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Epidemiology and spatial examination of bicycle-motor vehicle crashes in Iowa, 2001–2011

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ABSTRACT

Purpose: To identify how person, crash, environment, and population characteristics differ between bicycle-motor vehicle crashes that occur at intersections and non-intersections.
Methods: The Iowa Department of Transportation crash database for the years 2001 through 2011 was used to identify bicycle-motor vehicle (BMV) crashes and associated person, crash, and environment characteristics. Population-level data were drawn from the 2010 U.S. Census and the 2010 American Community Survey. Descriptive statistics, GIS mapping, and multivariable logistic regression were used to examine factors associated with crash risk and crash location.
Results: Compared to intersections, non-intersection BMV crashes had higher odds of involving young bicyclists (< 10 years old; OR: 1.8, 95%CI: 1.2–2.6), location outside city limits (OR: 5.7, 95%CI: 3.9–8.3), with driver vision obscured (OR: 1.5, 95% CI: 1.2–1.8), reduced lighting on roadway (OR: 1.9, 95% CI: 1.5–2.4), and lower odds when the bicyclist (OR: 0.4, 95% CI: 0.3–0.6) or motorist (OR: 0.6, 95% CI: 0.4–0.8) failed to yield right of way.
Conclusions: Environmental factors, as well as developmental (age) and behavioral factors of bicycle-motor vehicle crashes vary by location (intersection/non-intersection). Results from this study can be used to tailor and target multiple intervention approaches, such as making infrastructure changes, increasing safety behavior among both motorists and bicyclists, and identifying which age groups and locations would most benefit from intervention.

1. Introduction

Bicycling has become increasingly popular worldwide in the past decade and continues to grow. More people are riding bicycles for both transportation and recreation purposes, attributed in part, to health and environmental benefits, avoidance of traffic congestion, rising gas prices, and changes in infrastructure to better accommodate bicyclists (Alliance for Biking and Walking, 2012; National Highway Traffic Safety Administration, 2008; Reynolds et al., 2009; Pucher et al., 2011a,b). However, in the United States the number of bicycle crashes remain high and the fatality rates are 10.9 times higher per billion kilometers traveled and 2.3 times higher per 100 million person-trips for bicycles in comparison to passenger vehicles (Pucher and Dijkstra, 2000; Beck et al., 2007).

Research examining causes and prevention of bicycle crashes has lagged behind the growth of bicycling in the United States. Bicycle safety research is increasing, but the focus is often on large metropolitan areas, overlooking rural areas, small towns, and small metropolitan areas (Pucher et al., 2011a,b). These overlooked areas have not been immune to the surge in bicycling and positive changes in bicycling infrastructure (Rails-to-Trails Conservancy, 2012, Pucher et al., 2011a,b). As of 2009 commuting mode share via bicycle in small rural core areas was almost double that of urban cores (1.61% vs. 0.83%) and rural areas received almost twice the amount of federal

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funding per capita for improvements in cycling and walking infrastructure through the Transportation Enhancements program (Rails-to-Trails Conservancy, 2012).

Existing evidence on bicycle-motor vehicle (BMV) crashes within the U.S. has found that non-intersection crashes are less prevalent than intersection crashes and have more severe injuries with over half (59%) of all bicyclist fatalities occurring at non-intersections (e.g., National Highway Traffic Safety Administration, 2013; Moore et al., 2011). However, the characteristics that account for these differences between intersection and non-intersection crashes have not been fully evaluated, which is especially true for sparsely populated areas, like the mostly rural state of Iowa.

The objective of this study is to examine the characteristics and factors associated with BMV crash occurrence, overall, and to determine which factors are attributable to where crashes happen: intersections vs. non-intersections. We examine bicycle crashes in Iowa from 2001 to 2011 across four categories of factors related to those crashes: person, crash, environment, and population. We hypothesized that intersection and non-intersection crashes will have different attributes across all four categories of variables.

