Accident Analysis and Prevention 53 (2013) 78–88

Contents lists available at SciVerse ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

The effectiveness of helmets in bicycle collisions with motor vehicles: A case–control study

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ARTICLE INFO

Article history:
Received 22 August 2012
Received in revised form
29 November 2012
Accepted 2 January 2013

Keywords:
Bicycles
Helmets
Head injury
Brain injury
Motor vehicle collisions

ABSTRACT

There has been an ongoing debate in Australia and internationally regarding the effectiveness of bicycle helmets in preventing head injury. This study aims to examine the effectiveness of bicycle helmets in preventing head injury amongst cyclists in crashes involving motor vehicles, and to assess the impact of 'risky cycling behaviour' among helmeted and unhelmeted cyclists. This analysis involved a retrospective, case–control study using linked police-reported road crash, hospital admission and mortality data in New South Wales (NSW), Australia during 2001–2009.

The study population was cyclist casualties who were involved in a collision with a motor vehicle. Cases were those that sustained a head injury and were admitted to hospital. Controls were those admitted to hospital who did not sustain a head injury, or those not admitted to hospital. Standard multiple variable logistic regression modelling was conducted, with multinomial outcomes of injury severity.

There were 6745 cyclist collisions with motor vehicles where helmet use was known. Helmet use was associated with reduced risk of head injury in bicycle collisions with motor vehicles of up to 74%, and the more severe the injury considered, the greater the reduction. This was also found to be true for particular head injuries such as skull fractures, intracranial injury and open head wounds. Around one half of children and adolescents less than 19 years were not wearing a helmet, an issue that needs to be addressed in light of the demonstrated effectiveness of helmets. Non-helmeted cyclists were more likely to display risky riding behaviour, however, were less likely to cycle in risky areas; the net result of which was that they were more likely to be involved in more severe crashes.

1. Introduction

Mechanisms of active travel such as cycling, whether solely for sport and recreation or as a means of transport, can contribute towards population-level health benefits, however cycling also poses a risk of injury. Many of the serious and fatal injuries involve cyclists sustaining head injuries, and one of the mechanisms proposed to reduce the severity of head injury has been helmets (Cummings et al., 2006).

In Australia, the state of Victoria was one of the first regions worldwide to introduce mandatory helmet legislation for cyclists on public roadways in 1990, with the remaining Australian states introducing mandatory helmet legislation over the following two years. To date, there has been ongoing debate regarding the effectiveness of cycling helmets in preventing head injuries (Curnow, 2003; Thompson et al., 1999; Walter et al., 2011).

Prior studies that have examined this issue have been population-based cohorts (Povey et al., 1999; Scuffham and Langley, 1997; Scuffham et al., 2000; Tin Tin et al., 2010; Walter et al., 2011) and case–control studies (Amoros et al., 2012; Hansen et al., 2003; Heng et al., 2006; Maimaris et al., 1994; McDermott et al., 1993; Spaite et al., 1991; Thomas et al., 1994; Thompson et al., 1989, 1996). While the case–control studies have typically shown that helmets reduce the odds of head injury to some extent, they have had conflicting findings as to the magnitude of the reduction experienced. This is largely due to different study inclusion criteria, particularly in relation to the type of injury experienced (i.e. head, neck, or facial injury) and its severity, and the type of helmet worn (i.e. hard or soft shell).

Case–control studies are a valid method to examine whether helmets worn during cycling are effective in preventing head injury among cyclists (Cummings et al., 2006). Yet some of the previous case–control studies have had limitations. For example: (i) not all were population-based, with some studies only including a sample of trauma centres and/or hospitals, limiting the generalisability of

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http://dx.doi.org/10.1016/j.aap.2013.01.005

the results; (ii) some studies only had a relatively small number of cases, which precluded any in-depth examination of some risk factors, such as age, or the examination of different types of head injuries and their severity; (iii) not all studies included deaths that occurred outside the hospital system, which would underestimate injury severity estimates; (iv) not all studies examined the severity of the injury sustained by the cyclist; and (v) only one case–control study examined factors directly related to 'risky riding behaviour' in their analysis of alcohol intoxication (Heng et al., 2006). The limitations of previous case–control studies need to be addressed in order to determine whether bicycle helmets are an effective means of preventing head injury amongst cyclists in collisions with motor vehicles, or whether helmets are able to contribute towards a decrease in the severity of the injury experienced.

Risk compensation and homeostasis theories assume that an individual will change their risk taking behaviour based on how they perceive the level of actual risk (Lardelli-Claret et al., 2003). In relation to cycling, it has been argued that helmeted cyclists may be more cautious and therefore may be more likely to ride more carefully and/or in safer locations (for example, in parks, playgrounds, cycle paths) than unhelmeted cyclists, thus the cautious behaviour could account for the reduction in the experience of head injury in helmeted cyclists (Robinson, 2007). On the other hand, it has also been argued that helmeted cyclists could ride more recklessly as they feel more protected and as a result they are more likely to be involved in crashes (Thompson et al., 1996). The impact of risky cycling behaviour needs further investigation.

