Comparison of moped, scooter and motorcycle crashes: Implications for rider training and education

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ABSTRACT

Scooter and moped sales have increased at a faster rate than motorcycle sales over the last decade in countries such as Australia, Canada and the United States. This may be particularly evident in jurisdictions where moped riding is permitted for car license holders and a motorcycle license is not required, such as in Queensland, Australia. Having historically comprised only a small proportion of powered two-wheelers (PTWs) outside of Europe and Asia, the safety of scooters and mopeds has received relatively little focused research attention. However, the recent trends in sales and crash involvement have stimulated greater interest in these PTW types. The current paper examines differences and similarities between scooters (over 50cc), mopeds (up to 50cc) and motorcycles in crash involvement and crash characteristics through analyses of crash and registration data from Queensland, Australia.

The main findings include that moped and scooter riders are similar in terms of usage patterns, but the evidence suggests superior skills, greater experience and safer behaviour among scooter riders than moped riders. The requirement in Queensland for scooter riders but not moped riders to hold a motorcycle license, usually obtained through competency-based training and assessment, may help to explain some of this difference. Findings also suggest that scooter riders are safer than motorcycle riders in some respects, despite both being subject to the same licensing requirements which encourage participation in rider training. Safer attitudes and motivations rather than superior skills and knowledge may therefore underlie the differences between scooter and motorcycle riders. In summary, riders of larger scooters exhibit a combination of skills and behavior suggestive of safer riding than both their moped and motorcycle riding counterparts.

It is reasonable to expect that mopeds and scooters will remain popular and that their usage may increase further, along with that of motorcycles. This research therefore has important practical implications regarding pathways to improved PTW safety. Future policy and planning should consider options for encouraging moped riders to acquire better riding skills and greater safety awareness, as apparent among scooter riders, including rider training, education and licensing. As is noted in recent literature and reflected in some contemporary rider training programs, motorcycle safety may be improved by addressing rider attitudes more comprehensively in addition to developing skills and knowledge.

INTRODUCTION

Having historically comprised only a small proportion of powered two-wheelers (PTWs) outside of Europe and Asia, the safety of scooters (over 50cc) and mopeds (up to 50cc) has received relatively little focused research attention. However, upward trends in sales, registrations and crash involvement have stimulated greater interest in these PTW types. Scooter and moped sales have increased faster than motorcycle sales over the last decade in countries such as Australia, Canada and the United States (US). This may be particularly evident where moped riding is permitted for car license holders and a motorcycle license is not required, such as in Queensland, Australia, as well as some US jurisdictions.

Scooters and mopeds comprised 8.6% and 14.8% of total new on-road (registered) PTW sales (N=12,114) respectively in Queensland in the 12 months to September 2009 (FCAI, 2009). This reflects a general pattern in sales that had also been observed previously in Queensland (Haworth & Nielson, 2008), though not necessarily in other Australian jurisdictions. Regulatory differences influence the use of mopeds and scooters such that Queensland differs from some other Australian jurisdictions, including Victoria and New South Wales (Australia's two most populous States) where moped riders require a motorcycle license.

Coincident with increased sales and registrations, moped and motorcycle crashes increased in Queensland from 2001-2005, (Haworth & Nielson, 2008; Haworth, Nielson, & Greig, 2008) and from 2003-2008 (Blackman & Haworth, 2013a). Moped crashes and registrations can be readily identified as mopeds constitute a discrete registration category, but comparable data on larger (over 50cc) scooters are difficult to isolate as they are officially classified as motorcycles. This presents a considerable challenge for researchers seeking to compare mopeds, scooters and motorcycles with regard to both crash involvement and usage.

The current paper examines differences and similarities between scooters, mopeds and motorcycles in crash involvement and crash characteristics through analyses of crash and registration data from Queensland, Australia. A summary of background literature examining scooter, moped and motorcycle usage and safety is provided first, followed by description and discussion of the current research methods, findings and implications. The paper seeks specifically to emphasise differences between mopeds and their larger scooter counterparts, and the associated implications with regard to experience and rider training and education.

Scooter, moped and motorcycle use and safety

Many aspects of PTW use and safety have changed in the last three decades. Among the most important changes in high-income countries are increased usage, developments in PTW design and manufacture, and the changing demographic characteristics of riders. As with automobile use in general, in some places such as Australia and Great Britain, PTW use has become safer than in previous decades as there are fewer reported crashes relative to the number of registered vehicles and/or the average distance travelled (BITRE, 2012; Department for Transport, 2010). In the US, declining motorcyclist fatality rates have been reported in recent years for some jurisdictions, while others have seen little or no improvement (Hedlund, 2012, 2013). The absence of universal mandatory helmet use laws in many US jurisdictions is seen to contribute to the lack of progress relative to other countries.

