useful if these are relevant to the types of injuries motorcycle riders receive, particularly if a given crash type leads to a difference in the benefit of protective clothing compared to other crash types. The following is a review of the relationship between location and crash configuration.

In Hurt, Ouellet and Thom's (1981) in-depth study, only nine per cent of the crashes investigated were in rural or undeveloped areas. Crash configurations were compared in terms of pre-crash movements of the other vehicle and those of the motorcycle. The most common crash configuration involved a vehicle making a left turn (27% of crashes), often in front of the oncoming motorcycle, followed by both the motorcycle and other vehicle proceeding straight ahead (11%). Seventy-four per cent of crashes involved the motorcycle impacting with another car, motorcycle or four-wheel vehicle, 19 per cent were with the roadway, and the remainder were with animals, fixed objects or 'other'. Of the single vehicle crashes, the most common crash type involved the motorcycle proceeding straight ahead (60%) or the motorcycle turning either left, right or in a U-turn (35%) (Hurt et al.,1981). Unfortunately, these were not split into rural and metropolitan regions and therefore do not provide a location comparison useful to this review. However, considering the small percentage of crashes in rural regions, these findings are likely to be more relevant to built up areas.

Preusser, Williams, and Ulmer (1995) looked specifically at crash types involved in motorcycle fatalities in the United States in 1992. The most common crash types, in order of prevalence, included 'ran off road', 'ran traffic control', 'oncoming or head on', 'left turn oncoming' and 'motorcyclist down'. Of the 41 per cent of ran off road crashes, an object was struck in 24 per cent of the cases. These crashes were often in rural areas, whereas the 'ran traffic control' and 'left turn oncoming' crashes were often in more urban areas. The former accounted for 18 per cent of all fatal crashes and the later accounted for eight per cent. Both of these crash types occurred most often at intersections (Preusser et al., 1995).

A study investigated motorcycle crash circumstances and scenarios in Germany, Italy, Spain and the Netherlands (Pierini, Cappon, Koenig, Garcia & Lopez-Valdes, 2005). There was variability in the data for the four regions studied due to differences in data collection methods, in the proportion of metropolitan and rural roads in each region, and in the year of collection. Despite this, there were clear trends in the data. In three of the four regions, more motorcycle crashes occurred in metropolitan regions. In all regions, and in both metropolitan and rural areas, the minority of crashes were single vehicle crashes but the proportion of these crashes was often much greater in rural regions. In rural areas, single vehicle crashes tended to occur on a curve, whereas in metropolitan areas they often occurred on a straight or a curved mid-block rather than at an intersection. Crashes involving another vehicle in rural areas occurred most often on a straight midblock, rather than a curve or at an intersection, but in metropolitan areas they tended to be at intersections (Pierini et al., 2005).

The relevant information demonstrated by these studies is that geographical location can influence the prevalence of specific crash configurations. There are trends in the proportion of single and multiple vehicle crashes in metropolitan and rural areas, and where crashes are most likely to occur within these regions (e.g., at intersections, on curves etc.). Despite this, it is important to note that, within different countries, the extent of this trend is varied (i.e., the proportion of single vehicle crashes may be a minority in both rural and metropolitan regions but the size of this minority could be quite different in different countries). Nonetheless, if there are differences in crash configurations and types of crashes associated with different regions, this could have an influence on the utility of protective clothing in these regions. The following section examines the role of crash type in injury causation for motorcyclists.

2.5 Crash configurations

There have been a number of studies which have taken the investigation of injury related to motorcycle crashes a step further and considered the relationship between different crash types (i.e., head-on crashes compared to side-swipes or rear end collisions) and injury distribution or severity. These studies are reviewed here.

Kraus, Riggins and Franti (1975) collected information on the environmental, vehicle, and human characteristics of motorcycle crashes, as well as injury information for all motorcycle crashes resulting in injury in Sacramento County, California, in 1970. The researchers found that the severity of injury was likely to increase with greater impact speed, and that this was more important than pre-defined crash types (Kraus et al., 1975). The crash types considered in this study were, however, quite broad. All crashes were categorised into only five basic crash types: 'ran off road', 'collision with fixed object', 'collision with second motor vehicle', 'collision with other object' and 'overturned on road'.

