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Incidence, risk, and protective factors of bicycle crashes: Findings from a prospective cohort study in New Zealand ☆

Sandar Tin Tin *, Alistair Woodward, Shanthi Ameratunga

Section of Epidemiology Biostatistics, School of Population Health, University of Auckland, Auckland, New Zealand

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ABSTRACT

Objective. To estimate the incidence and risk of medically or police attended bicycle crashes in a prospective cohort study in New Zealand.

Method. The Taupo Bicycle Study involved 2590 adult cyclists recruited from the country's largest cycling event in 2006 and followed over a median period of 4.6 years through linkage to four administrative databases. Incidence rates with Poisson distribution confidence intervals were computed and Cox regression modelling for repeated events was performed.

Results. The 66 on-road crashes and 10 collisions per 1000 person-years corresponded to 240 crashes and 38 collisions per million hours spent road cycling. The risk increased by 6% and 8% respectively for an extra cycling hour each week. There were 50 off-road crashes per 1000 person-years. Residing in urban areas and in Auckland (region with the lowest level of cycling), riding in a bunch, using a road bike and experiencing a previous crash predicted a higher risk. Habitual use of conspicuity aids appeared to lower the risk.

Conclusion. The risk is higher in urban areas and where cycling is less common, and increased by bunch riding and previous crashes. These findings alongside the possible protective effect of conspicuity aids suggest promising approaches to improving cycle safety.

Introduction

Regular cycling provides significant health (Andersen et al., 2000; Bassett et al., 2008; Oja et al., 2011) and other benefits (Higgins, 2005; Litman, 2012). Despite this, cycling is not a popular mode of travel in New Zealand (Tin Tin et al., 2009) and accounts for only 2% of total travel time (Ministry of Transport, 2012a). While the bicycle is increasingly used for sport and recreation activity, just over one-fifth of adults reported engaging in either road cycling or mountain biking at least once over twelve months in the most recent national survey (Sport New Zealand, 2009).

For many people, safety concerns are a major barrier to riding a bicycle (Kingham et al., 2009; Mackie, 2009; Winters et al., 2011) and it is true that cyclists bear a higher risk than most other types of road users if time-based exposure is considered (Tin Tin et al., 2010; Wardlaw, 2002). For each million hours spent cycling on New Zealand roads, 29 deaths or injuries resulted from collisions with a motor vehicle (cf. 10 car driver deaths/injuries, 7 car passenger deaths/injuries and 5 pedestrian deaths/injuries) (Ministry of Transport, 2012b) and 31 injuries resulted in death or hospital inpatient treatment (cf. 2 driver injuries, 3 car passenger injuries and 2 pedestrian injuries) (Tin Tin et al., 2010). Furthermore, almost as many bicycle crashes occurred off-road (Munster et al., 2001).

Current statistics and epidemiological research in New Zealand and elsewhere (Amoros et al., 2011; Beck et al., 2007; Boufous et al., 2012; Buehler and Pucher, 2012; Garrard et al., 2010; Ministry of Transport, 2012b; Tin Tin et al., 2010) typically refer to a single official data source, either police reports or hospital records, which are known to undercount bicycle crashes (Elvik and Mysen, 1999; Langley et al., 2003; Tercero and Andersson, 2004). Other studies have relied on cross-sectional survey data (Aultman-Hall and Kaltenecker, 1999; Heesch et al., 2011; Moritz, 1997) thereby failing to account for reverse causation and potential biases (af Wåhlberg et al., 2010; Jenkins et al., 2002; Tivesten et al., 2012). Few prospective studies have reported the incidence and correlates of bicycle crash injuries (de Geus et al., 2012; Hoffman et al., 2010) but the findings could have been biased by differential loss to follow-up (Greenland, 1977).

This paper investigated the incidence of attended bicycle crashes and associated factors in a cohort of cyclists followed over a median period of 4.6 years. Attended bicycle crashes include those resulting in an admission to hospital, notification to the police or the Coroner (Medical Examiner), or a claim lodged with the Accident Compensation Corporation

* Corresponding author at: Section of Epidemiology and Biostatistics, School of Population Health, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
E-mail addresses: s.tintin@auckland.ac.nz (S. Tin Tin), a.woodward@auckland.ac.nz (A. Woodward), s.ameratunga@auckland.ac.nz (S. Ameratunga).

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(ACC), the government-funded universal no-fault injury compensation scheme.

Methods

Design, setting and participants

The Taupo Bicycle Study is a prospective cohort study with the sampling frame comprising cyclists, aged 16 years and over, who enrolled online in the Lake Taupo Cycle Challenge, New Zealand's largest mass cycling event held each November. Participants have varying degrees of cycling experience ranging from competitive sports cyclists to relative novices of all ages.

Recruitment was undertaken at the time of the 2006 event. Detailed methodology was described elsewhere (Thornley et al., 2008). In brief, email invitations, containing a hyperlink to the study information page, were sent to 5653 contestants who provided their email addresses at registration for the event. Those who agreed to participate in the study were taken to the next page containing a web questionnaire and asked about demographic characteristics, general cycling activity and crash experience in the past twelve months, and habitual risk/protective behaviours with options ranging from never to always. Copies of the questionnaire can be obtained from the authors. The questionnaire was completed and submitted by 2438 cyclists (43.1% response rate). Another 190 cyclists were recruited from the 2008 event by including a short description about the study in the event newsletter. Ethical approval was obtained from the University of Auckland Human Participants' Ethics Committee.

