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Observational study of compliance with Queensland bicycle helmet laws

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Abstract

Mandatory bicycle helmet laws have been found to increase helmet wearing rates in Australia and internationally. However, much of the research on factors influencing compliance with the Australian helmet laws is dated or focuses on commuters and city areas only. To address this gap, video recordings of bicycle riders were undertaken at 17 sites across Queensland, Australia, representing a mixture of on- and off-road locations, speed limits and regions. Helmet status was able to be determined for 98% of riders observed. The level of compliance with the laws was very high, with 98.3% of the more than 27,000 riders observed wearing helmets. Riders riding on roads were less compliant than those riding on bicycle paths, but no significant differences were observed between the school-holiday and school-term periods. Among the on-road riders, boys were less compliant than girls and overall children were less compliant than adults. Higher compliance levels were found for group riders, road bike riders, lycra-clad riders, during morning hours, and on 50 km/h or lower speed limit roads. While the overall level of compliance was very high, certain subgroups were identified as a possible focus for interventions to further improve the compliance level, for example children (particularly boys) riding mountain bikes away from groups during the afternoon hours on 60 km/h roads.

Keywords: bicycle helmets; helmet laws; compliance; bicycling

1. Introduction

Many studies have demonstrated that bicycle helmets reduce the likelihood of a bicyclist sustaining head or brain injury when involved in a bicycle crash (e.g., Cochrane Review by Thompson et al., 2009). Mandatory bicycle helmet laws have been found to increase helmet wearing rates, both in Australia and internationally (Karkhaneh et al., 2006, 2011; Macpherson and Spinks, 2009). However, a number of factors have been shown to influence helmet wearing rates, both for the jurisdictions where bicycle helmet use is voluntary and those where it is mandated. Ritter and Vance (2011) investigated the factors influencing voluntary helmet use in Germany using data from a nationwide household survey and showed that riding pattern, residential location, and rider gender are significant correlates of helmet use. Analysis of French population survey data showed that age, gender, and residential location have significant influence on voluntary helmet use (Richard et al., 2013). A US telephone survey study (Dellinger and Kresnow, 2010) showed that helmet wearing by children was significantly associated with presence/absence of helmet use law, household income, household education, region, race, ethnicity, and child age, but not associated with gender. In several Canadian jurisdictions, where helmet use is mandatory for people aged less than 18 years old, implementation of the law improved helmet use rate among the rider group targeted by the law, but minimal effects were observed for non-targeted groups (Karkhaneh et al., 2011). In research undertaken soon after the introduction of mandatory helmet laws in Australia, lower wearing rates were observed for teenagers compared to younger children and adults (Finch et al., 1993; TTM Consulting Pty Ltd, 1994); and for recreational riders than commuters (King and Fraine, 1994). Self-reported helmet use in Queensland was found to be lower for males than females in a more recent study (MCR, 2010).

Most of the above mentioned studies have used surveys or interviews (which may be susceptible to response bias) and few studies have observed actual bicycle helmet use. Other than the Canadian study by Karkhaneh et al. (2011), two recent Australian studies observed cyclists in inner-city commuting locations. Johnson et al. (2011) observed 4225 cyclists facing red traffic lights within 5kms of the centre of Melbourne and reported that only eight were not wearing helmets (0.19%). From observations of 4522 cyclists in the centre of Brisbane, Haworth et al. (2014) reported that 97.8% of riders were wearing a helmet that was correctly fastened, 1.2% wore a helmet that was not fastened, and 1.0% were not wearing a helmet. While these Australian studies showed very high levels of compliance with the helmet use laws, their focus was limited to riding in city areas only (i.e., mostly commuter riders). As a result, relatively little is known regarding current compliance with mandatory helmet laws in Australia by recreational riders, riders who are not riding in the inner city and by children. This important gap in the literature has important implications in terms of obtaining a comprehensive understanding of compliance with bicycle helmet laws and the factors influencing compliance levels.

While mandatory bicycle helmet laws are in effect in many countries across the world, only two studies (Dellinger and Kresnow (2010) in the US, and Karkhaneh et al. (2011) in Canada) have investigated the effects of the laws in terms of compliance levels. The current compliance levels with Australian mandatory bicycle helmet laws are not comprehensively understood as the existing studies kept their foci restricted to city areas and commuters and an analysis of the factors influencing compliance levels for different rider groups (commuters, recreational riders, children etc.) and riding locations (i.e., road and bike paths) has not been undertaken. Given that the laws have been in effect for a long time (since 1991), it would be interesting to know the current status of compliance levels in Australia so that the long-term effects of having such laws can be understood. The knowledge gaps regarding the current compliance rates and the determinants of helmet use in Australia warrant further research.