Another study conducted by Hell and Lob (1993) investigated motorcycle crashes in Munich and surrounds between 1985 and 1990. The crashes were at least minor in injury severity, two-thirds involved another vehicle and 70 per cent occurred outside of the town. Approximately a quarter of the crashes were fatal. The researchers investigated the injury patterns of the motorcyclists and examined associations with the type of crash they were involved in. The crash types were defined as straight (head-on); oblique (head-on but motorcycle is at a diagonal to other vehicle at impact); transverse (other vehicle impacting side of motorcycle); side impacts (motorcycle impacts side of other vehicle) where the motorcyclist also impacts the other vehicle or is thrown over the top of the other vehicle; glance-off collision (side-swipe); rear end collision with either a car or truck; crashes involving other motorcycles, bicycles or pedestrians; and single vehicle crashes which may or may not involve contact with an object. The researchers found that the least severe crashes involved a single vehicle with no object contact or a rear end collision with a car. From their sample, 26 per cent of riders had no protective clothing, while 55 per cent had full upper and lower body leather coverage. The researchers found leather clothing was particularly effective in reducing the severity of injuries, especially in the lower extremities (Hell & Lob, 1993).

Pai and Saleh (2007) conducted a study of motorcyclist injury severity in varied crash configurations specifically at T-junctions. The researchers utilised Great Britain's Government crash database for all local motorcycle crashes at T-junctions in the period from 1999 to 2004. The researchers identified seven basic crash configurations, with most of these including sub-types. Unfortunately, the crash configurations identified were likely to include different types of crash. For example, as noted by Pai and Saleh, a same-direction collision (when both the motorcycle and other vehicle are travelling in the same direction prior to the crash) could include a side-swipe or a rear end crash. This is an issue because the type of impact and post impact trajectory of the rider and the motorcycle is likely to be quite different for these crash types. The findings of Pai and Saleh's study were that the most severe crashes occurring at T-junctions for motorcyclists are head-on collisions and approach-turn B collisions (such as where a car turns right in front of an oncoming motorcycle in order to enter a side street). The researchers did not investigate in-depth the causes of the injuries, although this is likely to be due to limitations of the database used. Therefore, it is difficult to determine from this research whether lacerations or abrasions occurred due to sliding along the road.

Peek-Asa and Kraus (1996) also looked at injuries in specific crash types, focusing on approach turn crashes (when a vehicle turns in front of an oncoming vehicle that is travelling straight and has right of way). The study included data from both injury and fatal motorcycle crashes in California between 1991 and 1992. Injuries to riders involved in approach turn crashes were compared to four other crash types. Approximately 39 per cent of the crashes were single vehicle crashes while only around 16 per cent were approach turn crashes. The percentage of drivers ejected from the motorcycle for each crash type was calculated and compared to approach turn crashes. For all crashes, 76 per cent of crashes involved the rider being ejected from the motorcycle. The crash type where this occurred most often was in head-on collisions (82%), whereas in approach turn crashes this occurred the least (68%). Riders were ejected from their motorcycle in 79 per cent of single vehicle crashes (Peek-Asa & Kraus, 1996). Due to the researchers' specific interest in approach turn crashes, the statistical significance of these differences was only analysed in comparison to approach turn crashes. Ejection from the motorcycle did occur significantly less in approach turn crashes compared to all other crash types (Peek-Asa & Kraus, 1996). All crash configurations involving multiple vehicles were associated with greater numbers of lower extremity injuries compared to single vehicle crashes. Severity of injury was calculated using the Abbreviated Injury Scale (Association for the Advancement of Automotive Medicine, 1990 as cited in Peek-Asa & Kraus). The scores of the three body regions with the most severe injury were squared and summed to produce an index of overall injury severity in the form of the Injury Severity Score (ISS). The average ISS for single vehicle crashes was very similar to the average of all crashes (12.8 in comparison to an overall average of 12.9). Head-on crashes were associated with the highest average injury severity score (16.1), while same direction crashes were associated with the lowest average score (11.9). The average number of injuries per rider was similar across all crash configurations (ranging from 5.4 to 5.7), except for head-on crashes, which reached an average of 8.2 injuries per crash-involved rider (Peek-Asa & Kraus, 1996).

