What factors are associated with cyclists getting injured? Correlates of cyclist injuries in Queensland

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Abstract

Pedal cyclists are over-represented in traffic crash injuries in Australia. This study examined correlates of cycling injuries in a sample of Queensland cyclists. Members of Bicycle Queensland (n=1976) were asked about cycling injuries as part of an online survey. They also reported demographic characteristics, reasons for cycling, years of cycling as an adult, and cycling frequency. Multivariate logistic regression modelling was used to examine the association between these variables and experiencing cycling injuries last year (yes/no). Thirty-one percent of respondents (n=617) reported at least one cycling injury. Respondents had greater likelihood of injury if they cycled more frequently, had cycled <5 years, or cycled for recreation or competition. These findings suggest that injuries are mostly likely to occur among less experienced cyclists, those cycling the most, and those cycling for sport and recreation. Injury prevention interventions should include cycle skills training along with fostering safer cycling environments.

Key words

Bicycle, Cyclist, Injuries, Questionnaire, Online Survey

Introduction

Cycling is the fourth most popular form of physical activity in Australia, with 11.1% of Australians aged 15+ years reporting having cycled in the 12-month period prior to interview [1]. Bicycle mode share of travel, however, remains relatively low. On census day in 2006, 1.2% of trips to work in Australia were by bicycle only [2].

Despite low rates of transportation cycling in Australia, cyclists comprise about one in 40 traffic crash fatalities [3] and about one in seven serious injuries [4]. While fatalities and serious injuries for car occupants (drivers and passengers) have declined over time, cyclist fatalities have remained steady, and serious injuries have increased [3, 4].

In 2007, cyclists comprised 14.6% of serious injuries in road-based traffic crashes in Australia [4]. Over the period 2000 to 2007, based on data from the Australian Institute of Health and Welfare (AIHW) National Hospital Morbidity Database, serious injury rates for cyclists (per 100,000 population) increased by 47%, while for all other modes (motorcycles aside) rates either remained steady or declined [4]. The extent to which the increase in serious cycling injuries is attributable to increased rates of cycling is currently unknown, although there appears to have been no commensurate increase in bicycle travel in Australia [2, 5].

International comparative data show large variations in cyclist fatality and injury rates between and within countries [6]. Large variations also occur in the relative risk of injury for cyclists compared with car occupants. Based on survey data from commuter cyclists in Toronto, Canada, bicycle accident rates per kilometre cycled have been reported to be 26 to 68 times higher than for comparable car travel accident rates [7]. Moreover, these bicycle accident rates are much higher than reported for cyclists in Ottawa, Canada [7]. These large geographical variations in cyclist injury rates and in relative risks for cyclists and car occupants indicate substantial differences in driving/cycling conditions including, for example, road infrastructure and drive/cyclist behaviour.

Substantially lower cyclist fatality and injury rates in countries such as The Netherlands, Germany and Denmark have been attributed to better cycling infrastructure; national cycling education, skills and promotion programs; widespread traffic calming, including lower speed limits (30km/hr) in urban areas; and driver licensing and road safety systems that place greater responsibility on drivers for the safety of cyclists and pedestrians [6, 8, 9].

Although cyclists comprise a relatively high proportion of serious injuries among road users in Australia, little is known about the incidence of all types of cycling injuries in the population, and the causes of cycling injuries. Police crash reports include a relatively small proportion of the serious cyclist injuries treated in Australian hospitals [10, 11], and hospital datasets, in turn, exclude injuries treated by general practitioners and other health care providers. Because few cyclist injuries are investigated, little is known about the causes of cyclist injuries.

Cyclist surveys provide an opportunity to obtain information about the incidence and circumstances of cycling injuries that are currently unavailable from police and hospital records. This paper presents preliminary analysis of data from such a survey, conducted in Queensland in 2009. The aim of the paper is to examine incidence and correlates of cycling injuries in a sample of Queensland cyclists.