Increasing traffic congestion appears to have driven increased PTW use by commuters in cities, particularly scooter and moped use, while there has also been an increase in recreational riding in many countries. As might be expected, there are numerous ways in which moped, scooter and motorcycle use differ that are likely to have some bearing on their relative safety. Motivations for riding have been shown to influence crash and injury risk, as well as the types of PTW used. For example, sensation-seeking and risky riding behaviours are more prevalent among riders of sport-oriented motorcycles, younger riders and recreational riders (Morris, 2009; Rutter & Quine, 1996; Teoh & Campbell, 2010). Previous research shows that mopeds and scooters are used more for commuting and less for recreation in comparison to motorcycles (ACEM, 2008b; Moskal, Martin, & Laumon, 2012; Sexton, Baughan, Elliott, & Maycock, 2004).

Scooter and moped rider age and gender distributions differ from those of motorcyclists, as do licensing requirements in many locations. Moped riders tend to be younger than motorcycle riders (ACEM, 2008b; Haworth et al., 2008; Jamson & Chorlton, 2009; Noordzij, Forke, Brendicke, & Chinn, 2001), while scooter riders have been found to be older in the limited research available (Blackman & Haworth, 2013a). In most high-income countries more than 90% of motorcycle riders are male, but females comprise more than one third of moped and scooter riders in many places (Blackman & Haworth, 2013a; Kennedy, 2007; Perez et al., 2009). Moped use is encouraged by permissive licensing regulations in some locations and thus contributes to these differences.

Moped and motorcycle crash rates vary substantially across jurisdictions, limiting the transferability of research to other locations. Some studies have reported higher crash rates for mopeds than motorcycles (Koornstra, Lynam, Nilsson et al., 2002; Noordzij, Forke et al. 2001; Yannis, Golias, & Papadimitriou, 2005), while the reverse has been found in other research (Aare & Holst, 2003; Koornstra, Lynam et al., 2002; Sexton, Baughan et al., 2004). Crash rates for scooters over 50cc are rarely reported as they are they are typically classified as motorcycles. An estimation and discussion of crash rates in the current study area (Blackman and Haworth, 2013a) showed aggregate rates per 10,000 registration-years of 133 crashes for mopeds and 125 crashes for motorcycles and scooters combined. Interestingly, these moped crash rates declined from 194 in 2003/04 to 116 in 2007/08 (a 40% reduction), while the motorcycle and scooter crash rate per 10,000 registration-years declined only moderately by comparison, from 138 to 108 (a 22% reduction). There are several possible explanations for the observed reductions over time, including safer riding, reductions in the amount of riding per registered vehicle, and reductions in the ratio of reported to unreported crashes. Unfortunately none of these possibilities can currently be confirmed or denied. Crash rates relative to exposure were also estimated, suggesting that mopeds crashed at nearly four times the rate of motorcycles and scooters per million vehicle kilometres (~621,000 miles) travelled (6.3 versus 1.7) (Blackman & Haworth, 2013a).

Changes in PTW design, performance and intended purpose have occurred which are likely to have influenced both usage patterns and safety outcomes. For example, scooters were reported to range from 50cc to 250cc in the late 1980s (Salatka, Arzemanian, Kraus, & Anderson, 1990), however scooter engine capacities up to at least 650cc are now available (Bowdler, 2010), thereby satisfying a wider range of applications. Other technological improvements to mopeds and scooters in recent decades include the advent of hydraulic disc brakes as standard and, more recently, anti-lock braking systems (ABS) to prevent loss of control crashes under heavy braking. Further, front and rear brakes are sometimes linked in combined braking systems (CBS), helping to address inappropriate brake application. However, neither ABS nor CBS currently feature on most moped or scooter models (ACEM, 2008a, 2010). Other technologies found increasingly on motorcycles with potential to eventually filter through to many scooters and mopeds include traction control and switchable engine modes for modifying power delivery in different riding conditions. Piaggio recently announced the first inclusion of traction control on one of its scooters, the 150cc Vespa 946, which also includes ABS (AMCN, 2013).

