Motorcycle rider conspicuity and crash related injury: case-control study

Susan Wells, Bernadette Mullin, Robyn Norton, John Langley, Jennie Connor, Roy Lay-Yee and Rod Jackson

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Motorcycle rider conspicuity and crash related injury: case-control study

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Abstract

Objective To investigate whether the risk of motorcycle crash related injuries is associated with the conspicuity of the driver or vehicle.
Design Population based case-control study.
Setting Auckland region of New Zealand from February 1993 to February 1996.
Participants 463 motorcycle drivers (cases) involved in crashes leading to hospital treatment or death; 1233 motorcycle drivers (controls) recruited from randomly selected roadside survey sites.
Main outcome measures Estimates of relative risk of motorcycle crash related injury and population attributable risk associated with conspicuity measures, including the use of reflective or fluorescent clothing, headlight operation, and colour of helmet, clothing, and motorcycle.
Results Crash related injuries occurred mainly in urban zones with 50 km/h speed limit (66%), during the day (63%), and in fine weather (72%). After adjustment for potential confounders, drivers wearing any reflective or fluorescent clothing had a 37% lower risk (multivariate odds ratio 0.63, 95% confidence interval 0.42 to 0.94) than other drivers. Compared with wearing a black helmet, use of a white helmet was associated with a 24% lower risk (multivariate odds ratio 0.76, 0.57 to 0.99). Self reported light coloured helmet versus dark coloured helmet was associated with a 19% lower risk. Three quarters of motorcycle riders had their headlight turned on during the day, and this was associated with a 27% lower risk (multivariate odds ratio 0.73, 0.53 to 1.00). No association occurred between risk and the frontal colour of drivers' clothing or motorcycle. If these odds ratios are unconfounded, the population attributable risks are 33% for wearing no reflective or fluorescent clothing, 18% for a non-white helmet, 11% for a dark coloured helmet, and 7% for no daytime headlight operation.
Conclusions Low conspicuity may increase the risk of motorcycle crash related injury. Increasing the use of reflective or fluorescent clothing, white or light coloured helmets, and daytime headlights are simple, cheap interventions that could considerably reduce motorcycle crash related injury and death.

Introduction

Every day about 3000 people die and 30 000 people are seriously injured on the world's roads.[1] A disproportionate burden is borne by low to middle income countries and vulnerable road users such as pedestrians, cyclists, and riders of motorcycles and scooters.[2] By 2020, road traffic crashes are projected to be the third leading cause of death and disability worldwide.[3] Low motorcycle conspicuity, or the inability of the motorcyclist to be seen by other road users, is thought to be an important factor associated with risk of motorcycle crashes.[4] This may result from several factors, including size of motorcycle, irregular outline, low luminance or contrast with the background environment, and the ability to travel in unexpected places in the traffic stream. Inexpensive measures can potentially enhance conspicuity—for example, adding a light source and the use of light, bright, reflective, or fluorescent colours.

Much of the epidemiological literature on motorcycle conspicuity comprises historical cohort analyses investigating daytime use of headlights and motorcycle crash rates before and after legislation or ecological studies investigating regions with or without "lights on" laws.[5–12] We investigated the association between a range of conspicuity measures and the risk of motorcycle crash related injury in a country without mandatory daytime headlight laws.

Methods

Study population and setting—We conducted a population based case-control study in Auckland, New Zealand, between February 1993 and February 1996.[13 14] The source population was all motorcycle drivers riding on motorways and principal or arterial roads between 6 am and midnight in the Auckland region.

Case selection—We included in the study all motorcycle drivers or pillion passengers who were killed, admitted to hospital, or treated in a public hospital emergency department in the Auckland region, and who had an injury severity score of >5 within 24 hours of a motorcycle crash. We conducted

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Section of Epidemiology and Biostatistics, School of Population Health, Private Bag 92019, University of Auckland, Grafton Road, Auckland 1, New Zealand
Susan Wells *senior lecturer in epidemiology*
Bernadette Mullin *public health physician*
Jennie Connor *senior lecturer in epidemiology*
Rod Jackson *professor of epidemiology*

Centre for Health Services Research and Policy, School of Population Health, University of Auckland
Roy Lay-Yee *assistant research fellow*

Institute for International Health, University of Sydney, Sydney, NSW, Australia
Robyn Norton *professor of public health*

University of Otago, Otago, New Zealand
John Langley *director of injury prevention research unit*

Correspondence to: S Wells s.wells@auckland.ac.nz

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interviews face to face in hospital or by telephone if the participant had already been sent home. For people who died as a result of the crash, we asked next of kin to nominate a proxy respondent who could be interviewed.