Methods

Sampling and study protocol

An online survey was administered to Queensland cyclists in November 2009 to collect data on their attitudes, behaviours and experiences. The sample was drawn from the adult membership (aged ≥18 years) of Bicycle Queensland (BQ), a state-wide community and advocacy group for cyclists. BQ staff invited its members to participate in the study by sending an email invitation to the 'primary member' of each of the households in its database. All adult members of each household were encouraged to participate. Reminder emails were sent one to two weeks after the initial invitation email was sent. The study received ethical approval from The University of Queensland Human Research Ethics Committee.

Of the initial 4469 households that were sent the invitation, 2085 households responded, a response rate of 46.7%. These households included 2228 respondents, and of these respondents, those who reported that they cycled less than monthly (n=169) or that their residence was not in Queensland (n=83) were excluded from analysis, leaving 1976 available for inclusion in the analysis sample.

Measures

Cycling injuries. Respondents reported whether they had had any cycling injuries in the previous year (yes/no). Respondents who reported a cycling injury were asked for the cause of their most severe cycling injury in the last year (Table 2) and all treatments they sought for this injury (Table 3).

Potential correlates. Possible correlates included demographic characteristics (age, sex, and educational level); time spent cycling as an adult (weeks, months, years), cycling frequency in the last year (5–7 days/week to never), and cycling purposes (recreation [just for fun or exercise], competition, and/or transport [as a means of getting to and from places]).

Data analysis

Descriptive statistics were generated for all study variables. Univariate and multivariate logistic regression modelling that accounted for clustering by household was then used to examine possible correlates of incurring a cycling injury. Correlates examined were demographic characteristics, years spent cycling as an adult, cycling frequency and cycling purpose.

Results

Characteristics of the analysis sample are shown in Table 1. Most respondents were middle-aged, male, and university-educated. Most (91%) cycled for recreation, and over half (58%) cycled for transport. Few (18%) cycled for competition. Of the total sample, 31% (n = 617) reported one or more cycling injuries in

the previous year.

Table 1: Respondent characteristics and cycling injuries

Characteristic	**Sample (n=1976)**		**Injuries (n=617)**	
	n	% of the total sample	n	% of injuries in correlate category
Age (years)				
18-34	263	13.3	88	33.5
35-44	521	26.4	163	31.3
45-54	678	34.3	224	33.0
55-64	373	18.9	113	30.3
65+	141	7.1	29	20.6
Sex				
Male	1,410	71.4	460	32.6
Female	566	28.7	157	27.7
Education				
No post-school education	274	13.9	80	29.2
Trade/apprenticeship or certificate/diploma	380	19.2	117	30.8
Undergraduate degree	684	34.6	224	32.7
Postgraduate university degree	638	32.3	196	30.7
Years of cycling as an adult				
10+ years	828	41.9	242	29.2
5 - < 10	440	22.3	131	29.8
2 - < 5	478	24.2	165	34.5
0 - < 2	230	11.6	79	34.3
Cycling frequency				
5-7 days/week	480	24.3	191	39.8
3-4 days/week	791	40	250	31.6
1-2 days/week	573	29	156	27.2
Once/month	132	6.7	20	15.2
Cycle for Recreation				
Yes	1,789	90.5	567	31.7
No	187	9.5	50	26.7
Cycle for Transport				
Yes	1,159	58.7	383	33.0
No	817	41.4	234	28.6
Cycle for Competition				
Yes	352	17.8	142	40.3
No	1,624	82.2	475	29.2

The causes reported by participants for their cycling injuries are listed in Table 2. Just over one third of injuries were caused by a crash with an object on the road or path (e.g., pothole, kerb, animal) or skidding (e.g., wet or gravel surface). About a quarter of injuries were caused by a collision with or the avoidance of a collision with a motor vehicle (e.g., a moving vehicle, an opened vehicle door), with a cyclist on or off road, or with a pedestrian on or off road. One fourth of respondents reported that their injuries were due to falling off (not a collision or avoidance of a collision). These included failure to clip out of cleats and mechanical failures (e.g., flat tyre). Other causes included muscle strains that did not result in a fall.