Motorcycle and moped crash and injury characteristics and risk factors are broadly similar, though not identical, according to the literature. The common rider-specific crash risks include speeding (over limit) and inappropriate speeds, rider impairment, unlicensed riding, holding a foreign license, non-use of helmets, male gender, rider age (younger or older), rider inexperience and riding for recreation (Blackman & Haworth, 2013b; Greig, Haworth, & Wishart, 2007; Haworth, Greig, & Nielson, 2009; Lardelli-Claret et al., 2005; Lin & Kraus, 2009; Moskal et al., 2012). The higher crash risk of recreational motorcycling is generally associated with weekend riding, larger capacity motorcycles, and higher speed zones. Recreational riding has been found to contribute to higher moped as well as motorcycle crash risk (Moskal et al., 2012), though the characteristics of recreational moped crashes differ from those involving motorcycles, as well from non-recreational moped crashes (Blackman & Haworth, 2013b). Due to differences in usage patterns, vehicle performance and rider-dependent factors, the common risk factors may be expected to present differently in comparative analysis of moped, scooter and motorcycle crashes. For example, unlike motorcycles, mopeds are unlikely to exceed speed limits in higher speed zones due to limited performance. This may result in differences regarding crash severity and injury outcomes, as well as in statistical crash risk.

Rider licensing and training

Rider licensing systems usually incorporate or encourage a combination of practical training, skills testing and education elements into licensing processes. Historically, moped riders in many jurisdictions have been exempt from some or all of the testing and training requirements which apply to riders of larger PTWs, including scooters (over 50 cc). Such exemptions continue to apply in many places, including Queensland, as stated above. The rationale for such exemptions relies on the comparatively low power and limited speed of mopeds, as well as a presumption that knowledge of basic road rules has been attained by at least partial progression through the graduated licensing process applied to car drivers. While it seems intuitive to expect that moped riders without a specific PTW license would be at greater risk of crashing than those who hold a PTW license, this has not been clearly demonstrated in the literature.

In Queensland, moped riding is permitted for car license holders (minimum age 17 years) without any training, education or testing specific to PTW riding. Riders of larger PTWs require a motorcycle license, which can only be obtained after holding a car license for 12 months or more in the previous five years. This measure seeks to provide initial experience in a more protective vehicular environment (a car) (Haworth & Rowden, 2010), but does not extend to moped riders. The motorcycle license is usually obtained through competency-based training and assessment (Q-Ride) offered by accredited providers, while a small minority of riders (<10%) bypass Q-Ride in favour of the State transport authority's test-only regime (Q-Safe) (Haworth, Rowden, et al., 2012). An 'automatic' ('A') condition is available for scooter riders, restricting them to PTWs with automatic transmission only. While the vast majority of new Queensland riders (excluding moped riders) have entered through the Q-Ride system since its introduction in 2001, many older riders, including those originally licensed outside of Queensland, will not have undertaken any rider training.

Regardless of licensing requirements, rider training and education has historically been seen as important for improving rider safety, and continues to be widely promoted by researchers and industry (ACEM, 2010; Bowdler, 2011; Buche, Williams, & Ochs, 2010; Haworth & Mulvihill, 2006; Hurt, Ouellet, & Thom, 1981). However, the effectiveness of particular programs remains unclear and some training programs have been associated with elevated crash risk (Haworth & Rowden, 2010; Haworth & Schulze, 1996; Savolainen & Mannering, 2007). The lack of positive training program evaluations may not reflect the failure of training *per se*, but the need for more effective program design and delivery (Rowden, Watson, & Haworth, 2007). Training program evaluations have also been typically compromised by methodological problems (Buche, Williams et al., 2010), which may help to explain the limited number of evaluations published to date. Where evaluations of individual programs have shown positive or negative effects, the relevance to other jurisdictions depends on a necessary but often lacking degree of similarity in regulatory, economic and cultural environments.

Until relatively recently, rider training has focused largely on vehicle control skills and traffic awareness, with little attention to attitudinal and behavioural issues. It is now recognised that such an approach may fail to recognise different training needs of riders of different PTW types. A review of PTW crash countermeasures potentially relevant for Queensland noted that moped and scooter riders may have specific training needs due to different performance and design characteristics compared with motorcycles (Haworth & Rowden, 2010). Moped and scooter rider training is available in some jurisdictions including Queensland, generally consisting of a modified (shorter) version of basic motorcycle rider training courses. However, such training is voluntary and discussions with providers suggest that uptake of these courses by new and existing moped riders is low (Haworth, Greig, & Wishart, 2008).

METHODS

This study involved analysis of PTW crash data for the period July 2003 to June 2008 provided by the Queensland Department of Transport and Main Roads (TMR). Mopeds, scooters and motorcycles were separated by the researchers to identify differences between the PTW types regarding the variables of interest, including crash characteristics and circumstances, and riders involved. The descriptive analysis is considered within the context of trends in PTW usage in the study area as indicated by vehicle registrations.