Although not the purpose of Peek-Asa and Kraus's (1996) study, the researchers demonstrated the great variability in post impact movements that can occur from similar crash configurations. For example, the researchers noted that in approach turn configurations, if it was the car that turned in front of the motorcycle, the motorcycle was more likely to be the striking vehicle. When the motorcycle was the striking vehicle, the rider was more likely to be ejected than if the car were the striking vehicle. Differences in injury severity and frequency also occurred depending on whether the car or the motorcycle was the turning vehicle or which vehicle was the striking vehicle (Peek-Asa & Kraus, 1996). This research demonstrates the complexity within even a single crash configuration and may suggest problems with this form of analysis for determining rider injuries. There are likely to be large amounts of variability from various factors, and if these are not taken into account, it could lead to misleading findings.

The above studies demonstrate that differences in crash configurations can have an influence on the severity and distribution of injuries. Unfortunately, most of the studies to date have used largely varying categories for crash configurations making comparison difficult. However, these studies also demonstrate the problems associated with using such a variable to investigate rider injuries. Not only could varied results be found depending on the grouping of crashes but there are many factors which are often not taken into account in these studies that may influence rider injuries, such as speed of impact, type of vehicle impacted and point of impact, presence or absence of a pillion passenger, the heading angle of the motorcycle, road vertical alignment and so on. Although it is arguably impossible to control for all potential confounding factors, it is likely that these factors would influence the forces applied to the rider in a given crash, as well as the post-impact movements of the rider (e.g., whether they are carried by the other vehicle, vaulted over the vehicle, and/or tumble and slide along the ground post-impact). The analysis of motorcycle crash configurations is more likely to be of use in developing ways of preventing crashes from occurring. Once a crash occurs, the post-impact movements of the rider, the surfaces they encounter, and the forces they are subjected to, are likely to be more important to the distribution and severity of injury, and the benefit of protective clothing, compared to the initial events leading to the crash itself.

2.6 Summary and conclusions

The preceding review demonstrates the paucity of research into post-impact rider movements and specific causes of motorcyclist injury. However, the combination of research into crash configurations, rider movements, and injury patterns suggests that protective clothing, to protect the rider from injury associated with sliding along the road post-impact, is important in both rural and metropolitan locations, regardless of differences in the frequencies of crash types.

Of particular note is the study by Hurt et al. (1981). The crashes in this study were predominantly in metropolitan regions and involved another vehicle. Still, one third of the injuries to riders involved contact with the environment, and 83% of those injuries involved the pavement. Also, only a small proportion of riders stopped near their point of impact (9%). These results suggest that a significant proportion of metropolitan crashes, including those involving multiple vehicles, are likely to lead to injuries that could be prevented by protective clothing.

The preceding review suggests that, although there are trends in the types of crashes that occur in metropolitan and rural regions, the importance of this in influencing motorcyclists' chances of sliding post-impact are quite small. The majority of crashes, whether or not they involve another vehicle, do involve ejection from the motorcycle (e.g. Peek-Asa & Kraus, 1996). In addition, those studies that have looked at the post-impact trajectories of riders have found a high likelihood of movements (e.g., sliding, tumbling, rolling) likely to cause injury and for which protective clothing may be useful. Other variables such as impact speed, type of vehicle impacted, point of impact, presence or absence of a pillion passenger, heading angle of the motorcycle and road vertical alignment are more likely to influence the injuries to the motorcyclist and post-impact movements of the motorcyclist than crash type, which is often categorised quite differently across studies.