This paper aimed to understand the current compliance rates with the mandatory bicycle helmet laws in the Australian state of Queensland, and to examine the factors associated with the compliance rates.

2. Methods

2.1 Study setting

This research was conducted in the State of Queensland, Australia. Queensland has 4.7 million inhabitants and a climate that varies from sub-tropical to tropical, allowing year-round bicycle riding. A recent national population survey estimated that about 22% and 16% of the Queensland population rode a bicycle in the previous month and previous week, respectively (Austroads, 2015). Most urban roads in Queensland have signed 60 km/h speed limits. Vehicles drive on the left side of the road and cycling on the footpath is legal for riders of all ages unless there are signs prohibiting riding.

The mandatory helmet use law for bicycle riders was introduced in Queensland on 1 July 1991, accompanied by widespread publicity (Haworth et al., 2010). The law specifies that "the rider of a bicycle must wear an approved bicycle helmet securely fitted and fastened on the rider's head" (approved bicycle helmets comply with AS 2063 or AS/NZS 2063). Introduction of the law was followed by development of an offence system and enforcement of the law from 1 January 1993 onwards. The current maximum penalty for not wearing an approved bicycle helmet or failing to securely fit and fasten on rider's head is 20 penalty units (1 unit has a value of $117.80 on 1 July 2016). In Queensland, a rider or a pillion is exempt from wearing a bicycle helmet if any of the following conditions apply to them: (1) they are carrying a current doctor's certificate that states that they cannot wear a bicycle helmet for medical purposes for a state period, (2) it would be unreasonable to require them to wear a bicycle helmet because of a physical characteristic of the person, (3) the person is a member of a religious group and the person is wearing a type of headdress customarily worn by members of the group. The law is enforced by police, as evidenced by findings from a recent Queensland report (Schramm et al., 2015) which showed that majority (71.6%, n=5945) of bicycle related infringements during the period 1 April 2012 to 30 June 2015 were related to helmet non-use.

2.2 Data collection

Video data of cyclists was collected at 17 locations which included urban locations, suburban locations in South East Queensland and regional locations, tourist locations and off-road bicycle paths. Table 1 summarises how the observation locations varied according to infrastructure type (road or path), posted speed limit (for on-road sites), and regions. The Kedron Brook Bikeway site was near Kedron State High School, and therefore it was hoped would provide observations of school travel, as well as significant numbers of commuter and recreational riders. These 17 sites were not a random sample of all roads and off-road bike paths across Queensland, but were selected because of the high likelihood of observing a large number of cyclists and the availability of roadside infrastructure to mount video cameras for data collection. While the sites may not be a representative sample of all Queensland riding locations, the large number of cyclists observed (n=27,057) is likely to be a statistically representative sample of all Queensland cyclists. Due to inability to collect accurate demographic information about cyclists (e.g., age, education, income)—as a video-recording-based observation method was used—it was not possible to conduct statistical tests for the sample's representativeness.

Table 1 Data collection sites

Road/Path name	Suburb	Region	Speed limit (km/h)
Road			
Breakfast Creek Rd	Newstead	Brisbane	60
Gladstone Rd	Dutton Park	Brisbane	60
Annerley Rd	Dutton Park	Brisbane	60
Cordelia St	South Brisbane	Brisbane	60
Grey St	South Brisbane	Brisbane	40
Montague Rd	West End	Brisbane	60
Sandgate Rd	Bracken Ridge	Brisbane	70
Jacaranda Av	Logan	Brisbane	60
Hope Island Rd	Hope Island	Gold Coast	70
The Esplanade	Surfers Paradise	Gold Coast	40
Pacific Boulevard	Buddina	Sunshine Coast	50
Cooroy-Noosa Rd	Tewantin	Sunshine Coast	80
Mt Sampson Rd	Dayboro	Sunshine Coast	100
Dean St	North Rockhampton	Rockhampton	60
Bruce Highway	South Rockhampton	Rockhampton	70
Path			
Kedron Brook Bikeway at Gympie Rd	Kedron	Brisbane	N/A
Ted Smout Bridge	Clontarf	Brisbane	N/A

Video data were collected using cameras equipped with infrared filters to provide both day and night recordings typically attached to poles and sign posts. The primary data collection phase at all locations occurred from Thursday 7 to Sunday 10 May 2015. Data was also collected on 16 to 19 April 2015 at two sites (Kedron Brook Bikeway and The Esplanade on the Gold Coast) to allow a comparison of school holiday and non-holiday periods. Theft of the camera at Mt Sampson Rd, Dayboro, required replacement data to be collected on 28 and 29 May 2015.