Data acquisition and cleaning

As PTW type (moped, scooter, motorcycle) is not captured reliably in the official crash database, a new database was created in which TMR crash and registration data were merged using registration number as the matching variable. This critical step allowed identification of PTW type via make and model details, with each case checked and coded accordingly. Examination of the original data indicated numerous crashes where the coding of vehicle body type was inconsistent with vehicle make and model details. Taking vehicle make and model details as generally accurate (where complete) these inconsistencies were rectified where possible through reference to a number of sources including industry magazines and Bikez.com online motorcycle catalogue (Bikez.com, 2010). Cases with insufficient information to reliably determine PTW type (n =1,251) were excluded, leaving a total of 7,347 valid cases for analysis. A more detailed description of the research methods including the data acquisition and cleaning process is available in Blackman and Haworth (2013a).

Data analysis

Descriptive analysis was performed incorporating Chi Square (χ^2) tests to identify statistically significant differences at an alpha level of .05. Unless otherwise stated, cases with missing values in variables of interest were excluded from analysis on those variables. Of primary interest were the characteristics and patterns observable in scooter, moped and motorcycle crashes. Differences between scooter crashes and those involving mopeds and motorcycles were examined and tested for significance where the number of crashes of each PTW type sufficed for valid statistical analysis. To provide sufficient power for statistical analysis, some categorical variables (age, speed zone, crash type) were collapsed where necessary due to low numbers in some cells. Analyses of contributing circumstances and fault attribution were conducted to identify the main factors in crash causation and the road user types (PTW rider or other road user) deemed most at fault. These analyses assist in the identification of areas which may be amenable to interventions for reducing crash risk.

RESULTS

Where the type of PTW could be reliably identified, 91.3% of crashes involved motorcycles, 7.4% involved mopeds and 1.3% involved scooters (N = 7,347) (Table 1). There was an increase each year in the total number of reported crashes, from 1,296 in 2003/04 to 1,584 in 2007/08. There was a statistically significant difference between the increase in moped, scooter and motorcycle crashes over time ($p < .001$), reflecting larger proportional increases in moped and scooter crashes than motorcycle crashes. Reported moped crashes increased twofold over the study period, with scooter crashes increasing at a similar rate, while motorcycle crashes increased only moderately by comparison. Due to moped crashes increasing at a faster rate than motorcycle crashes, they comprise an increasing proportion of all PTW crashes over the study period.

Table 1: Queensland PTW crashes by type and year, July 2003-June 2008

	PTW type			
Year *n* (%)	**Motorcycle**	**Moped**	**Scooter**	**Valid total**
03/04	1,210 (93.4)	74 (5.7)	12 (0.9)	1,296
04/05	1,328 (93.3)	85 (6.0)	10 (0.7)	1,423
05/06	1,382 (90.1)	130 (8.5)	21 (1.4)	1,533
06/07	1,384 (91.6)	106 (7.0)	21 (1.4)	1,511
07/08	1,407 (88.8)	146 (9.2)	31 (2.0)	1,584
Total 03/08	6,711 (91.3)	541 (7.4)	95 (1.3)	7,347

Rider characteristics

The median age was highest for scooter riders (39 years), lowest for moped riders (32 years) and intermediate for motorcycle riders (35 years) in crashes. The age distribution of crashed moped riders differed from that of both motorcycle and scooter riders, and the differences were statistically significant ($p < .001$). Moped crashes involved a higher proportion of riders under 25 years of age (31%) than either motorcycle crashes (23%) or scooter crashes (9%). Scooter crashes involved a relatively high proportion of older riders with 14% aged 60 years older, compared with 9% and 3% for moped and motorcycle riders respectively.

Approximately 92% of riders in motorcycle crashes were male, compared with 78% and 63% of scooter and moped riders respectively. This difference was statistically significant ($p < .001$). For moped crashes only, female riders were more likely to be aged under 30 (54%) compared to male riders (42%). Females were also less likely to be aged 60 years or over (3.5%) compared to male moped riders (12%). The difference in age distribution by gender for moped crashes was statistically significant ($p = .015$) when cases with age unknown and gender unknown were excluded. There was no significant difference in age by gender for motorcycle crashes, while scooter crash numbers were too low to allow a valid statistical analysis of age distribution by gender.