This study aims to use a case–control methodology to examine the effectiveness of bicycle helmets in preventing head injury amongst cyclists in crashes involving motor vehicles in New South Wales (NSW), Australia during 2001–2009, and to assess the impact of 'risky cycling behaviour' among helmeted and unhelmeted cyclists. While there have been many case–control studies assessing the protective effect of helmets, the novel aspects of the present study include the use of linked data, the inclusion of many possibly confounding variables determined from police crash reports, the restriction to only motor vehicle collisions on public roadways, the inclusion of cyclist casualties that did not require hospital treatment and the use of multinomial outcome logistic regression models to model the severity of the head injuries sustained. A number of limitations identified in previous case–control studies are addressed.

2. Methods

This is a retrospective case–control study using linked police-reported road crash, hospital admission and mortality data in NSW.

2.1. Data collections

The Admitted Patient Data Collection (APDC) includes information on all inpatient admissions from all public and private hospitals, private day procedures, and public psychiatric hospitals in NSW. The APDC contains information on patient demographics, source of referral, diagnoses, external cause(s), separation type and clinical procedures. Diagnoses and external cause codes are classified using the International Classification of Diseases, 10th Revision, Australian Modification (ICD-10-AM) (National Centre for Classification in Health, 2006). The NSW Registry of Births, Deaths and Marriages (RBDM) records information on all deaths in NSW and contains information on basic demographics and the date of death.

The CrashLink data collection contains information on all police-reported road traffic crashes where a person was unintentionally fatally or non-fatally injured, or at least one motor vehicle was towed away and the incident occurred on a public road in NSW. Information pertaining to the crash and conditions at the incident site, the traffic unit or vehicle, and the vehicle controller and any casualties resulting from the crash are recorded. Each individual is identified as being non-injured, injured or killed (died within 30 days). Data were extracted for pedal cyclists involved in collisions with motor vehicles that were injured or killed, and are termed 'cyclist casualties'. Data for cyclists that were non-injured were excluded, since these incidents are rarely reported to police and the group is thus difficult to identify and may suffer from selection bias. Data were extracted from all data collections from 1 January 2001 to 31 December 2009.

2.2. Data linkage

The APDC and the RBDM data collections were linked to CrashLink by the Centre for Health Record Linkage (CHeReL). The CHeReL uses identifying information (e.g. name, address, date of birth, gender) to create a person project number (PPN) for each unique person identified in the linkage process. The record linkage used probabilistic methods and was conducted using *ChoiceMaker* software (Choicemaker Technologies, 2012). A successful link with CrashLink was defined as when the PPN matched in both data collections, and the admission date in the APDC was on the same day or the next day as the crash date, or the death date in the RBDM was on the same day or within 30 days of the crash date.

2.3. Injury identification

Head injuries were defined as those that affected the skull and brain only. Specific injury categories considered include skull fractures (i.e. vault, base and other or multiple skull fractures; ICD-10-AM: S02.0, S02.1, S02.7, S02.8, S02.9), intracranial injury (i.e. concussive, diffuse or focal brain injury; ICD-10-AM: S06), open wounds (of the scalp; ICD-10-AM: S01.0, S01.83), and head injury generally (i.e. skull fractures, intracranial injury, open wounds and multiple or other head injury; ICD-10-AM: S01.0, S01.83, S02.0, S02.1, S02.7, S02.8, S02.9, S06, S09.7, S09.8, S09.9).

Injuries to body regions other than the head were identified by ICD-10-AM injury codes S10 – T89 excluding the head injury codes previously mentioned. There were 42 cyclist fatalities resulting from collisions with motor vehicles during the study period, and in 24 (57.1%) cases no injury information could be obtained. These 24 cases were excluded from the study population.

2.4. Injury severity

Injury severity was calculated directly from the ICD-10 injury codes, using the probability of survival for each individual code, termed a Survival Risk Ratio (SRR). The SRR for an ICD code is the proportion of survivors among all cases with that ICD-coded injury. The procedure has been compared with the Abbreviated Injury Scale (AIS) and has proved equivalent or superior in assessing mortality (Davie et al., 2008; Stephenson et al., 2004). In a separate study using the APDC for all land transport trauma, the hospital records for 109,843 individuals were used to generate SRRs for all ICD-10 injury codes during 2001–2007 (Bambach et al., 2012). These data represent a census of all land transport trauma in NSW during the period, and for each ICD injury (ICD_i) the SRR was calculated from Eq. (1). The SRRs for the head injury codes relevant to the present study are presented in Appendix A. The mean SRRs for the AIS categories of serious (AIS 3) and severe (AIS 4) were identified as 0.965 and 0.854, respectively (AAAM, 2005). These values are used in the present study for identifying serious and severe injury using