The recorded videos were manually coded by researchers to gather information on helmet use and rider characteristics. Automated detection of helmet use by using video analytics software was not possible due to insufficient quality of the video and variations in quality due to light conditions. Variables coded from the video recordings included helmet worn (yes, no, or unknown), apparent gender (male, female, or unknown), apparent age (child, adult, or unknown), bicycle type (road, mountain, or other), clothing type (lycra, everyday, other, or unknown), individual or group riding, location of site, region (Brisbane, Moreton Bay, Logan, Sunshine Coast, Gold Coast, and Rockhampton), road or path, speed limit, date, and time. In the classification of bicycle type, "Road" included road, TT, and Fixie (single-speed/fixed gear with narrow tyres). "Mountain" included mountain, hybrid, BMX, cargo, CityCycle, city/step-through, and fat bikes. "Other" included child seat, trailer, tag-along, electric, elliptigo, folding, ped-cab, tandem, and tricycle.

Ethics approval for the observational study was obtained from the Queensland University of Technology (QUT) Human Research Ethics Committee (approval number 1500000220).

2.3 Analysis

Helmet wearing rate for each site was calculated based on the number of all riders observed for whom helmet use could be determined. Helmet use was unable to be determined from the video recording for 2.1% of all cyclists observed, because of poor contrast or image quality in the recorded videos. These observations were discarded for the analyses. There is no reason to believe that these observations would show any different pattern to those for which helmet use was able to be scored.

Table 2 Summary of observations and helmet wearing rates

Characteristic	Number of observations	Percent of observations	Helmet wearing rate (%)
Apparent gender			
Male	20667	76.4	98.2
Female	6004	22.2	98.5
Unknown	386	1.4	
Apparent age			
Child	1714	6.3	94.2
Adult	25327	93.6	98.6
Unknown	16	0.1	
Type of bicycle			
Road	14347	53.0	99.9
Mountain	12289	45.4	96.4
Other	222	0.8	99.1
Unknown	199	0.7	
Type of clothing			
Lycra	14253	52.7	99.9
Everyday	12496	46.2	96.4
Other/unknown	308	1.1	
Type of riding			
Individual	15751	58.2	97.8
Group	11294	41.7	99.0
Unknown	12	0.1	
Day of week			
Thursday	5339	19.7	98.3
Friday	5771	21.3	98.3
Saturday	8284	30.6	98.6
Sunday	7663	28.3	98.0
Time of day (hours)			
0500-0859	11566	42.7	99.5
0900-1259	7180	26.5	98.1
1300-1659	6051	22.4	96.5
1700-1959	2146	7.9	97.6
2100-0459	114	0.4	99.1
Type of location			
Road	18066	66.8	97.8
Path	8991	33.2	99.2
Speed limit			
50 km/h or less	8758	48.5	96.9
60 km/h	7608	42.1	98.5
70 km/h or more	1700	9.4	99.5
Region			
Brisbane	19046	70.4	99.0
Gold Coast	6528	24.1	96.6
Sunshine Coast	1276	4.7	96.7
Rockhampton	207	0.8	99.5
Time of year			
School term	20501	75.8	98.4
School holiday*	6556	24.2	98.0

* School holiday data collected only for two sites (Kedron Brook Bikeway and The Esplanade); Note that the characteristics in the above table were included in the regression models as categorical explanatory variables.

A Binary Logistic model (BLM) was formulated in order to understand the associations between the helmet status of a cyclist (i.e., helmet not worn or worn) and the characteristics of cyclists, bicycles, and riding locations. Helmet status was defined as a dichotomous dependent variable (helmet not worn = 1; worn = 0) in the BLM. A range of explanatory variables explaining the characteristics of cyclists, their bicycles, and riding locations (see Table 2), which were hypothesised to have significant associations with helmet status, were included in the model.