Therefore, although there is no study that fully addresses all of the issues considered in this review, current research suggests that sliding, and other forms of contact with the road, occurs within all locations and crash types. This road contact often leads to injuries of minor to moderate severity and occurring over all body regions. These less severe injuries caused by the road are likely to be reduced or prevented by protective clothing. Therefore, upper and lower body protective clothing is important to be worn in all regions and in all types of riding (i.e., commuting or recreational riding).

3 Analysis of in-depth crash data

3.1 Introduction

This section is concerned with analysis of data collected by CASR as part of its program of in-depth crash investigation. The aim of the analysis was to examine the post-impact movements of motorcyclists in crashes in South Australia. Specifically, the aim was to determine the proportion of crashes in which riders struck the road surface or slid along the road surface following an impact with another vehicle or coming off the motorcycle in the case of a single vehicle crash. Of particular interest was the comparison between urban and non-urban crashes. It was hypothesised that riders would slide or tumble on the road surface more often in non-urban crashes. If riders rarely slide or tumble on the road surface in urban crashes, then there is less need for protective, abrasion resistant clothing in urban areas.

3.2 Method

3.2.1 Method – in-depth crash investigation

CASR has crash investigation teams made up of engineers, psychologists and health professionals who travel to the crash scene once notified about the event on the ambulance radio or ambulance pager. The sequence of events for a crash investigation is as follows:

- Notification of the crash on the SA Ambulance service radio or pager
- Attend the crash at-scene
- Photograph the scene and involved vehicles
- Discussions with police attending the crash
- Mark the positions of the vehicles and any skid or gouge marks
- Brief introduction and discussion with participants and witnesses at-scene (where appropriate)
- Examine the vehicle(s) at the scene and/or elsewhere
- Record video footage of the approach to the crash site from a driver's perspective
- Make an engineering survey of the crash site

Follow-up investigations include:

- Obtain the police report on the crash
- Obtain injury information from hospitals
- Conduct a detailed interview with consenting crash participants and witnesses
- Review site design and crash history of the site
- Review crash history of the drivers
- Review Coroners file where appropriate
- Computer aided crash reconstruction where relevant and practicable
- Perform a multidisciplinary case review

Following the crash, an engineering survey is made of the site to record road geometry, the location of roadside objects and any other relevant information such as line marking and vegetation. Engineering drawings of the road section are also obtained from the responsible road authority. Sites may also be revisited for more detailed follow-up survey work or reassessment from a road engineering perspective.

Follow up inspections are made of the involved vehicles as needed to gather any missing information or reconfirm crash injury mechanisms. The information collected for each vehicle includes:

- Photographic record of the vehicle, including detailed photos of any visible damage and evidence of occupant (or pedestrian) contact
- Recording of VIN (Vehicle Identification Number) and current registration details
- Inspection of tyres: dimensions, tread and pressure
- Inspection of seatbelts for condition and load marks
- Measurement of deformation
- Inspection for window tinting and any vehicle modifications

Follow up personal interviews are conducted whenever possible with those involved in the crash and any witnesses. Participation in interviews is only voluntary but, as CASR is protected from subpoena under Section 64D of the South Australian Health Commission Act 1976, we are able to promise confidentiality to the crash participants who do consent to an interview. For this reason, participants are able to share their knowledge of the events of the crash without fear that there will be any legal consequences for them in doing so. Nonetheless, we are still vigilant to the possibility of participants either deliberately misrepresenting the crash or describing the crash in terms that preserve their own self-esteem. We are careful always to compare participants' descriptions of the crash with evidence at the scene, evidence from examination of vehicles, and evidence given by other participants or witnesses. In this way we hope to minimise the possibility of erroneous information. The information sought during these interviews includes:

- Personal details (age, sex and, for pedestrians, height and weight)
- Driving experience, traffic violation and crash history
- Familiarity with the road and the vehicle driven in the crash
- Trip details
- Possible distractions
- Alcohol and drug use, if any, prior to the crash
- Emotional and fatigue factors
- Pre-existing medical and physical disabilities
- Perception of the crash and its contributing factors
- Immediate injuries and resultant disabilities
- Clarification of vehicle/pedestrian movements, positions and the crash sequence

Data on injuries are obtained from hospital records. Police accident reports are obtained to provide information about the crash as reported to, and interpreted by, the police. Where appropriate, Coroners files are also examined to check consistency of findings or shed further light with previously unobtainable evidence. These contain full reports from the Police Major Crash Investigation Unit, autopsy and toxicology reports, together with information on any medical issues that may have been affecting the deceased individual.