The license characteristics of crash-involved riders suggest that moped riders are less experienced than scooter and motorcycle riders. While scooter riders were excluded from significance testing due to low numbers, the difference between moped and motorcycle riders in license status was statistically significant after excluding cases where license status was ‘not known’ or ‘not applicable’ (p < .001). While 82% and 81% of scooter and motorcycle riders respectively held a full open class license, such was held by only 65% of moped riders. It must also be noted that in the case of moped riders this refers to either a car or motorcycle license, where for other PTW riders it indicates possession of an open motorcycle license.

Temporal characteristics

Characteristics of crashes by PTW type are presented in Table 2. Moped and scooter crashes were significantly more likely than motorcycle crashes to occur on weekdays (79-81% compared with 69%) (p <.001). More than three quarters of all crashes occurred during daylight hours (6am – 6pm), with the highest frequency in the 3pm – 6pm period. Analysis of weekend crashes only found a statistically significant difference between mopeds, scooters and motorcycles in daytime and night-time crash involvement (p = .04). Moped crashes were more likely to occur at night on weekends (29%) than on weekdays (21%). The reverse was true of scooter crashes, with a smaller proportion of weekend crashes occurring at night (11%) compared with weekday crashes (18%). For motorcycles, similar proportions of crashes occurred at night-time on weekdays (23%) and weekends (20%). On weekends, moped crashes peaked between 12pm and 3pm, while motorcycle crashes were evenly distributed from 9am to 6pm. Weekend scooter crashes mainly occurred from 12pm to 6pm.

Table 2: Characteristics of scooter, moped and motorcycle crashes, July 03 - June 08

		PTW type		
Characteristic *n* (%)	**Moped** *N*=541	**Scooter** *N*=95	**Motorcycle** *N*=6711	***p* value**
Single vehicle	157 (29.0)	20 (21.1)	2301 (34.3)	.001
Weekday	428 (79.1)	77 (81.1)	4659 (69.4)	<.001
Speed zone (mph)				<.001
0-60 km/h (37)	485 (89.6)	84 (88.4)	4666 (69.6)	
70-90 km/h (43-56)	42 (7.8)	9 (9.5)	1109 (16.5)	
100> km/h (62)	14 (2.6)	2 (2.1)	936 (13.9)	
Intersection	289 (53.4)	50 (52.6)	3088 (46.0)	.002
Wet road (sealed only)	68 (12.7)	6 (6.3)	557 (8.4)	.003
Rider at fault	292 (54.0)	43 (45.3)	3940 (58.7)	.004
Crash configuration				.001
Angle	220 (40.7)	42 (44.2)	2330 (34.7)	
Fall from vehicle	98 (18.1)	17 (17.9)	1570 (23.4)	
Hit object	70 (12.9)	6 (6.3)	1016 (15.1)	
Rear end	74 (13.7)	12 (12.6)	815 (12.2)	
Sideswipe	49 (9.1)	13 (13.7)	503 (7.5)	
Head-on	4 (0.7)	2 (2.1)	148 (2.2)	
Other*	26 (4.8)	3 (3.2)	329 (4.9)	
Controller gender male	344 (63.1)	75 (78.1)	6284 (92.3)	<.001
Controller median age	31.7	38.8	34.6	<.001

*Includes 'hit animal', 'hit parked vehicle', 'hit pedestrian', 'overturned' and 'other'

Roadway characteristics
Moped and scooter crashes were significantly more likely than motorcycle crashes to occur in speed zones of 60 km/h (37 mph) or less ($p < .001$). A large majority of moped and scooter crashes (90% and 88% respectively) occurred in speed zones up to 60 km/h (37 mph), compared with 70% for motorcycle crashes. Motorcycle crashes occurred in speed zones of 70 km/h (49 mph) or more in 30% of cases, compared with 10% and 12% for moped and scooter crashes respectively.

Mopeds and scooters were similar in the proportion of crashes occurring at intersections. Just over half (53%) of all moped and scooter crashes occurred at intersections, compared with 46% for motorcycle crashes, a difference which was statistically significant ($p = .002$). All three PTW types differed significantly with regard to roadway horizontal alignment ($p < .001$). While most crashes occurred on straight road sections for all PTW types (72%), this was more common for mopeds (83%) and scooters (86%) than for motorcycles (71%). Moped crashes were significantly more likely than motorcycle crashes to occur on wet roads ($p = .003$), while scooter crashes were slightly less likely.