Control selection—We obtained a random sample of motorcycle riding by identifying motorcycle drivers from 150 roadside survey sites in the study region and time period (see bmj.com for details). We administered identical questionnaires to both cases and controls, covering circumstances of the crash or current trip and sociodemographic, personal, motorcycle related, and environmental characteristics.

Conspicuity measures—We asked participants if their headlight had been off or on and, if on, whether it had been set to high or low beam. We divided the self identified main colour of clothing worn into two categories: frontal colour from waist up and frontal colour from waist down. We defined motorcycle colour as the main colour of the motorcycle from the front. As well as describing the main colour of their clothing, motorcycle, and helmet, participants nominated the colour as either light or dark. We asked participants if they were wearing any reflective or fluorescent clothing or other articles such as a jacket, vest, apron, sash, ankle or wrist band, or back pack including stripes, decals, or strips.

Potential confounding variables—We considered the following potential confounders: age, sex, ethnicity, income, education, motorcycle licence and insurance status, self reported alcohol consumption in the previous 12 hours, years on-road riding experience, kilometres travelled on the specific motorcycle at interview, posted speed limit, ambient illumination, and weather conditions. All data were self reported except for road type and traffic speed zones, which were ascertained by environmental surveys. New Zealand has three main speed limit zones: 50 km/h in most urban areas, 70-80 km/h in restricted speed zones principally on main highways, and 100 km/h on motorways and the open road.

Statistical analysis—We calculated odds ratios together with 95% confidence intervals by using unconditional logistic regression (see bmj.com for details of modelling strategy). As this was a population based study and the outcome of interest is rare, the odds ratios calculated will approximate to relative risks. We calculated population attributable risk estimates. We considered pillion passengers to be part of the driver-motorcycle unit and did not include them in the analyses.

Results

The cases were 490 motorcycle drivers (including 32 deaths), and interviews were completed for 463 (95%). The controls were 1518 motorcycle drivers. Interviews were completed with 1233 (81%) control drivers. Men accounted for 94% of the motorcycle riding population in Auckland during the study period; most crashes occurred in urban 50 km/h speed limit zones (66%), during the day (64%), and in fine weather (72%) (table 1).

Table 1 Sociodemographic, personal, and environmental characteristics of motorcycle crash related injury cases and population controls. Values are numbers (percentages)

	Controls (n=1233)	Cases (n=463)
Age (years)		
15-19	131 (10.6)	86 (18.6)
20-24	322 (26.1)	148 (32.0)
≥25	780 (63.3)	229 (49.5)
Sex		
Female	71 (5.8)	26 (5.6)
Male	1162 (94.2)	437 (94.4)
Type of motorcycle licence		
Learner	198 (16.1)	90 (19.4)
Restricted	97 (7.9)	34 (7.3)
Full	780 (63.3)	224 (48.4)
No licence, lapsed, or lost	125 (10.1)	100 (21.6)
Missing	1 (0.1)	6 (1.3)
Familiarity with specific motorcycle (km)		
<1000	166 (13.5)	99 (21.4)
1000-10 000	477 (38.7)	179 (38.7)
>10 000	570 (46.2)	166 (35.9)
Missing	19 (1.5)	20 (4.3)
Any alcohol ingested in the previous 12 hours		
Yes	129 (10.5)	92 (19.9)
No	1084 (87.9)	365 (78.8)
Missing	20 (1.6)	4 (0.9)
Posted speed limit (km/h)		
50	693 (56.2)	307 (66.3)
70-80	93 (7.5)	40 (8.6)
100	447 (36.3)	111 (24.0)
Missing	0	5 (1.1)
Light conditions		
Daylight	954 (77.4)	294 (63.5)
Dusk or dawn	104 (8.4)	49 (10.6)
Night	175 (14.2)	119 (25.7)
Missing	0	1 (0.2)
Weather conditions		
Fine	804 (65.2)	333 (71.9)
Cloudy	370 (30.0)	76 (16.4)
Rain	59 (4.8)	49 (10.6)
Missing	0	5 (1.1)

Use of reflective or fluorescent clothing

Nearly 20% of control drivers were wearing some type of reflective or fluorescent clothing. Drivers wearing reflective or fluorescent clothing had a 37% lower risk of crash related injury than those who were not wearing such materials (table 2). When stratified by ambient illumination (day, twilight, night), the protective association seemed to increase with falling light levels, although numbers were small at twilight, reducing the precision of the effect estimate (see bmj.com).