Table 2: Main cause of the most severe cycling injury in the previous 12 months (n = 617)

Cause reported	n	%
Collision or avoidance of a collision with a motor vehicle	94	15.2
Collision or avoidance of a collision with another cyclist or with a pedestrian	71	11.5
Crash with an object on the road or path; skidding	214	34.7
Falling off	158	25.6
Off-road mountain bike injury	15	2.4
Cause not given/other causes	65	10.5

The treatments that respondents sought for their most severe injury are described in Table 3. Just under half of respondents (47%) who reported an injury sought no treatment other than first aid. Almost as many (44%) sought treatment from a health care practitioner, either a medical professional or an allied health practitioner. The total number of injuries involving a trip to a hospital emergency department or admission to hospital was 116 (18.8% of injuries): due to multiple response options, some respondents reported visiting a hospital emergency department and being admitted to hospital, while others reported being admitted to hospital only.

Table 3: Treatments reported for the most severe cycling injury in the last year (n = 617)

Treatment	n	%
No consultation with a health professional or only first aid	291	47.2
Consultation with a medical professional (general practitioner, nurse, medical specialist, paramedic)	153	24.8
Consultation with an allied health practitioner (physiotherapist, chiropractor)	116	18.8
Trip to a hospital emergency department	97	15.7
Admitted to hospital	38	6.2

Note: Respondents could select more than one treatment.

Multivariate regression modelling revealed that having spent less than 5 years cycling as an adult, cycling for recreation, and cycling for competition were positively associated with incurring a cycling injury; while older age (65+) and cycling less than 5 days per week were negatively associated with incurring a cycling injury (Table 4).

Table 4: Injury risk (n=1976)

Variable	Injury			
	UNADJUSTED		ADJUSTED[1]	
	OR	(95% CI)	OR	(95% CI)
Age (years)				
18-34	1.02	0.75-1.38	0.89	0.64-1.24
35-44	0.92	0.72-1.18	0.88	0.68-1.14
45-54 referent	1.00		1.00	
55-64	0.88	0.76-1.16	0.93	0.71-1.23
65+	**0.52**	**0.34-0.81**	**0.57**	**0.36-0.90**
Sex				
Male	1.00		1.00	
Female	**0.79**	**0.64-0.98**	0.84	0.67-1.06
Education				
No post-school education	1.00		1.00	
Trade/apprenticeship or certificate/diploma	0.85	0.62-1.15	0.89	0.64-1.22
Undergraduate degree	0.91	0.70-1.20	0.93	0.70-1.23
Postgraduate university degree	0.91	0.72-1.15	0.93	0.74-1.18
Years of cycling as an adult				
10+ years	1.00		1.00	
5 - < 10	1.03	0.80-1.32	1.08	0.83-1.40
2 - < 5	**1.28**	**1.00-1.62**	**1.42**	**1.10-1.84**
0 - < 2	1.27	0.93-1.73	**1.50**	**1.07-2.09**
Cycling frequency				
5-7 days/week	1.00		1.00	
3-4 days/week	**0.70**	**0.55-0.89**	**0.72**	**0.56-0.92**
1-2 days/week	**0.57**	**0.44-0.73**	**0.58**	**0.44-0.77**
At least once/month	**0.27**	**0.16-0.45**	**0.30**	**0.18-0.51**
Cycle for recreation				
No	1.00		1.00	
Yes	1.27	0.91-1.78	**1.47**	**1.03-2.09**
Cycle for transportation				
No	1.00		1.00	
Yes	**1.22**	**1.01-1.50**	1.13	0.90-1.42
Cycle for competition				
No	1.00		1.00	
Yes	**1.64**	**1.29-2.07**	**1.49**	**1.17-1.91**

Note: OR = odds ratio. 95% CI = 95% confidence interval. The first category is the referent except where stated otherwise. Bold: P< 0.05
[1]Adjusted for all other variables in the table.

Discussion

The sample of 1976 regular cyclists in Queensland who responded to an online survey of Bicycle Queensland members reported a one-year cycling injury rate of 31%. While this rate seems quite high, it is important to bear in mind that it includes a high proportion of minor injuries that did not require treatment from a health professional. Injuries that are generally classified as serious were less common: 19% of injured respondents reported hospital emergency department treatment and/or admission to hospital. Some of these respondents reported visiting a hospital emergency department and being admitted to hospital, while others reported being admitted to hospital only.

