Journal of Transport Geography xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Transport Geography

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

A geography of child and elderly pedestrian injury in the City of Toronto, Canada

Emily Grisé[a,*,1], Ron Buliung[a], Linda Rothman[b], Andrew Howard[c,d]

[a] Department of Geography and Programs in Environment, University of Toronto Mississauga, 3359 Mississauga Road, Mississauga, ON L5L 1C6, Canada
[b] Faculty of Health-School of Kinesiology & Health Science, York University, Norman Bethune College, Canada
[c] Child Health Evaluative Sciences, Departments of Surgery & Health Policy, Management & Evaluation, University of Toronto, Canada
[d] Orthopedic Surgery, The Hospital for Sick Children, Canada

ARTICLE INFO

Keywords:
Pedestrian motor vehicle collisions
Age
Spatial analysis
Built environment

ABSTRACT

Walking is one of the most accessible forms of physical activity for people of all ages. Promoting increased walking for transport may contribute to reduced air pollution, noise and traffic congestion. Understanding the geography of pedestrian motor vehicle collisions (PMVCs) can provide evidence to inform policy and planning that targets increased walking while reducing pedestrian injury risk, however age-related differences in the geography of injury are expected given differences in activity patterns and physical and cognitive abilities. The purpose of this paper is to explore spatial patterns of pedestrian motor vehicle collisions (PMVCs) by age, injury severity, and location in Canada's largest city, the City of Toronto. Geographical variation in PMVCs and injuries by age (namely seniors and children) and severity were explored using indirect standardized rates. Moran's *I* statistics were estimated to study the spatial clustering of PMVCs across urban and inner suburban neighbourhoods. Distinct spatial patterns of PMVCs and injuries were evident among children and seniors. While evidence of spatial clustering was indicated for both age groups, children's injuries revealed the strongest clustering, while PMVCs involving seniors were more dispersed. Furthermore, fatal and major injury events appeared to be concentrated toward and within Toronto's inner suburbs for both age groups. Findings from this study demonstrate the importance of planning pedestrian safety interventions that acknowledge spatial differences in geographic patterns of PMVCs by age.

1. Introduction

Walking for transport has the potential to contribute to reduced air pollution, noise and traffic congestion, while also providing a form of physical activity that is widely accessible for individuals of all ages. While such benefits may accumulate, to the individual and broader society, without question the act of walking in many cities presents some risk of injury and even fatality, particularly in the presence of a modernist legacy of planning for and accommodating automobility. These risks, and injury outcomes are unevenly distributed over space and across the population. Walking also requires a variety of cognitive skills, including reaction time and understanding or anticipating the behaviour of other road users. The design of road networks can further complicate and potentially endanger the safety of pedestrians, particularly in urban regions with road designs that favour automobile traffic flow (Dumbaugh and Rae, 2009). Furthermore, the complexity of the road environment, particularly in areas with high vehicle volumes and speeds, creates potentially dangerous situations for older pedestrians (O'Hern et al., 2015) and children (Zeedyk et al., 2001).

Road traffic injury is the single largest cause of years of life lost (YLL) (17%) in children and youth in Canada (Institute for Health Metrics and Evaluation, 2013). Among all types of road traffic injury, child and youth pedestrian injury accounts for 25% of total injuries. In regard to seniors, their overrepresentation among pedestrian motor vehicle collisions (PMVCs) is alarming. According to a 2012 report produced by the International Transport Forum, individuals aged 65 years represented up to 50% of injured pedestrians in OECD countries (International Transport Forum (ITF), 2012). Specifically in Canada, individuals over the age of 65 represented 35% of the pedestrian fatalities between the years 2004–2008, despite this age group only representing 13% of the population (Transport Canada, 2011). However in the City of Toronto, Canada's largest city, between the years 2011–2015, older pedestrians (55 + years of age) comprised 63% of fatalities despite their relatively low representation in the population

* Corresponding author at: Department of Geography and Programs in Environment, University of Toronto Mississauga, 3359 Mississauga Road, Mississauga, ON L5L 1C6, Canada.
E-mail addresses: emily.grise@mail.mcgill.ca (E. Grisé), ron.buliung@utoronto.ca (R. Buliung), lrothman@yorku.ca (L. Rothman), andrew.howard@sickkids.ca (A. Howard).
[1] Present address: School of Urban Planning, McGill University, Suite 400, 815 Sherbrooke St. W., Montréal, Québec, H3A 0C2, Canada

http://dx.doi.org/10.1016/j.jtrangeo.2017.10.003
Received 14 July 2016; Received in revised form 2 October 2017; Accepted 11 October 2017

(26%) (City of Toronto, 2016).

The focus on vulnerable road users such as children and the elderly is particularly salient given the unique physical and cognitive aspects of these populations that shape their injury risks. The literature on child pedestrian injury risk factors indicates that children experience unique risk factors and exhibit distinct locational patterns of injury (Ha and Thill, 2011; Koopmans et al., 2015; Lightstone et al., 2001; Rothman et al., 2012), which appear to differ from locational patterns of injury involving seniors (Dunbar et al., 2004; Oxley et al., 2004; Zegeer, 2002). Accordingly, locational patterns of collisions involving children and seniors' should be examined separately, as it is hypothesized that the geographic distribution of pedestrian injury risks among children and seniors will also differ. Accordingly, this research explores spatial patterns of PMVCs involving children and seniors using the City of Toronto as a case study. Results of this study are intended to provide planners, engineers and policy makers with a better understanding of the geographical locations of high risk for child and elderly pedestrian injury, to enable the development of effective age-based interventions in the built environment. This sort of spatial analysis can be followed by site visits by practitioners to assess the situation on the ground in terms of the presence of infrastructures and behaviours (of all road users) that may be putting pedestrians at risk of injury or death.