Helmet colour

The main colours of helmet reported by control drivers were black (39.8%), white (30.6%), and red (13.8%). Compared with wearing a black helmet, use of a white helmet was associated with a 24% lower risk (table 2). We found similar associations for red and a combined group of yellow and orange helmets, although these did not achieve standard levels of statistical significance. Self nominated description of "light coloured" helmet compared with "dark coloured" helmet was associated with a 19% lower risk.

Headlight operation

Three quarters of motorcycle riders had their headlight turned on during the day. Overall, voluntary use of headlight in daytime was associated with a 27% lower risk of crash related injury (table 2).

Frontal colour of clothing and motorcycle

Approximately 80% of 1233 control drivers wore either black, blue, or brown clothing on the upper body (955) and black or blue clothing on the lower body (988). Of the main frontal motorcycle colours, 299 (24%) motorcycles were black, 282 were (23%) red, 188 (15%) were white, 183 (15%) were chrome or silver, and 148 (12%) were blue. We observed no association between risk of crash related injury and the frontal colour of drivers' clothing or motorcycle. Similarly, no difference in risk occurred for self nominated light versus dark coloured clothing or motorcycle.

Population attributable risk

The population attributable risk is the estimated proportion by which the incidence of crash related injuries could potentially be averted if a specific risk factor was eliminated from the population. In this population, assuming that the associations described are causal and unconfounded, the population attributable risk associated with not wearing fluorescent or reflective clothing was approximately 33%. Other population attributable risks were 18% for wearing a non-white helmet, 11% for wearing a dark coloured helmet, and 7% for not using headlights during the day.

Discussion

Strengths and weaknesses of the study

We were able to identify all motorcyclists involved in a crash resulting in moderate to severe injury or death from a large geographically defined base population. The controls were a random sample of motorcyclists from the same study population over the same study period. In this study the prevalence of each characteristic in controls is an estimate of its prevalence in all motorcyclists in the study region.

Most variables investigated were self reported, and recall bias may be a problem. However, exposures such as colour of helmet, colour of clothing, use of high visibility clothing, and operation of headlight are less likely to be influenced by recall bias than other behaviours such as alcohol consumption or speeding. Furthermore, cases may be more inclined than controls to over-report having used conspicuity enhancing measures as they analyse and apportion fault in a multi-vehicle crash. The net effect would be an underestimate of the effects.

The validity of our findings depends on the ability to control for confounding. In this study a wide range of potential confounders were measured and modelled

Table 2 Adjusted odds ratios of risk of crash related injury associated with potential conspicuity enhancing measures. Values are numbers (percentages) unless stated otherwise

			Odds ratio (95% confidence interval)	
Measures	**Controls (n=1233)**	**Cases (n=463)**	**Age adjusted**	**Multivariate model**
Wearing high visibility clothing				
No	985 (79.9)	408 (88.1)	1.00	1.00
Yes	242 (19.6)	49 (10.6)	0.50 (0.36 to 0.70)	0.63 (0.42 to 0.94)
Missing	6 (0.5)	6 (1.3)		
Colour of helmet				
Black	491 (39.8)	213 (46.0)	1.00	1.00
White	377 (30.6)	112 (24.2)	0.69 (0.53 to 0.91)	0.76 (0.57 to 0.99)
Yellow or orange	31 (2.5)	8 (1.7)	0.65 (0.29 to 1.43)	0.79 (0.35 to 1.82)
Red	170 (13.8)	55 (11.9)	0.71 (0.50 to 1.01)	0.80 (0.56 to 1.14)
Blue	70 (5.7)	26 (5.6)	0.90 (0.56 to 1.45)	0.96 (0.58 to 1.59)
Other colours (12)	69 (5.6)	41 (8.9)		
Missing	0	8 (1.7)		
Self nominated light or dark coloured helmet				
Dark	610 (49.5)	259 (55.9)	1.00	1.00
Light	616 (50.0)	192 (41.5)	0.74 (0.59 to 0.92)	0.81 (0.64 to 1.01)
Missing	7 (0.6)	12 (2.6)		
Headlight operation				
Off	216 (17.5)	76 (16.4)	1.00	1.00
On	985 (79.9)	365 (78.8)	0.99 (0.74 to 1.32)	0.74 (0.51 to 1.07)
Missing	22 (1.8)	7 (1.5)		
Daytime headlight operation	(n=954)	(n=294)		
Off	207 (21.7)	72 (24.5)	1.00	1.00
On	719 (75.4)	205 (69.7)	0.77 (0.56 to 1.05)	0.73 (0.53 to 1.00)
Missing	28 (2.9)	17 (5.8)		
Self nominated light or dark coloured clothing (waist up)				
Dark	938 (76.1)	365 (78.8)	1.00	1.00
Light	268 (21.7)	92 (19.9)	0.89 (0.68 to 1.16)	0.97 (0.70 to 1.34)
Missing	27 (2.2)	6 (1.3)		
Self nominated light or dark coloured clothing (waist down)				
Dark	820 (66.5)	302 (65.2)	1.00	
Light	379 (30.7)	149 (32.2)	1.08 (0.85 to 1.36)	1.21 (0.91 to 1.59)
Neither or missing	34 (2.8)	12 (2.6)		
Self nominated light or dark coloured motorcycle				
Dark	609 (49.4)	233 (50.3)	1.00	
Light	599 (48.6)	218 (47.1)	0.94 (0.76 to 1.17)	1.00 (0.77 to 1.29)
Missing	25 (2)	12 (2.6)		

