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The relationship between visibility aid use and motor vehicle related injuries among bicyclists presenting to emergency departments

B.E. Hagel[a,b,c,*], N.T.R. Romanow[a], N. Morgunov[d], T. Embree[a], A.B. Couperthwaite[b], D. Voaklander[e], B.H. Rowe[f]

[a] Department of Paediatrics, Faculty of Medicine, University of Calgary, Alberta Children's Hospital, 2888 Shaganappi Trail NW, Calgary, Alberta T3B 6A8, Canada
[b] Department of Community Health Sciences, Faculty of Medicine, University of Calgary, Alberta, Canada
[c] Alberta Children's Hospital Research Institute for Child & Maternal Health, University of Calgary, Alberta, Canada
[d] Faculty of Nursing, University of Calgary, 2800 University Way N.W., Calgary, Alberta T2N 1N4, Canada
[e] School of Public Health, Alberta Centre for Injury Control & Research, University of Alberta, 4075 RTF, 8308-114 Street, Edmonton, Alberta T6G 2E1, Canada
[f] Department of Emergency Medicine & School of Public Health, University of Alberta, 1G1.50 Walter Mackenzie Centre, 8440-112 Street, Edmonton, Alberta T6G 2B7, Canada

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ABSTRACT

Background: Little is known about the effectiveness of visibility aids (VAs; e.g., reflectors, lights, fluorescent clothing) in reducing the risk of a bicyclist–motor-vehicle (MV) collision.
Purpose: To determine if VAs reduce the risk of a bicyclist–MV collision.
Methods: Cases were bicyclists struck by a MV and assessed at Calgary and Edmonton, Alberta, Canada, emergency departments (EDs) from May 2008 to October 2010. Controls were bicyclists with non-MV injuries. Participants were interviewed about their personal and injury characteristics, including use of VAs. Injury information was collected from charts. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated for VAs during daylight and dark conditions, and adjusted for confounders using logistic regression. Missing values were imputed using chained equations and adjusted OR estimates from the imputed data were calculated.
Results: There were 2403 injured bicyclists including 278 cases. After adjusting for age, sex, type of bicycling (commuting vs. recreational) and bicyclist speed, white compared with black (OR 0.52; 95% CI 0.28, 0.95), and bicyclist self-reported light compared with dark coloured (OR 0.67; 95% CI 0.49, 0.92) upper body clothing reduced the odds of a MV collision during daylight. After imputing missing values, white compared with black (OR 0.57; 95% CI: 0.32, 0.99) and bicyclist self-reported light compared with dark coloured (OR 0.71; 95% CI 0.52, 0.97) upper body clothing remained protective against MV collision in daylight conditions. During dark conditions, crude estimates indicated that reflective clothing or other items, red/orange/yellow front upper body clothing compared with black, fluorescent clothing, headlights and tail lights were estimated to increase the odds of a MV collision. An imputed adjusted analysis revealed that red/orange/yellow front upper body clothing colour (OR 4.11; 95% CI 1.06, 15.99) and tail lights (OR 2.54; 95% CI: 1.06, 6.07) remained the only significant risk factors for MV collisions. One or more visibility aids reduced the odds of a bicyclist MV collision resulting in hospitalization.
Conclusions: Bicyclist clothing choice may be important in reducing the risk of MV collision. The protective effect of visibility aids varies based on light conditions, and non-bicyclist risk factors also need to be considered.

1. Introduction

Bicycling injury prevention has focused on the high-quality case–control study evidence that bicycle helmets significantly reduce the risk of head injury (Attewell et al., 2001; Thompson et al., 2004). Other areas for bicycling injury prevention, including bicyclist visibility aids, have been less well studied and hold much promise in reducing the risk of a bicyclist motor vehicle (MV) collision. A Cochrane systematic review suggested that yellow, red

* Corresponding author at: Alberta Children's Hospital, University of Calgary, 2888 Shaganappi Trail NW, Calgary, Alberta T3B 6A8, Canada. Tel.: +1 403 955 7403; fax: +1 403 955 3055.
E-mail address: brent.hagel@albertahealthservices.ca (B.E. Hagel).

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and orange fluorescent clothing can improve driver detection and recognition of bicyclists during the day whereas lights and retroreflective materials may improve bicyclist conspicuity at night (Kwan and Mapstone, 2004). However, there is little evidence on the effectiveness of visibility aids in reducing the risk of a bicyclist being struck by a MV.

Wells et al. examined conspicuity in motorcyclists and found that reflective or fluorescent clothing, use of a white or light coloured helmet, and voluntary daytime headlight use reduced the risk of crash related injury with an indication that the effectiveness of reflective or fluorescent clothing may increase as light levels fall (Wells et al., 2004). Recent evidence from a cross-sectional study of bicyclists 16 and older who entered a mass-participation cycling event found that fluorescent clothing use was associated with fewer days off work for bicycling related injury (Thornley et al., 2008). Miller et al. published a protocol outlining a population based case-control study approach to examine the relation between conspicuity aids and adult commuter and utility bicyclist injuries but as yet no results have been published (Miller et al., 2010). Limited epidemiologic data exist on the relationship between visibility aids and risk of a bicycling injury and more studies will contribute to our knowledge base in this important area.