Number of vehicles involved
Crashes were coded according to the number of units involved, where a 'unit' is defined as any road user or vehicle involved in the actual collision. This includes pedestrians and unoccupied (usually parked) vehicles as well as occupied vehicles, whereby a collision with such a unit was coded as a multiple-unit crash. Road users who may have contributed to a crash but were not involved in actual collision are excluded.

Scooters were the most likely to be involved in a multi-unit crash (79%), followed by mopeds (71%), with motorcycles least likely to be involved in a multi-unit crash (66%). The differences were statistically significant when all three PTW types were analysed together ($p = .001$), and also when scooters were excluded to compare only mopeds with motorcycles ($p = .013$). The average number of units involved in multi-unit crashes was 2.06 for mopeds, 2.05 for scooters and 2.08 for motorcycles.

Police attribution of contributing circumstances and fault
As summarised in Table 2, PTWs overall were designated Unit 1 (most at fault) in 58% of cases and there was a statistically significant difference between PTW types ($p = .004$). In single and multi-unit crashes combined, scooters were least likely to be designated Unit 1 (45%), compared with mopeds (54%) and motorcycles (59%). Scooters were designated Unit 1 in 31% of multi-unit crashes, compared with 35% for mopeds and 37% for motorcycles, but the difference was not statistically significant.

Table 3 presents the distribution of contributing circumstances attributed to a PTW in all crashes. This table does not indicate that a PTW was necessarily most at fault (Unit 1) and as such is purely the distribution of contributing circumstances attributed to the three PTW types. The most frequent group of circumstances for mopeds and motorcycles was 'Inattention/distracted/negligent', which was second only to 'other' circumstances in the case of scooters. The 'other' variable contains the commonly cited violation 'undue care and attention' and was cited in 16%, 17% and 18% of all moped, scooter and motorcycle crashes respectively. It was frequently cited for at-fault PTWs in single and multi-unit crashes alike.

In both single and multi-unit crashes, speed-related circumstances were more likely to be attributed to motorcycle riders (7%) than to moped (2%) or scooter (0%) riders.

Overall, 'road condition' contributed to more motorcycle crashes (14.5%) than moped (10.0%) or scooter (4.2%) crashes. In single vehicle crashes, this was deemed a contributing circumstance in about one third of moped and motorcycle crashes alike, but was clearly less likely to be reported in scooter crashes.

Alcohol appears to have contributed to a small minority (<5%) of all crashes where a PTW rider was at fault and was least observed in scooter crashes. In single vehicle crashes, alcohol was more frequently attributed to a PTW rider in moped crashes (11%) and motorcycle crashes (9%).

Scooter crashes attracted a relatively high proportion of 'other' circumstances due to the inclusion in this group of 'age; lack of perception, power or concentration'. This contributing circumstance is typically attributed to older road users, who comprised a higher proportion of scooter riders than moped or motorcycle riders (Table 2). 'Inexperience' is more frequently cited in moped crashes (9%) than in motorcycle (5%) or scooter (4%) crashes due to a relatively high involvement of young riders. In terms of factors which actually contributed to a crash, the criteria for attribution of age-related circumstances other than age itself are ambiguous and hence should be viewed with caution.

Crash type and configuration

Crash type (Table 3) differed significantly between PTW types ($p < .001$) after excluding the two least frequently cited crash types due to low numbers (no scooters were involved in 'overtaking' or 'left or right turn' crashes). For all PTWs, the most common crash group descriptions were 'same direction' crashes, followed by 'adjacent approach' crashes ('same direction' crashes exclude 'overtaking crashes, which are coded separately). Mopeds were more likely than motorcycles to be involved in 'adjacent approach' (intersection), 'off path on straight' and 'manoeuvring' crashes. Motorcycles were more likely than either mopeds or scooters to be involved in 'off path on curve' crashes. Scooters were more likely than either mopeds or motorcycles to be involved in 'same direction' crashes and, generally, did not appear consistently similar to either of the other PTW types across the range of crash group descriptions listed.

There was a statistically significant difference in crash configuration by PTW type ($p = .001$), as presented in Table 2. 'Angle' crashes comprised a large minority of cases for all PTW types, but were most likely for scooters (44%), followed by mopeds (41%), with motorcycles least likely (35%). By contrast, 'fall from vehicle' crashes were more prevalent for motorcycles (23%) than both mopeds and scooters (18%). Scooters were less likely than either mopeds or motorcycles to be involved in 'hit object' crashes, and more likely than either mopeds or motorcycles to be involved in 'sideswipe' crashes. The differences in crash configuration are likely a consequence of the difference in number of units involved shown earlier. 'Fall from vehicle' and 'hit object' constitute 99% of single vehicle crash configurations, consistent with the higher proportion of motorcycle crashes with these configurations. 'Angle' crashes accounted for 53% of multi-unit configurations, explaining the relatively high involvement of mopeds and scooters compared to motorcycles in that type of crash.