When all the evidence has been collected, a review is conducted of each case by a multidisciplinary group of CASR staff and factors that contributed to the causation of the crash and the resulting injuries are established.

3.2.2 Method – sample for analysis

Two samples of road crashes investigated by CASR were chosen for this analysis. The two sets of crashes were the Metropolitan In-Depth Crash Study (2002 to 2005) and the current In-Depth Crash Study database (2006 to the present).

The Metropolitan In-Depth Crash Study

The Metropolitan In-Depth Crash Study sample was comprised of 298 crashes. The criteria for the inclusion of a crash in the study were that:

- The crash occurred in the Adelaide metropolitan area (nominally within 10 km of the CASR offices on Frome Road in the City centre).
- The crash involved at least one person who was injured severely enough to be transported by ambulance to hospital for treatment or was fatally injured. The injury outcomes associated with transportation to hospital ranged from fatal (died within 30 days of the crash as a result of injuries sustained in the crash), hospital admission (admitted to hospital for treatment, also known as a 'serious' injury in official statistics), and hospital treatment (treated at hospital but not serious enough to require admission, often called a 'minor' injury in official statistics).

The sample was not intended to be representative of all crashes in the metropolitan area. Crashes were generally attended during weekday business hours in daylight conditions. However, there were some exceptions to this and some night time pedestrian crashes were also attended. The implications of this are that caution has to be exercised in making generalisations from the investigated cases to the broader road safety situation in metropolitan Adelaide.

In terms of broad crash types, there were 91 intersection crashes, 79 pedestrian crashes, 77 midblock crashes (e.g. rear end, U-turn) and 51 single vehicle crashes. With regard to motorcycles, there were 18 crashes in this database involving a motorcycle. There were five single vehicle crashes and 13 multiple vehicle collisions (3 right angle, 3 right turn, 3 side swipe, 2 rear end, 1 U-turn, 1 'other').

The current In-Depth Crash Study

The current In-Depth Crash Study has a sample of 247 crashes. Starting initially as a rural crash study, it has now been changed to incorporate metropolitan crash investigation. As with the previous metropolitan study, the criterion for inclusion is that at least one person is injured severely enough to be transported to hospital. The 247 crashes consist of 63 metropolitan area crashes and 184 rural area crashes. The rural area was defined as the area beyond the metropolitan area but within 100 km of Adelaide. This external boundary was chosen to allow crash investigators to get to the scene at least within 1.5 hours of the collision.

Of these 247 crashes, 43 involved a motorcycle (30 in rural areas and 13 in metropolitan Adelaide). These included 15 single vehicle crashes and 28 multiple vehicle collisions (10 head on, 7 right turn, 3 rear end, 3 side swipe, 2 right angle, 1 u-turn, 1 entering or exiting road, 1 left turn).

3.2.3 Method – data analysis

Determination of the post-impact movements of the motorcyclist in the crash was based on analysis of photographs of the scene, interviews with riders and witnesses, and physical evidence marked on the engineering surveys of the crash site. The software used for preparing site plans of the crash site allows for measurements of distances within the diagram. Upon determining a point at which a rider would have struck the road surface and approximate final position of the rider, the distance between these two points could be measured. These measurements are therefore approximate and could only be calculated in cases for which the investigators were able to pinpoint a final rider position. In some cases, the latter was not possible.