Since the collected data involves both school-holiday and school-term periods (for 1 road site and 1 path site), school-term periods only (14 road sites, and 1 path site) and road and path sites (15 road sites, and 2 path sites), models were estimated for several data subsets: (1) school-term periods data for all sites (2) road sites during school-term periods, (3) path sites during school-term periods, (4) the two sites from which both school-holiday and school-term data were collected. The first data subset is actually a combination of subsets 2 and 3. Since data during school-holidays were collected from two sites only, the major focus of the analyses (data subsets 1, 2, and 3) was on the school-term periods. The fourth data subset focused on a comparative examination of helmet wearing rates for the school-holiday and school-term periods. The calibrated models for the four data subsets are referred hereafter as 'school-term model' (Model 1 using data subset 1), 'road during school-term model' (Model 2 using data subset 2), 'path during school-term model' (Model 3 using data subset 3), and 'school-holiday vs. school-term model' (Model 4 using data subset 4).

In all models, to identify the subset of explanatory variables which yield the most parsimonious model, a backward elimination procedure was employed to eliminate the non-significant variables one by one so that the Akaike Information Criteria (AIC) was minimized. Significance of the explanatory variables was examined by using the z-test. To evaluate if the models have sufficient explanatory power, likelihood ratio statistics (G^2) were computed.

3. Results

The results are presented in three sections. The first section summarises the general characteristics of the 27,057 riders observed. The helmet wearing rates are then presented, followed by the results obtained from the BLMs estimated.

3.1 Sample characteristics

The numbers of observations and helmet wearing rates are summarised in Table 2. About three-quarters of riders were male and more than 90% were adults. Type of bicycle was almost evenly split between road and mountain (including hybrid) styles and type of clothing was also almost evenly split between lycra and everyday. Almost 60% of the riders were judged to be riding alone, not part of an identifiable group.

About 40% of observations were collected on weekdays (Thursday and Friday) and about 60% were collected on weekends (Saturday and Sunday). School holiday data was collected at two sites (Kedron Brook Bikeway and The Esplanade) and these comprised almost one-quarter of total observations. More than 40% of riders were observed between 5am and 9am. About one-third of the riders were observed on roads compared to bike paths. Of those riders observed on roads, about 50% were on roads with a 50 km/h or lower speed limit. Less than 10% of riders were observed on roads with speed limits of greater than 60 km/h. About 70% of riders were observed in Brisbane, followed by almost a quarter on the Gold Coast.

3.2 Helmet wearing rates

Overall, 98.3% of riders were wearing a helmet. Helmet wearing rates did not differ by gender (98.2% males, 98.5% females), but the rate was lower for children (94.2%) than adults (98.6%). Mountain bike riders had a lower helmet wearing rate (96.4%) than the road bike riders (99.9%). Similar results were found for type of clothing (96.4% everyday, 99.9% lycra). People riding in groups had a slightly higher helmet wearing rate than individual riders (99.0% vs 97.8%). Helmet wearing rates did not differ substantially between weekdays and weekends, but the rate during 1pm to 5pm (96.5%) was lower than other time periods. Road sites had lower helmet wearing rates than path sites (97.8% vs. 99.2%). Among the road sites, lower helmet wearing rates were observed on roads with speed limits of 50 km/h or less, than the higher speed limit roads. Helmet wearing rates at the Gold Coast and Sunshine Coast sites were lower than the Brisbane and Rockhampton sites. No major difference was seen between the school term and school holiday periods. While the above univariate analysis results provide a quick overview of the compliance rates with helmet laws in Queensland, the results from multivariate regression analysis (presented in the following section) provide detailed and more accurate understanding about the compliance rates by simultaneously controlling for the effects of all variables.

3.3 Regression model results

The parameters of the four formulated models were derived using the maximum likelihood estimation method in the software STATA 13. The ‘school-term model’ was first calibrated to examine if the observation data from road sites and path sites are to be modelled aggregately (Model 1: ‘school-term model’) or separately (Model 2: ‘road during school-term model’ and Model 3: ‘path during school-term model’). If the explanatory effects are consistent between the two separate models (Models 2 and 3), an aggregate model (Model 1) would be preferred, otherwise two separate models would be preferable. A likelihood ratio test of the aggregate and separate models yielded a likelihood ratio statistics of 19.1 with 10 degrees of freedom (*df*). Since this value is higher than the critical chi-square value for 10 *df* at 95% confidence level (= 18.3), the null hypothesis of the likelihood ratio test (explanatory effects are consistent between the separate models) was rejected, implying that separate models are preferred.