Table 3: Crash type and contributing circumstances attributed to a PTW

		PTW type	
	Moped	**Scooter**	**Motorcycle**
Crash type *n* (%)	*N*=541	*N*=95	*N*=6711
Same direction	126 (23.3)	31 (32.6)	1562 (23.3)
Adjacent approach	103 (19.0)	17 (17.9)	947 (14.1)
Off path on straight	88 (16.3)	10 (10.5)	836 (12.5)
Opposite approach	75 (13.9)	15 (15.8)	1058 (15.8)
Manoeuvring	56 (10.4	9 (9.5)	386 (5.8)
Off path on curve	38 (7.0)	6 (6.3)	1032 (15.8)
On path	24 (4.4)	1 (1.1)	332 (4.9)
Passenger & misc.	15 (2.8)	4 (4.2)	308 (4.6)
Pedestrians	8 (1.5)	2 (2.1)	57 (0.8)
Overtaking	6 (1.1)	-	166 (2.5)
Left or right turn	2 (0.4)	-	27 (0.4)
Contributing circumstance *n* (%)			
Speed-related	11 (2.0)	-	478 (7.1)
Drink driver	23 (4.3)	2 (2.1)	293 (4.4)
Violation	75 (13.9)	11 (11.6)	611 (9.1)
Inattention/distracted/negligent	85 (15.7)	16 (16.8)	1,209 (18.0)
Dangerous driving	10 (1.8)	1 (1.1)	180 (2.7)
Fatigue-related	2 (0.4)	-	124 (1.8)
Inexperience	51 (9.4)	4 (4.2)	348 (5.2)
Road condition	54 (10.0)	4 (4.2)	970 (14.5)
Vehicle defects	3 (0.6)	1 (1.1)	103 (1.5)
Other	79 (14.6)	19 (20.0)	1,031 (15.4)

DISCUSSION

Ongoing increases in the number of reported PTW crashes, more specifically those involving mopeds and scooters, justifies research which separates these PTW types from their motorcycle counterparts and from each other. Viewed in light of the sales data presented at the beginning of this paper, scooter involvement in 1.3% of reported crashes suggests that they may be underrepresented relative to mopeds and motorcycles in Queensland. Reliable exposure data for the study area are required to confirm if this is actually the case, but such data are notoriously difficult to obtain.

There are numerous apparent differences among the PTW types regarding crash type, crash configuration, fault attribution and contributing circumstances that further suggest safer riding by scooter riders than moped or motorcycle riders. In particular, scooters were less likely to be involved in a single-vehicle crash and to be most at fault. Speed was not a factor in any reported scooter crashes, but was reported in 2% and 7% of moped and motorcycle crashes respectively. Alcohol involvement was also less prevalent in scooter crashes, though is not prominent in Queensland PTW crashes generally. Moped riders appear to be relatively inexperienced as indicated by their license characteristics and, more tentatively, by the attribution of 'inexperience'[1] as a contributing crash circumstance.

Considering briefly the topic of vehicle control skills, research suggests that many PTW crashes are attributable in part to poor braking performance and application (ACEM, 2008b, 2010). Half of all crashes in MAIDS data involved a PTW braking in collision avoidance manoeuvres, where loss of control was mainly related to braking (ACEM, 2008b). Given the relatively high involvement of mopeds in crashes on wet roads, in poor road conditions and, compared to scooters, in single vehicle crashes, this may be an area in which moped rider safety can be improved. Technological advancements such as ABS, CBS and traction control may assist in this area. Loss of control in some situations may also be addressed by increasing knowledge through education, which can be delivered independent of practical skills training. For example, do untrained riders know how to apply brakes effectively in different situations, or that painted road markings can be hazardous, particularly when recently applied and/or wet?

A crucial implication of the current research is that scooter riders may provide a potential safety benchmark that should conceivably be achievable for their moped riding counterparts. This is not to suggest that the safety of all PTW riders cannot or should not also be improved, but that the safety of moped riders may be of high priority given the increased moped usage observed. As moped and scooter usage patterns are demonstrably similar, suggesting similar motivations for riding, experience emerges as a likely key difference between moped and scooter riders regarding crash involvement. Previous exploratory research by the authors lends support to this argument, having revealed greater knowledge of and concern about safety issues and vehicle performance among scooter riders than moped riders in focus group discussions (Blackman & Haworth, 2010). Although the sample in this study may not have been representative, scooter riders were also relatively more experienced and tended to value both experience and rider training highly.