About a quarter of injuries involved colliding with, or attempting to avoid collision with another road/path user (motor vehicle occupants, cyclists and pedestrians). The largest category of injuries was for non-collision crashes due to road/path obstacles or conditions (i.e., crash with an object on the road or path; skidding), and incidents arising from the rider falling off (e.g., from mechanical failure) (combined

60%). While improvements in cycling safety often focus on cyclist/driver interactions (and there is evidence that these lead to the most serious cyclist injuries [12, 13]), the majority of injuries were attributable to poorly designed and/or maintained cycling infrastructure, lack of cycling skills and/or risky cycling behaviour, and poor bicycle maintenance.

As noted above, nearly half of the survey respondents reporting a cycling injury in the previous year did not require treatment from a health practitioner and few were admitted to hospital. While these data indicate that only a small minority of cycling injuries were serious, they also indicate that hospital records and police crash reports capture only a small (albeit more serious) fraction of total cycling injuries. Interventions aimed at preventing bicycle-motor vehicle collisions will undoubtedly reduce cyclist fatalities and serious injuries, but additional actions aimed at improving the design and maintenance of cycling infrastructure, increasing a cyclist's skills, encouraging safe cycling behaviours, and bicycle maintenance are also required to reduce the overall incidence of cycling injuries. The distribution of bicycle injury severity is not known, but it is likely that a substantial proportion of the burden of cycling injury arises from a large number of non-serious injuries.

Demographic analysis of cycling injuries can assist in planning interventions to improve cycling safety. However, the demographic breakdowns of cycling injuries reported in studies based on hospital data [4, 11] and police crash reports [12] are based on the total injury dataset and do not take into account demographic differences in cycling participation. For example, to what extent is the substantially higher proportion of injuries among males[1] due to men cycling more than women? This study found that, after adjusting for age, and cycling experience, purpose and frequency, there was no significantly increased risk of injury for males. This finding suggests that the consistently reported higher injury rates for males in hospital and police-based studies [10-12] may be at least partly due to cycling exposure rather than riskier conditions (e.g., choice of route) and/or behaviours for male cyclists. The absence of a significant gender effect in this study suggests that controlling for exposure eliminates the gender difference in injuries, at least for all injuries irrespective of severity. Further data analysis is being conducted to examine the effect of gender on more serious cycling injuries, based on indications that as injury severity increases, the proportion of males increases [11, 12].

Except for reduced risk of injury for the oldest age group (65+ years), this study found no significant impact of age on cycling injuries. It therefore appears that cycling exposure may at least partially account for the high rates of cycling injuries reported for younger age cohorts (particularly the 30-50 years of age group) based on hospital data and police crash reports. The lower risk of injury for cyclists aged 65+ years was unexpected and may reflect more years of cycling experience (>10 years), shorter trips and therefore less exposure, differences in choice of cycling route and cycling time (i.e., weekday/weekend, time of day), lower cycling speed, or greater caution. Not surprisingly, the analysis revealed that less experienced cyclists are more likely to be injured, and that exposure in the form of cycling frequency is associated with injury. In fact there is a graded relationship between cycling frequency and injury.

The finding that cycling for recreation or competition is associated with an increased risk of injury, but cycling for transport is not, is interesting, given that cycling for transport is more likely to occur on-road [14], at peak travel time with high vehicle flow (at least for commuter cycling). There is some evidence that on-road bicycle routes and on-road marked bicycle lanes are associated with reduced risk of injury, and that footpaths and multi-use trails pose the highest risk [15]. It appears that those who cycle for transport are not at significantly greater risk of injury than people who cycle for recreation and competition, although increased risk for recreation and competition cycling may simply reflect great distances cycled for those purposes than cycled for transport.