The parameter estimates, odds ratios (O.R.), and their statistical significance for Models 2 and 3 are presented in Table 3. Model fitness statistics (G^2) of both Model 2 (682.5, 19 *df*) and Model 3 (60.1, 5 *df*) were well above the corresponding critical values of for significance at the 99% confidence level, implying that the models have sufficient explanatory power.

Model 4 was calibrated to examine if non-compliance with the mandatory helmet laws differs between school-term and school-holiday periods. The results showed no statistically significant difference between these two periods, therefore, the detailed results of this model are not reported in this paper. The statistically significant variables of Models 2 and 3 are discussed below.

When riding on roads, females were less likely to be non-compliant (40% lower odds of not wearing helmet) than males, and children were more likely (5.1 times higher odds) than adults. Cyclists who ride mountain bikes had 5.5 times higher odds of not wearing helmet when riding on the road than the road bike riders. In the case of riding on bike paths, no statistically significant differences were observed for males vs. females, children vs. adults, or road bike riders vs. mountain bike riders.

Type of clothing was found to have statistically significant associations with helmet non-wearing rates in both road and path riding contexts. Cyclists wearing ‘everyday’ clothing were more likely to be non-compliant (9.6 times higher odds for road riding and 11.2 times higher odds for path riding) than those wearing ‘lycra’ clothing. In the path riding data, all observed cyclists wearing ‘other’ types of clothing or for whom the type of clothing information was unknown were found to be wearing helmets. On the other hand, in the road riding data, this group of cyclists had considerably higher odds (O.R. = 21.3) of not wearing helmets than the cyclists wearing ‘lycra’ clothing.

Compared to individual riders, the riders in groups had about 50% lower odds of not wearing helmets when riding on roads. A similar result was seen for path riding, but it lacked statistical significance.

Table 3 Regression model results

Variables	Road during School-term model			Path during School-term model		
	Coeff.	**O.R.**	**p-value**	**Coeff.**	**O.R.**	**p-value**
Apparent age						
Adult	Ref			Ref		
Child	1.638	5.147	<0.001	-		
Unknown	4.858	128.755	<0.001	-		
Apparent gender						
Male	Ref			Ref		
Female	-0.516	0.597	0.001	-		
Unknown	-2.890	0.056	0.015	-		
Type of bicycle						
Road	Ref			Ref		
Mountain	1.713	5.543	<0.001	-		
Other	1.232	3.430	0.128	-		
Unknown	0.529	1.698	0.663	-		
Type of clothing						
Lycra	Ref			Ref		
Everyday	2.265	9.636	<0.001	2.417	11.210	0.001
Other/unknown	3.057	21.253	<0.001	#		
Group riding^^	-0.673	0.510	<0.001	-0.514	0.598	0.109
Time of day (hours)						
05:00-08:59	Ref			Ref		
09:00-12:59	0.461	1.586	0.022	2.256	9.551	0.030
13:00-16:59	0.777	2.174	<0.001	2.747	15.609	0.008
17:00-19:59	0.517	1.677	0.032	2.045	7.733	0.097
20:00-04:59	1.416	4.121	0.186	#		
Speed limit						
50 Km/h or less	Ref			^		
60 km/h	0.825	2.282	0.012	^		
70 km/h or more	-0.222	0.801	0.555	^		
Region						
Brisbane	Ref					
Gold Coast	1.287	3.622	<0.001	^		
Sunshine Coast	1.301	3.671	<0.001	^		
Rockhampton	-2.652	0.071	0.009	^		
Constant	-8.285	0.000	<0.001	-8.709	0.000	<0.001
Model statistics						
No of observations	15070			5410		
Log-likelihood at zero	-1413.16			-245.9411		
Log-likelihood at model	-1071.897			-215.8727		
AIC	2183.795			443.7455		
Likelihood ratio stat	682.53 (19 *df*)		<0.001	60.14 (5*df*)		<0.001

Ref: Reference category; AIC: Akaike Information Criteria; - variable not retained in the most parsimonious model; # variable predicts failure (y=0) perfectly so not used in model; ^ variable not applicable for model; ^^ Individual riding is reference category

It appears that 'time of day' influences helmet wearing rates significantly. In comparison with the morning peak hours (5am – 8.59am), the morning off-peak hours (9am – 12.59pm) had 1.6 times and 9.6 times higher odds for road riding and path riding, respectively. During the afternoon hours (1pm-4.59pm), the corresponding odds of not wearing helmets were 2.2 times and 15.6 times higher. About 68% higher odds were found for the hours between 5pm and 7.59pm in the road riding data, but the results were not statistically significant for the path riding data.