As noted earlier, despite the limited evidence supporting moped rider training and rider training generally, belief in its potential to improve rider safety is widely held among researchers, government, (trained) riders and the PTW industry (ACEM, 2010; Bowdler, 2011; Schoon, 2004; Buche et al., 2010). In regard to the current research, some moped riders appear deficient in areas that could potentially be addressed by rider training, such as vehicle control skills and hazard perception and responding. However, given that scooter and

[1] At the time of data collection 'inexperience' was often attributed on the basis of age rather than any objective determination of inexperience contributing directly to crash causation.

motorcycle riders are trained and licensed under the same system in the study area, it appears that the relative safety of scooter riders may be attributable to factors other than or additional to training and licensing. As noted previously, psychological and social factors associated with rider motivations may underlie some of the differences observed in the safety of moped, scooter and motorcycle riders (Watson, Tunnicliff et al., 2007).

Lack of experience is mostly addressed formally through a range of rider licensing, training and education programs for which, as noted previously, there is a lack of rigorous evaluations. Programs generally target new riders regardless of age, tending to capture not only young riders but also older ones who comprise a large proportion of those seeking a license (Haworth & Rowden, 2010). For riders who already hold a license for PTW riding, including moped riders requiring only a car license, such programs are undertaken voluntarily and participation is generally low. Participation depends on a range of factors, though it seems that inexperience is often not the key motivator for self selection (Haworth, Mulvihill, & Rowden, 2006). Some research has shown a preference among PTW riders for informal learning processes, supported by a belief that skills and knowledge (and by extension, safety) are accumulated though experience over time (Blackman & Haworth, 2010; Natalier, 2001). The extent to which rider training and education programs can compensate for a lack of experience is largely unknown, but some authors have expressed the view that single isolated courses of short duration fail to produce lasting effects (Buche et al., 2010; Goldenbeld, Twisk, & de Craen, 2004; Haworth & Rowden, 2010). The accumulation of on-road experience in conjunction with repeated or progressive exposure to training and education certainly seems to offer potential, but encouraging participation in voluntary programs remains a major challenge.

Research has shown that different groups of riders can be identified by their common motivations, attitudes and approaches to riding, which in turn can reflect differing levels of risk associated with their riding behaviour (Broughton & Walker, 2009; Christmas, Young, Cookson, & Cuerden, 2009; Jamson & Chorlton, 2009). If it is the case that most moped and scooter riders are similarly motivated, as proposed here and in the literature, then it seems logical to suggest that the focus should be primarily on developing moped rider skills. This is not to dismiss the potential benefits of also addressing attitude and behaviour, but acknowledges a lower propensity for risk taking among moped and scooter riders than is seen among some motorcycle riders. Thus there are arguably two major challenges for addressing moped rider safety in the study area. The first is to increase participation in rider training and/or education for those with deficient vehicle control skills, either through voluntary or mandatory programs, while the second is to ensure that programs are designed and delivered appropriately to address the specific needs of moped riders.

Limitations

Although other road users contribute to a large proportion of multi-vehicle PTW crashes, this paper does not examine the specific contributing factors attributable to other road users. Additionally, examination of crash severity by PTW type is not provided here, but a detailed analysis of these issues is available in Blackman and Haworth (2013a). Findings of the current research may not be transferrable to other jurisdictions where licensing regulations, socio-economic and environmental conditions differ considerably from the study area. As inexperience was sometimes reported on the basis of rider age alone, the actual contribution of inexperience is difficult to determine, particularly in the case of motorcycle crashes as the age of new motorcycle riders is known to be relatively high. With only a small proportion of the reported crashes involving scooters, the power available for comparative statistical analysis was limited on some variables. Finally, as this research has necessarily considered police-reported crashes only, the results may not be representative of unreported crashes, which are generally less serious yet considered to be numerically substantial.

CONCLUSION

Comparison of moped, scooter and motorcycle crashes in Queensland, Australia, suggests important differences regarding usage patterns and crash and rider characteristics which likely influence their relative safety. It is tentatively concluded that scooter riders are safer than their moped and motorcycle riding counterparts, due to a combination of experience and skills coupled with a lower propensity for risk-taking. Options for encouraging moped riders to improve their skills and knowledge should be considered in policy and planning. As noted in other research, motorcycle safety may be improved by addressing rider attitudes more comprehensively in addition to developing skills and knowledge.

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