All participants were resurveyed in 2009 using a web questionnaire. The questionnaire asked about changes in cycling activity and risk/protective behaviours, as well as crash experience in the past twelve months, and was completed by 1537 cyclists (58.5% response rate).

Injury outcome data

Injury outcome data were collected through record linkage to four administrative databases, covering the period from the date of recruitment to 30 June 2011. All participants consented to link their data to the following databases.

Insurance claims

In New Zealand, ACC provides personal injury cover for all residents and temporary visitors to New Zealand no matter who is at fault. The claims database is a major source of information on relatively minor injuries with over 80% of the claims related to primary care (e.g., GPs, emergency room treatment) only (Accident Compensation Corporation, 2012). Approval for record linkage was obtained from the ACC Research Ethics Committee.

Hospital discharge and mortality data

The hospital discharge data contains information about inpatients and day patients discharged from all public hospitals and over 90% of private hospitals in New Zealand. The mortality data contains information about all deaths registered in New Zealand. Diagnoses in each hospital visit and underlying causes of death are coded under ICD-10-AM. Bicycle crashes were identified using the E codes V10-V19; those that occurred on public roads were identified using the E codes V10-V18.3-9, V19.4-6, V19.9; and those that involved a collision with a motor vehicle were identified using the E codes V12-V14, V19.0-2 and V19.4-6. Readmissions were identified as described previously (Davie et al., 2011) and excluded.

Police reports

In New Zealand, it is mandatory that any fatal or injury crash involving a collision with a motor vehicle on a public road be reported to the police. This database therefore contains information on all police-reported bicycle collisions.

Match rate and data quality

There was a 99.0% match rate by the National Health Index number. The completeness of the linked data, based on the capture–recapture models, was 73.7% for all crashes, 74.5% for on-road crashes and 83.3% for collisions (Tin Tin et al., 2013). In comparison with self-reported data collected in 2009, the linked data had 63.1% sensitivity, 93.5% specificity and 59.0% positive predictive value for all crashes and 40.0% sensitivity, 99.9% specificity and 91.7% positive predictive value for collisions.

Analyses

The study sample was restricted to the 2590 participants who were resident in New Zealand at recruitment. All baseline data were complete for the 2435 participants (94.0%). Missing values were computed using multiple imputation with 25 complete datasets created by the Markov chain Monte Carlo method (Schafer, 1997), incorporating all baseline covariates and injury outcomes.

Bicycle crashes extracted through record linkage were categorised into on-road crashes (crashes that occurred on public roads) and others, as factors predicting these crashes may differ. Crashes involving a collision with a motor vehicle were also identified. As more than a single crash may be experienced during follow-up, incidence rates of repeated events were calculated using the person-years approach. Exposure-based incidence rates were also estimated for on-road crashes and collisions, using the average time spent road cycling at baseline. Confidence intervals were based on the Poisson distribution. The participants were censored on 30 June 2011 or date of death.

Cox proportional hazards regression modelling for repeated events was performed using a counting process approach and factors influencing the likelihood of experiencing crash episodes were identified. Hazard ratios (HRs) were first adjusted for cycling exposure and then adjusted for all covariates. SAS (release 9.2, SAS Institute Inc., Cary, North Carolina) was used for all analyses.

Probabilistic bias analyses (Lash et al., 2009) assessed the potential impact of outcome misclassification bias on association estimates, assuming that the sensitivity and specificity of the linked data ranged from 0.65 to 0.75 and from 0.94 to 0.99 respectively for on-road and other crashes and from 0.40 to 0.85 and from 0.98 to 1.00 respectively for collisions.

The impact of changes in exposures on association estimates was assessed by incorporating repeated measurements (at baseline and in 2009) of covariates in the Cox models. This analysis was restricted to 1526 cyclists who were resident in New Zealand and completed the second questionnaire.

Results

The participants' baseline characteristics are presented in Table 1. During a median follow-up of 4.6 years, six deaths occurred, of which one was due to a bicycle–car collision and five others were due to cancer. A total of 855 participants experienced 1336 bicycle crashes, of whom 32.4% experienced more than a single crash (Table 2). This corresponds to 116 crashes per 1000 person-years (95% CI: 109.93, 122.47) or 391 crashes per million hours spent cycling per year (95% CI: 370.38, 412.62).

On-road bicycle crashes

There were 66 crashes per 1000 person-years or 240 crashes per million hours spent road cycling per year (Table 3). The adjusted HR for one hour increase in average time spent cycling each week was 1.06 (95% CI: 1.05–1.08). Age over 35 years, residing in urban areas or in the Auckland region, riding in a bunch, using a road bike and history of a crash at baseline predicted a higher risk whereas being overweight or obese, cycling off-road and using lights in the dark lowered the risk. Bicycle commuting, however, did not increase the risk.

Bicycle crashes involving a collision with a motor vehicle

There were 10 collisions per 1000 person-years or 38 collisions per million hours spent road cycling per year (Table 4). The adjusted HR for one hour increase in average time spent cycling each week was 1.08 (95% CI: 1.05–1.12). Due to a very small number of events, "overweight" and "obese" categories were combined and helmet use was excluded in the multivariate models. Residing in urban areas, riding a road bike and having a crash history were associated with an increased risk.