2. Methods

2.1. Design and data

This cross-sectional study uses person, crash, and environment data from the State of Iowa Department of Transportation (DOT) crash database for years 2001–2011. This database contains all motor vehicle crashes (MVCs) that were reported via a police report or driver's report. The dataset was reduced to bicycle crashes only by selecting non-motorist or seating type as “pedalcyclist” or “pedalcyclist passenger”. The crash database is organized hierarchically with multiple subsets of data starting at the crash-level and ending at the person-level. These subsets were linked by crash key and person (bicyclist) identifiers, resulting in a bicyclist-level dataset. Less than two percent ($N=76$) of the bicyclists in this dataset were in crashes that involved more than one bicyclist. All identified bicycle-related crashes included in this dataset involved at least one motor vehicle. There were 185 (4.2%) crashes that involved more than one vehicle/driver. In these scenarios we included only one driver and corresponding vehicle that was indicated in the crash data to have been the one to collide with the bicyclist. Other driver and vehicle information was removed. We examined all bicycle crashes (injury and non-injury) in order to determine predictors of crash location (intersection or non-intersection).

Education (high school and bachelor's degree) and household income by census tract were obtained from the American Community Survey (2010). Population density by zip code tabulation area (ZCTA) was obtained from the 2010 U.S. Census. These population-level data were obtained via the American Fact Finder web site (U.S. Census Bureau, 2012).

The *X* and *Y* coordinates of crash locations from the DOT dataset were used to map crash locations using ArcGIS software (ESRI, 2011). These were captured via GPS readings, recorded by the reporting law enforcement officers. ArcGIS was also used to spatially identify the zip code tabulation area (ZCTA) and census tract of each crash. A ZCTA is a U.S. Census entity that approximates a zip code area. Census tracts are larger than ZCTAs. ZCTAs were used for population density in this study because they are small enough to approximate variations in population density as one would travel through a town. Census tracts were used for education and household income because they were the smallest division available for which reliable data could be assigned. Crash locations were spatially joined to population density by ZCTA and education and income by census tract, and appended to the crash dataset to be included in analyses.

2.2. Intersection vs. non-intersection crashes

The main outcome used for this analysis was crash location: intersection or non-intersection. This location was determined using the geo-mapped crashes and the road type variable in the Iowa DOT dataset. For this study, intersections are defined as locations where two roadways meet, including the following: four-way, T, Y, five-leg or more, offset four-way, intersection with ramp, on-ramp merge area, off-ramp diverge area, on-ramp, off-ramp, with bike/pedestrian path, or other intersection. Non-intersections are those reported as one of the following: non-intersection no special feature, bridge/overpass/underpass, railroad crossing, business drive, farm/residential drive, alley intersection, crossover in median, or other non-intersection.

2.3. Person, crash, and environment variables

Person variables included age and gender of bicyclist and motorist and safety devices of bicyclist (helmet, reflective clothing, lighting). Crash characteristics included motor vehicle type and action, day of week, time of day, season, location (urban/rural), motorist and bicyclist contributing circumstances (e.g. failure to yield right of way), and major cause (both motorist and bicyclist, motorist only, bicyclist only, neither). Environmental characteristics included posted speed limit, vision obscurement (yes/no), surface conditions (dry, wet, other), and reduced lighting (yes/no). Person, crash, and environmental characteristics were all obtained from the Iowa DOT crash database. Actual or estimated speed were not available in our dataset and only a small number of crashes ($N=12$) were attributed to the driver exceeding authorized speed, therefore the examination of speed in this study is limited to posted speed limit.

2.4. Population variables

Population-level characteristics included population density by ZCTA, education by census tract (high school degree or higher, bachelor's degree or higher), and annual household income by census tract. Population density was categorized into quartiles, based on Iowa's population distribution in the 2010 census and then each ZCTA was assigned to one of the resulting four categories. Education and annual household income were categorized into above or below state median for each census tract. In addition to being locally informative, these variables also allow for comparison across the entire United States, as they are nationwide US Census measures.

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