3.3 Results and discussion

Of the 18 motorcycle crashes in the Metropolitan In-Depth Study, there were 10 (56%) in which the rider of a motorcycle slid or tumbled along the road at some point in the crash sequence. These 10 crashes included three side swipes, two right turn crashes, one single vehicle crash, one U-turn crash, one rear end collision, one right angle crash and one pedestrian collision. There was one case in which the sliding (or tumbling) distance could not be determined and two in which the sliding distance was less than five metres. Of the other seven cases, the sliding distance ranged from 5m to 85m. In three cases, the motorcyclist only struck the road surface. In the remaining seven cases, the rider also impacted with other objects, including a car (5), the road median (2), a bus (1), a road sign (1), and a pedestrian (1). Of the 10 sliding crashes, nine resulted in serious injuries (fatal or hospital admission), while, of the eight non-sliding crashes, three were serious.

Of the 30 rural crashes in the current In-Depth Crash Study sample, there were 18 (60%) in which the rider of a motorcycle slid along the road, and one case in which the exact post-impact movements of the rider have not yet been possible to determine. The 18 sliding cases included nine single vehicle crashes, four head on collisions, two rear end collisions, two right angle crashes, and one side swipe. In four cases, the distance of sliding was unknown and in two cases it was less than five metres. Of the other 12 cases, the sliding distance ranged between 5m and 65m. In five cases, the motorcyclist only struck the road surface. In the remaining 13 cases, the rider also impacted other objects, including a car (7), a tree (4), a guardrail (2), a post or pole (2), a cutting (1), a culvert (1), and a truck (1). Of the 18 sliding crashes, 15 resulted in serious injuries (fatal or hospital admission), while, of the 11 non-sliding crashes, 10 were serious.

Of the 13 metropolitan crashes in the current In-Depth Crash Study sample, there were six (46%) in which a motorcyclist slid along the road surface. In three cases, the sliding distance was unknown, while, in the other cases, the approximate sliding distances were 5m, 20m and 25m, respectively.

On the basis of the analysis above, it appears that there are no great differences between rural and urban crashes in the likelihood of a motorcyclist sliding or tumbling on the road in a crash. It needs to be borne in mind that the sample sizes are not large and so the results are only suggestive. Also, the distances are only approximate. Nonetheless, the findings do suggest that protective clothing is likely to be important in urban crashes as well as in rural ones.

4 Overall summary and conclusions

Motorcycling in South Australia is growing in popularity, with huge increases in motorcycle registrations in recent years, particularly for scooters. Travel by motorcycle, however, involves a higher risk than other modes of transport. Per distance driven, motorcyclists have 30 times the fatality rate and 41 times the serious injury rate of car occupants (Johnson, Brooks & Savage, 2008).

In response to this, the South Australian Motor Accident Commission has developed an advertising campaign to encourage riders of motorcycles to wear protective clothing. The campaign, called “Gear Up”, uses five time world 500cc motorcycle racing champion, Mick Doohan, as a spokesman to promote the benefits of protective clothing for preventing injury. The campaign uses television advertisements, posters at roadhouses and pubs, advertisements in motorcycle magazines, and is supported by a website that features links to Doohan speaking in more detail about the specific components of motorcycle attire that riders should purchase (gloves, helmet, jacket, pants and boots). Additionally, copies of ‘The Good Gear Guide’ (de Rome, 2009) have been distributed to South Australian motorcyclists. The campaign began in November, 2010. It follows MAC’s earlier favourably received “No Place to Race” campaign.

It is expected that increased wearing of protective clothing by motorcyclists would be beneficial for riders in both urban and rural areas. A literature review revealed that the majority of motorcycle crashes, whether single or multi-vehicle, involve ejection from the motorcycle. Studies looking at post-impact trajectories of riders have found a high likelihood of movements (e.g. sliding, tumbling, rolling) likely to cause injury and for which protective clothing may be useful. The high likelihood of sliding or tumbling on the road surface in a motorcycle crash applies to both urban and rural contexts and irrespective of crash type.

An analysis of CASR’s in-depth crash databases produced findings consistent with the literature review. In a sample of 30 rural crashes, 18 (60%) involved the motorcyclists sliding along the road, while in a total of 31 crashes in metropolitan Adelaide from two separate databases, there were 16 cases (52%) in which the rider slid along the road. Therefore, it appears that protective clothing for motorcyclists is likely to be important in urban crashes as well as in rural ones in South Australia.

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