Limitations of this study should be noted. One limitation is the sample selection bias due to the use of online survey data from members of a bicycle community and advocacy group. Therefore, the sample does not necessarily represent all Queensland cyclists, and the prevalence of reporting injuries could be different in other populations of cyclists. It is noteworthy, however, that the sample size was large, which

[1] 80% in the MUARC study of police crash reports in Victoria, Queensland, Western Australia and South Australia; and 78% - 84% based on three hospital-based datasets in Victoria) 12. Watson, L. and M. Cameron, *Bicycle and motor vehicle crash characteristics*. 2006, Monash University Accident Research Centre: Melbourne. 11.Sikic, M., et al., Bicycling injuries and mortality in Victoria, 2001-2006. *Medical Journal of Australia*, 2009. **190**(7): p. 353-356.

allowed us to examine a number of different possible correlates of cycling injuries. Others limitations include the cross-sectional design, which does not allow for causality to be determined, and the collection of descriptive data on only respondents' most severe injuries, which limited our ability to describe causes of some of the less severe injuries. However, most respondents who reported injuries in the previous year reported one injury, and, therefore, our descriptions reflect the experiences of most respondents in the sample.

Conclusions

These findings suggest that injuries are most likely to occur among inexperienced cyclists, those cycling the most, and those cycling for sport and recreation. Collision or avoidance of a collision with a motor vehicle was responsible for a relatively small proportion of injuries, although these may represent the most serious injuries [10-12]. Further data analysis will examine this issue. Most of the injuries were attributable to poorly designed and/or maintained cycling infrastructure, lack of cycling skills and/or risky cycling behaviour, and poor bicycle maintenance. In addition to strategies designed to reduce collisions and near-collisions with motor vehicles, interventions aimed at improving the design and maintenance of cycling infrastructure, increasing a cyclist's skills, encouraging safe cycling behaviours, and bicycle maintenance are, therefore, important for reducing the overall incidence of cycling injuries.

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References

1. Australian Sports Commission, *Participation in exercise, recreation and sport: Annual Report 2008*. 2009, Australian Sports Commission: Canberra.
2. Australian Bureau of Statistics, *2006 Census data online*. 2008; Available from: http://www.abs.gov.au/websitedbs/d3310114.nsf/home/Census+data.
3. Department of Infrastructure Transport Regional Development and Local Government, *Road deaths Australia 2008 statistical summary*. 2009, Department of Infrastructure, Transport, Regional Development and Local Government: Canberra.
4. Henley, G. and J. Harrison, *Serious injury due to land transport accidents, Australia 2006–07. Injury research and statistics series no. 53. Cat. no. INJCAT 129*. 2009, AIHW: Canberra.
5. Australian Bureau of Statistics, *Environmental issues: Waste management and transport use, Cat No. 4602.0.55.002*. 2009, ABS: Canberra.
6. Pucher, J. and R. Buehler, Making cycling irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews*, 2008. **28**(4): p. 495-528.
7. Aultman-Hall, L. and M. Kaltenecker, Toronto bicycle commuter safety rates. *Accident Analysis and Prevention*, 1999. **31**(6): p. 675-686.
8. Fedtke, J., Strict liability for car drivers in accidents involving "Bicycle Guerrillas"? Some comments on the proposed Fifth Motor Directive of the European Commission. *American Journal of Comparative Law*, 2003. **51**: p. 941-958.
9. Christie, N., et al., How exposure information can enhance our understanding of child traffic "death leagues". *Injury Prevention*, 2007. **13**(2): p. 125-129.
10. Richardson, D.B., *Amalgamation of police and hospital trauma data in the Australian Capital Territory 2001-2003*. 2009, Australian National University Medical School: Canberra.
11. Sikic, M., et al., Bicycling injuries and mortality in Victoria, 2001-2006. *Medical Journal of Australia,* 2009. **190**(7): p. 353-356.
12. Watson, L. and M. Cameron, *Bicycle and motor vehicle crash characteristics*. 2006, Monash University Accident Research Centre: Melbourne.

13. Scott, D., et al., Bicycle injury in Queensland. *Injury Bulletin: Queensland Injury Surveillance Unit*, 2005. **86**(April): p. 1-4.
14. Garrard, J., S. Crawford, and N. Hakman, *Revolutions for women: Increasing women's participation in cycling for recreation and transport*. 2006, Deakin University: Melbourne.
15. Reynolds, C., et al., The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental Health*, 2009. **8**: p. 47.