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Motor-vehicle collisions involving child pedestrians at intersection and mid-block locations

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ABSTRACT

We study motor-vehicle collisions involving child pedestrians walking to school in Hamilton, Ontario, Canada to understand and contrast collision risks at mid-block and intersection locations. We use a matched case–control study design and apply it to intersection and mid-block locations instead of people. Cases are intersections/mid-blocks where collisions occurred and controls are locations where collisions did not occur. We match cases to controls on geography, socio-economic status and year. We use conditional logistic regression to predict the log-odds of collision risk at intersections and mid-blocks as a function of various environmental measures while controlling for volume of child pedestrian activity. Our results suggest that child pedestrian injuries at intersections are associated with intersection control type, traffic volume, and land use characteristics. In contrast, mid-block child pedestrian collisions are not associated with small scale environmental features. The results of this study suggest that some factors associated with the risk of collision differ across location types. These findings may be useful in the planning of safer walking journeys to school.

1. Introduction

Child pedestrian injuries – resulting from collisions between child-pedestrians and motor-vehicles – are a leading cause of injury related deaths for Canadian children aged 14 years and under (Safe Kids Canada, 2009). Prevention of child pedestrian injuries is challenging, but both educating children on road safety and modifications to the environment seem to reduce risk of injury and mortality (Desapriya et al., 2011; Carver et al., 2008; Donroe et al., 2008). While changes in the urban environment can be more costly to implement compared to safety education programs, they may also be more effective in minimizing injuries to child pedestrians (DiMaggio and Li, 2012). As such, there remains interest in understanding how modification of the built environment can reduce child pedestrian injury (Mecredy et al., 2011).

Considerable research has linked aspects of roadway infrastructure and other aspects of the built environment to the risk of collision between child pedestrians and motor-vehicles over the last 25 years. Stevenson et al. (1993) found that arterial roads were associated with more severe injuries to child pedestrians than smaller local roads. Children were found to be at greater risk of injury on roadways with more than two lanes of traffic compared to roadways with fewer lanes (Dougherty et al., 1990). The speed of traffic is also an important influence on a child's risk of injury (Donroe et al., 2008; Roberts et al., 1995), with a greater effect on risk than number of vehicle lanes and other attributes of the road environment (Mueller et al., 1990). Several studies have found a positive association between motor-vehicle traffic volume and risk of child pedestrian injury (Yiannakoulias and Scott, 2013; Morency et al., 2012; Donroe et al., 2008; LaScala et al., 2004; Stevenson et al., 1996, 1995; Stevenson, 1997; Roberts et al., 1995; Mueller et al., 1990). Curb side parking has been found to increase a child's risk of injury as parked cars are thought to obstruct the visibility of both drivers and children (Roberts et al., 1995; Stevenson et al., 1996; Stevenson, 1997). Land-use was also found important for understanding child pedestrian injuries, where children living in multi-family dwellings, (such as apartment buildings) are at a greater risk of collision than children living in single family dwellings (Agran et al., 1996).

Collisions between pedestrians and motor-vehicles occur at both intersection and mid-block locations, and understanding environmental risks in both these settings are critical for devising informed injury prevention strategies (Lightstone et al., 2001). Previous research shows that the majority of child pedestrian injuries occur at mid-block locations; for example, Oxley et al. (2012) and Lightstone et al. (2001) found that 59.4% and 62.3% of

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collisions between child pedestrians and motor-vehicles occurred mid-block, respectively. Using data from police reports, Brustman (1999) found that collisions between motor-vehicles and pedestrians where the pedestrian is at fault occur more frequently at mid-block locations, while collisions between motor-vehicles and pedestrians where the driver is at fault occur more frequently at intersections. The shortest path for a pedestrian to reach a destination – such as entrances to school yards – often involves crossing roads at mid-block locations (Sandt and Zegeer, 2006), and could partly explain why the proportion of child pedestrian injuries that occur at mid-block locations increases with closer proximity to a school (Walsh et al., 2009). Similarly, the concentration of paths to school very likely increases as a child gets closer to their school destination. However, the differences between intersection and mid-block collision risk are also due to differences in these environments. The majority of mid-block collisions occur at locations with no signals or crosswalk present; in contrast, most intersection collisions occur at intersections with signals or stop signs present (Ha and Thrill, 2011; Sandt and Zegeer, 2006). Mid-block injuries frequently occur on roads with lower traffic volume, two lanes of traffic or less and with a posted speed limit of 25 miles per hour or less (Agran et al., 1994; Sandt and Zegeer, 2006). In contrast, child pedestrian injuries occurring at intersections tend to happen on roads with moderate to heavy traffic volume, more than two lanes of traffic and with a posted speed limit of greater than 25 miles per hour (Agran et al., 1994).