The remainder of the paper is organized as follows. The next section of this article discusses the background literature on determinants of pedestrian injury specific to children and seniors. This is followed by a detailed overview of the study area and a description of the data used in this study. The next section describes the study's research methods, which is followed by the empirical results. Finally, the findings of this paper are discussed and the research findings and the policy and planning implications are drawn into focus in the final section.

2. Literature review

Walking requires a variety of cognitive skills, including visual examination, gap judgment, reaction time and understanding or at least anticipating the behaviour of other road users. At different ages, variation in these abilities may be critical to understanding and explaining injury risk. The cognitive and perceived risks associated with being a pedestrian and the unique characteristics and locational patterns associated with pedestrian injury within an urban environment, specifically in relation to children and seniors are outlined and discussed below.

Research into the relationship between the built environment and child pedestrian injury suggests that features that either slow down traffic (e.g. traffic calming), separate children in space from traffic (e.g. playgrounds) or separate children in time (e.g. exclusive traffic-light phasing) decrease pedestrian injury risk (Rothman et al., 2013). The majority of child pedestrian injury occurs close to home (Ha and Thill, 2011; Lightstone et al., 2001), particularly on non-arterial, neighbourhood roads or local streets. Furthermore, child PMVCs are more common during mid-block crossings, producing more severe injuries (Rothman et al., 2012). As children age, the prevalence of severe injury on neighbourhood roads appears to decline (Rothman et al., 2010), and children are more likely to be involved in PMVCs at intersections (Koopmans et al., 2015).

For elderly pedestrians, supportive walking environments are particularly important, as walking is a preferred form of physical activity for this age group (Eyler et al., 2003). There are several explanations to account for the heightened crash risk for older pedestrians. Older pedestrians are more exposed to potential collisions than younger people, as they tend to reduce or stop driving and are thus limited to walking (aided or unaided) or combine walking with public transportation (Oxley et al., 2004). Seniors are more likely to use signalized intersections than young pedestrians when they cross streets (Lightstone et al., 2001; Zegeer, 2002). This observation can be explained in part by the preference of older pedestrians (70 years and older), to cross at signalized intersections because they perceive that this type of crossing is safer, and they feel it is dangerous to cross the road where these facilities are missing (Bernhoft and Carstensen, 2008). Despite the perception of safety at intersections, a high proportion of pedestrian injuries involving seniors occur at signalized intersections. Specifically, in a review of pedestrian fatalities that occurred across Canada between 2004 and 2008, 63% of individuals who were involved in a fatal collision at intersections were aged 65 years and older (Transport Canada, 2011). Reduced walking speeds of older adults increase exposure levels to vehicle traffic. The reduced physical mobility and perceptual and cognitive functions of some of the elderly also affects their judgment and their ability to safely crossing streets (Oxley et al., 2004; Oxley et al., 1997).

With regard to environmental risk factors, two primary determinants of pedestrian injury include vehicle and pedestrian volume (Lee and Abdel-Aty, 2005; Miranda-Moreno et al., 2011; Wier et al., 2009). Urban development patterns and urban design impact safety primarily through the traffic volumes they produce and attract, and secondarily through the allowable speed limits or the traffic speeds they inadvertently encourage (Ewing and Dumbaugh, 2009). Traffic speed is a critical predictor of pedestrian injury severity and the likelihood of suffering a fatal injury, and it is generally accepted that the chance of survival decreases non-linearly with increasing vehicle speed (Rosen et al., 2011). Accordingly, fatality risk is severely diminished at speeds less than or equal to 40 km/h. However, achieving slower speeds, even on residential streets, is known to be as much a political challenge more than anything else (Keenan, 2017).

While speed remains a critical risk factor for PMVCs and fatality (Peden, 2004), children and seniors are particularly vulnerable to a severe injury outcome in the event of a collision with a vehicle. Children may be impacted differently due to their physical size. As a result of the short stature of a child, a vehicle may directly strike a child's head or vital organs resulting in a more severe injury outcome regardless of speed. In adults, a vehicle's windshield and its frame are the main source of head injuries in PMVCs, which can cause severe brain injuries and lead to lifelong disability or death (Yao et al., 2008). While vehicle speed is a critical predictor of the severity of injury sustained after a collision, pedestrians over the age of 65 experience higher injury rates than younger people at all speeds (Henary et al., 2006). Therefore, while speed remains a critical factor of the severity of injury following an accident for these two populations, emphasis must simultaneously be placed on reducing potential conflicts with vehicles, particularly in areas where there is a high presence of children and seniors.

A limitation of the literature discussed above and within the broader field of pedestrian planning, is that there is insufficient evidence of the geography of pedestrian injury. While it is imperative for research to continue to expand our knowledge on the determinants of injury to develop evidence to support effective interventions, planners, policy makers, and injury epidemiologists should probe more deeply into the geographies of injury risk and outcomes, because the processes that produce injury are likely to be geographically and temporally uneven. Understanding the geography of injury production and reduction, is helpful knowledge, particularly for those working in the urban professions who wrestle with the fiscal, political and design challenges that are often folded into discussions about the prioritization and targeting of spending in both the fixed capital and operational domains. Accordingly, this paper presents an exploratory spatial analysis of pedestrian injury by age and severity, with a view to contributing to a global conversation about urban traffic injury among vulnerable road users. With the majority of the world's population concentrated in urbanized areas, and with the global burden of traffic injury on the rise (Organisation for Economic Co-operation and Development, 1998; World Health Organization, 2015), it is particularly salient to contribute to a conversation about where traffic injury occurs within major global cities.