Despite assumptions that visibility aids are an important strategy to reduce the risk of bicyclist injury, and that bicyclists understand this association, studies suggest many riders do not use them. A recent observational study in Australia found that 38% of bicyclists had "high" frontal conspicuity, and that "high" rear conspicuity was 18% (Raftery and Grigo, 2013). A pilot study regarding the prevalence of visibility aid use among uninjured bicyclists in a Canadian city demonstrated a low prevalence of visibility aid use, with estimates of brightly coloured and white bicyclist headgear ranging from 17% to 19% and 13% to 14%, respectively (Hagel et al., 2007). In addition, less than one quarter of bicyclists had a front light, while half had a rear reflector (Hagel et al., 2007). Other studies have suggested only 10–32% visibility aid use for bicyclists and pedestrians (Mcguire and Smith, 2000; Mayr et al., 2003; Mulvaney et al., 2006).

1.1. Purpose

This study was designed to determine the effectiveness of visibility aids in reducing the risk of a bicyclist being struck by a MV and whether visibility aids reduce injury severity following collision. It is unlikely that visibility aid use will increase unless stakeholders such as parents, policy makers, and bicyclists have robust evidence that these aids are effective at reducing injury risk, hospitalization, or both in the event of a bicycle-MV collision.

2. Materials and methods

2.1. Data collection

Cases were bicyclists injured in a collision with a MV and assessed at one of the study emergency departments (ED). Controls were bicyclists with an injury that was not related to being struck by a MV. All controls were obtained from the same EDs as the cases, over the same time period. The study sites included all hospitals in Calgary (Alberta Children's Hospital, Foothills Medical Centre, Peter Lougheed Centre, Rockyview General Hospital), and a representative catchment of 3 hospitals in Edmonton (University of Alberta Hospital, Stollery Children's Centre, and Northeast Community Health Centre), Alberta, Canada. The EDs included the regional trauma centres for adult and paediatric patients in each city.

Injured bicyclists were screened for eligibility using the Regional Emergency Department Information System, and by reviewing ED records daily. Following written informed consent, bicyclists were interviewed in the ED using a structured questionnaire, which was based on previous work (Rivara et al., 1997; Wells et al., 2004), and pilot tested with a convenience sample of respondents. The information collected included demographics, clothing visibility, reflective devices, parental supervision (if less than 18 years of age), experience, and environmental conditions. Injury details were recorded from the patient's medical chart. If bicyclists were missed in the ED, they were mailed a study information package and contacted by telephone several days later. Upon verbal consent, a telephone interview was conducted. To assess data reliability, follow-up interviews using the same questionnaire were conducted by phone with a sub-sample of participants starting two weeks after the initial interview.

Non-English speaking bicyclists, bicyclists missed in the ED who had incomplete or invalid contact information, bicyclists riding indoor or on stationary bikes were not enrolled. Clear descriptions of mountain biking, BMX riding (including BMX track and skatepark locations), or stunt riding were classified as off-road riding and excluded for bicycling location (Fig. 1). Many of the individuals excluded for bicycling location were riding off-road in commercial terrain parks and are the subject of another paper (Romanow et al., 2012). However, in some instances it was difficult to determine from the participants' description if they were cycling in a location that would result in some exposure to motor vehicles and, as such, these cyclists were included in the analysis (see the variable "where riding" in Table 2).

The Conjoint Health Research Ethics Board at the University of Calgary and the Health Research Ethics Board at the University of Alberta approved this study.

2.2. Data analysis

We compared the frequency of visibility aid use for cases and controls. We also conducted a subgroup analysis among the cases comparing bicyclists who were injured in a MV collision and hospitalized with those who were injured in a MV collision, presented to the ED, and then were discharged (i.e., not hospitalized). The subgroup analysis evaluated whether visibility aid use resulted in less severe injuries due to the MV driver having more time to break through earlier detection of the bicyclist. The operational definitions for helmet and clothing colour were similar to those used in Hagel et al. (2007) and Wells et al. (2004). The colour groups were: (i) black (incl. dark grey/blue); (ii) white; (iii) red/orange/yellow; and (iv) other colours. To examine the potential relationship between time of travel and MV collision, a peak time variable was created. Weekday peak time was a combined variable that accounted for day and time of injury. Those bicycling between 06:31-08:30 and 16:01-18:00 Monday-Friday were coded as "yes" for travelling during peak time.

For the complete case analysis, we used multiple logistic regression to examine the independent effect, after adjusting for potential confounders (e.g., age, sex, type of bicycling [i.e., commuting vs. recreational], bicyclist self-reported speed), of each visibility aid. Separate analyses were conducted for daylight and dark conditions. Odds ratios (OR) and corresponding 95% confidence intervals (CI) were calculated. Potential confounders were chosen based on previous indication of a relationship to bicycling injury risk (Rivara et al., 1997; Bil et al., 2010; Chong et al., 2010). We chose to relax the "rule of thumb" of 10 events per variable in order to include these important confounders (Vittinghoff and Mcculloch, 2006). Due to the small number of cases included in the analysis for dark conditions, only crude estimates for each visibility aid were calculated.

Missing values were imputed using chained equations and a custom prediction imputation model (White et al., 2010) in