The objective of this study is to identify and differentiate small scale features of the transportation environment that are associated with motor-vehicle collisions involving child pedestrians at mid-block and intersection locations. Our analysis is unique since it is at a small geographical scale but is representative of an entire urban environment. We also attempt to account for different levels of child pedestrian activity at different locations in the transportation system. Our hope is to enhance general understanding of how small scale features of the transportation environment differentially influence risk of collisions at intersection and mid-block locations, and secondarily, assess the effect of using child pedestrian activity information on small scale analyses of pedestrian safety generally.

2. Material and methods

Our study area is Hamilton, Ontario, Canada, and is located midway between Toronto, Ontario, Canada and Buffalo, New York, USA on the western end of Lake Ontario.

2.1. Data

2.1.1. Collision data

We use a pedestrian-motor-vehicle collision database maintained by the City of Hamilton to obtain information on pedestrian collisions involving motor vehicles. Minor collisions that did not involve police or other emergency services are not included in the database. The database includes collisions that occurred from 2002 to 2011 inclusively. We restrict our study to collisions involving children aged 5–14 that occurred on weekdays, during the months from September to June and occurred between 7:00 am and 5:00 pm. These time and date restrictions are used to restrict our analysis to injuries that are likely to occur when school aged children commute to or from school. All the collision locations are geo-coded to a location on a road network. The location represents approximately where the collisions occurred and can be located at mid-blocks or at intersections. If the collision occurred 10 m or less from an intersection then it was classified as an intersection collision, otherwise, the collision was classified as a mid-block collision.

2.1.2. Road and intersection data

We created a detailed pedestrian road database based on a road database provided by the City of Hamilton (2010). Off-road pedestrian infrastructure, including trails and pathways, was manually added to the database using a map produced by the City of Hamilton (2005). Short-cuts (including walking across green spaces and schoolyards) and unmarked pedestrian infrastructure were verified using Google Earth imagery (Google Inc., 2015). Roads classified as “expressways” and “major highways” are excluded from the pedestrian road database because walking is prohibited on these roadways. The pedestrian road database is comprised of interconnected sets of segments each with a unique identifier. A segment refers to an individual line digitized within the pedestrian road database; all road and off-road infrastructure in the database is made up of multiple segments. For segments along roadways (primarily sidewalks), the database contains information on road attributes such as road classification, speed limit, and if it is a one-way road. Other sources of digital data made available by the City of Hamilton were linked to the pedestrian road database, including: transportation signs (speed limit signs, chevron warning signs and general information signs), bus stops, fire hydrants, bike lanes, and sidewalks. The length of each segment in meters was calculated using a geographic information system.

We also created a database containing information on each individual intersection in the study area. The resulting intersection database contains location information on crossing guards, signalized intersection controls, and yield or stop sign intersection controls. We also calculated mean speed limit, defined as the mean of the speed limit of the segments travelling through the intersection and one-way, a dummy variable indicating if any of the segments connected to the intersection are a one-way road, for each intersection in the database.

Land use information was added to both the pedestrian road and intersection databases using parcel land information (Teranet Inc., 2010). The land use data are classified into five discrete categories: residential, commercial, industrial, institutional and vacant or open space. Estimated traffic volume is also added to the road and intersection databases. For the intersection database, the mean traffic volume for each intersection was calculated using the traffic flow estimates for all segments travelling through the intersection. We used the methods outlined by Morency et al. (2012) to estimate traffic volume for the study area. Using journey to work data from Statistics Canada (2008a) we generated an origin-destination table to represent trips taken by drivers living within the study area. We then used a trip allocation model that incorporates road capacities to estimate the traffic volume on the roads in the original road database that included major highways and expressways. The estimated volumes for road segments were compared to traffic counts from 62 locations in the City of Hamilton, and correlated modestly ($R = 0.56$). This value is similar to the correlation result presented in Morency et al. (2012).

2.1.3. Child pedestrian injury clustering distance

We used a spatial scan clustering detection method to determine the critical distance at which child pedestrian injuries cluster around primary public school locations. This method provides a value indicating the distance from schools at which the largest magnitude of clustering occurs (Yiannakoulias and Bland, 2012). The result from the focused spatial scan clustering detection method is a distance value of 150 m Euclidean distance away from schools. Case and control locations are classified as within or not within this critical distance, and this indicator is used as a variable in our analysis to control for the effect of school-related traffic volume that may not be accounted for in the motor-vehicle traffic volume estimation above.