Cyclists riding on roads with 60 km/h speed limits had 2.3 times higher odds of wearing helmet than those riding on lower speed limit roads (50 km/h or less). Results for 70 km/h or more roads were not statistically significant.

Brisbane appeared to have lower likelihood of non-compliance with the helmet laws than the Gold Coast and Sunshine Coast, but not Rockhampton. The odds of not wearing a helmet for both Gold Coast and Sunshine Coast were 3.6 times of the odds for Brisbane. Rockhampton had 93% lower odds than Brisbane.

The speed limit and region variables were not included in the ‘path and school-term model’ as there were only two path sites in the database and speed limit is not relevant for such sites.

Based on the results presented above, the characteristics of riders, cycles, and riding locations were combined together to identify the ‘best possible’ and ‘worst possible’ combinations for compliance with the helmet laws. In the best possible combination, a 100% compliance rate could be obtained if a rider is an adult female who wears lycra clothing and rides a road bike in a group between 5am to 8.59am on a Rockhampton road with posted speed limit of 70 km/h or more. On the other hand, the worst possible combination (55.8% probability of not wearing a helmet) is a boy who wears everyday clothing and rides a mountain bike away from groups during the 13 to 16.59 hours on a 60 km/h Sunshine Coast road.

4. Discussion

This research has provided some useful insights into compliance rates when mandatory helmet wearing laws have been in place for a long time, as well as a better understanding of the factors that may be associated with compliance levels. The results showed that the overall compliance level with the Queensland mandatory bicycle helmet use laws was very high (98.3%). This finding is in agreement with earlier research (Johnson et al., 2011; Haworth et al., 2014) which reported very high bicycle helmet wearing rates in Australian cities. When broken down to different categories of riders, bicycles, and ridings locations, similarly high levels of compliance were observed, which implies that the laws have been effective in encouraging all cyclist groups to wear helmets. This finding is important as the scope of existing knowledge about compliance levels in Australia was mostly related to city areas and commuters (Johnson et al., 2011; Haworth et al., 2014). This study extended the research scope to the recreational riders, non-city areas, and most importantly children riders. High levels of compliance for all rider groups were observed.

Given the overall compliance rate with the mandatory helmet law was very high (98.3%), in order to further improve compliance, the focus needs to be on the relatively small group of riders who were observed non-compliant (1.7%). As this small percentage value indicates, any differences in the likelihoods of non-compliance among different rider groups need to be treated as important results in order to reduce the 1.7% non-compliance rate.

While all rider groups had high compliance rates, some differences were observed among groups. Boys had a lower probability of helmet use than girls and children overall had lower probability than adults. Although children comprise only a small portion of the observed cyclists (6.3%), the lower probabilities for children, particularly for boys, are a key concern in further improving the compliance levels.

Educational campaigns and enforcement activities should target the rider groups who have lower likelihood of helmet use. For example, results showed that the combination of characteristics that has the least probability of helmet use involves boys who wear everyday clothing and ride mountain bikes away from groups during the 13 to 16.59 hours on a 60 km/h Sunshine Coast road. Riders with these characteristics (all or some) should be targeted to educational campaigns to further improve compliance.

Model estimation results showed that the effects of explanatory variables on compliance levels at road sites and path sites are not similar, which was the reason to separately model the observed data from the road sites and the path sites. Many of the explanatory variables in the road sites model were found significant, but only few were found significant in the path sites model. The relatively high compliance rate observed for the path sites (99.2% as compared to 97.8% for road sites) may mean that the variability in the categories of the explanatory variables were too low to have statistically significant differences between the variable categories for the path sites. Future research should focus on collecting more data from path sites with a variety of characteristics in order to investigate the effects of the factors.