What is already known on this topic

Low conspicuity, or the inability of the motorcycle and rider to be seen by other road users, is thought to be associated with motorcycle crash related injury and death

Previous studies suggest a benefit from daytime use of motorcycle headlights, although the evidence is limited

What this study adds

Wearing reflective or fluorescent clothing and white or light coloured helmets and using headlights in daytime could reduce serious injuries or death from motorcycle crashes by up to one third

in the multivariate analyses. Riders wearing high visibility clothing and white helmets are likely to be more safety conscious than other riders. However, we were able to adjust for sociodemographic variables, the propensity for risk taking behaviour, and environmental characteristics.

Bright colours worn during the day, daytime use of headlight, and reflective or fluorescent clothing are thought to enhance conspicuity by increasing the brightness contrast between the surface or object it is on and the background environment. The finding that helmet colour was associated with injury crash risk whereas frontal colour of clothing was not was unexpected. A possible explanation for our findings is that 80% of the controls wore black, blue, or brown top clothing and black or blue clothing from the waist down. Accordingly our study may not have had the power to detect an effect of brightly coloured clothing if it existed. Our study was also limited by the one "catch-all" category for reflective and or fluorescent clothing. These materials offer maximum conspicuity advantage in differing ambient light conditions—fluorescence at twilight and reflective material at night. We were unable to determine the individual contributions of these materials.

Implications for prevention of injuries

This study took place in a predominantly urban area and in a country where motorcycles make up a small percentage of all registered motor vehicles. Factors contributing to poor conspicuity, such as contrast from the background environment and ambient illumination, may differ between settings. The population attributable risks are not generalisable as they depend on the background prevalence of the risk factors in specific populations. However, there is no reason to believe that the relative risk estimates for the conspicuity measures investigated would not be generalisable to other settings.

This seems to be the first population based aetiological study investigating motorcycle conspicuity and risk of crash related injury and death. The study suggests that low physical conspicuity is a contributing factor in a significant proportion of road traffic crashes causing injury. The social costs of motorcycling deaths and disability are high, not only through premature deaths and hospital admissions but also through costs of rehabilitation, lost income, sickness benefits, insurance, property, and legal expenses as well as personal costs of grief and suffering. This study supports the introduction of both active and passive injury prevention strategies through laws requiring daytime use of headlights and measures encouraging greater visibility of motorcycle riders on the roads.

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Competing interests: None declared.

Ethical approval: The study was approved by the Northern Regional Health Authority Ethics Committee.

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Endpiece

Knowledge and comfort

He who is seeking knowledge should give up comfort,
He who is seeking comfort should give up learning knowledge,
As the knowledge seeker can not get comfort and a comfort seeker can not learn knowledge

Quotable quotes in Sanskrit language from Indian culture. Shloka 6. www.geocities.com/dipalsarvesh/indexLanguage.html

Samiran Nundy,
Department of Surgical Gastroenterology,
Sir Ganga Ram Hospital, New Delhi