4.1 Study limitations

The current study includes a large sample of cyclists (n=27,057) observed at 17 sites across Queensland but there are limitations nonetheless. Apparent age and gender were judged from the video recording. Some errors may have occurred and gender was not able to be determined for 1.4% of observations. Apparent age was able to be judged for all but 0.1% of observations, but it is possible that some teenagers were coded as adults while others of the same age were coded as children. The lack of fine-grained age data also precludes any comparisons according to age of the child or checking the statistical representativeness of the data sample with Queensland's cyclist population. All of the observations were of riding on the road or on off-road bike paths. No observations of riders on the footpath were collected, although this is legal in Queensland. Observational studies by the authors in the Brisbane city centre in 2010 and 2012 found lower helmet wearing rates for riders on the footpath (93.8%) compared to the road (98.6%). In addition, helmet wearing rates may potentially be lower for footpath riding in suburbs where the ride might be part of a short trip that does not include much road riding. As mentioned earlier, the limited number of sites prevented direct comparisons of the effects of road versus path riding on compliance.

The small number of riders observed using bicycles from the public bicycle scheme (CityCycle) prevents any reliable comparison between helmet use by riders of public and private bicycles. All of the 28 riders of CityCycle bicycles observed in the current study were wearing helmets. This is consistent with the observational studies in the Brisbane city centre in 2010 and 2012 which included 138 riders of CityCycle bicycles and found their helmet wearing rates to be the same as riders of private bicycles (96.4% vs 97.6%).

Due to the observational nature of this study, it was not possible to ascertain if any of the non-compliant riders were exempted from using a helmet (as described earlier in Section 2.1) or to collect information about some variables that may affect helmet wearing rates, such as education, income, residential location, composition of household, perceptions about helmet use and safety. Information about these variables could be collected using a survey or interview method, but this approach may produce response bias (Karkhaneh et al., 2011). Observation of cyclists followed by conducting a survey/interview with cyclists stopped at a location downstream of the observation point could be a potentially feasible improved approach for future research.

4.2 Representativeness of the data

It was not feasible to collect data at all riding locations across Queensland, at all times of the day and on all days of the year. Therefore it is necessary to assess how representative the data are likely to be of compliance across Queensland.

While the data were only collected on four days of the week (Thursday to Sunday), the differences in helmet wearing rates by day of week were not large (ranged between 99.5% and 96.5%). If it is assumed that helmet wearing rates during weekdays are similar, then the data are representative of riding on all days of the week. The lack of an effect of holiday periods on helmet wearing rates in the study suggests that the overall results are representative of both holiday and non-holiday periods. All of the data were collected in April and May (autumn in Australia) and it is unclear whether helmet wearing rates in those months are representative of all times of the year. While it was not possible to statistically test the representativeness of the data collected in this study in terms of age and gender distribution as accurate age and gender information was not possible to be collected from observation of riders, it is reasonable to assume that the age and gender distribution is representative of riders in Queensland because of the large number of cyclists observed.

The sites chosen for data collection were not a random sample of all roads and off-road bike paths across Queensland but were chosen because it was expected that there would be an adequate number of riders observed at those sites. It is not possible to determine whether the helmet wearing rates would be the same at sites where there were fewer riders but there did not appear to be any correlation between number of riders observed at a site and the helmet wearing rate in the current study. Almost all of the observations were conducted in South East Queensland, with only 1% coming from two sites at Rockhampton. The helmet wearing rates at the Rockhampton sites were similar to those at the other sites, suggesting that the helmet wearing rates may be similar across regional cities. However, it is unclear whether helmet wearing rates would be similar in smaller towns and rural and remote areas. It should be noted, though, that potentially most of the bicycle riding in Queensland occurs in the regions covered by the study.

5. Conclusions

There is a very high level of compliance with Queensland's compulsory helmet wearing laws, but the compliance levels vary by the characteristics of riders, cycles, riding location, and riding pattern. While statistically significant differences were observed among these characteristics, the differences were small in terms of percentage points. However, these small differences need to be treated as important in order to further improve the current high level of compliance. The results showed that cyclists riding on roads have a lower level of compliance than those riding on bicycle paths, but no significant differences were observed between the school-holiday and school-term periods. Among the cyclists who ride on roads, lower compliance levels were found for children than adults, boys than girls, mountain bike riders than road bike riders, everyday clothing worn riders than lycra-clad riders, individual riders than group riders, morning hours than other time periods, and lower speed limit roads (50 km/h or lower) than most urban roads (60 km/h). While the overall level of compliance was very high, certain subgroups were identified as a possible focus for interventions to further improve the compliance level, for example children (particularly boys) riding mountain bikes away from groups during the afternoon hours on 60 km/h roads.

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