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School environments and social risk factors for child pedestrian-motor vehicle collisions: A case-control study

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ABSTRACT

Background: Child pedestrian-motor vehicle collisions (PMVCs) have decreased in Canada in the past 20 years. Many believe this trend is explained by the rise in automobile use for all travel. Initiatives to increase walking to school need to consider PMVC risk. Potential risk factors related to walking to school, the built environment and social factors were examined for schools with historically high child PMVC rates.
Methods: Child PMVCs (age 4–12 years) from 2000 to 2013 and built environment features were mapped within school attendance boundaries in the City of Toronto, Canada. Case and control schools were in the highest and lowest PMVC quartiles respectively. Observational counts of travel mode to school were conducted. Logistic regression evaluated walking to school, built environment and social risk factors for higher PMVC rates, stratified by geographic location (downtown vs. inner suburbs).
Results: The mean PMVC rates were 18.8/10,000/year (cases) and 2.5/10,000/year (controls). One-way street density (OR = 4.00), school crossing guard presence (OR = 3.65) and higher social disadvantage (OR = 1.37) were associated with higher PMVCs. Higher residential land use density had a protective effect (OR = 0.56). More walking was not a risk factor. While several built environment risk factors were identified for the inner suburbs; only social disadvantage was a risk factor within older urban neighbourhoods.
Conclusions: Several modifiable environmental risk factors were identified for child PMVCs. More walking to school was not associated with increased PMVCs after controlling for the environment. School social disadvantage was associated with higher PMVCs with differences by geographic location. These results have important implications for the design of roadways around schools.

1. Introduction

Road traffic injuries are a leading cause of preventable child death in Canada. Motor vehicle fatalities are six times more common than any other unintentional injuries, and are the leading cause of unintentional injury death in those ages 0–24 (Public Health Agency of Canada, 2012). Hospitalization because of motor vehicle injuries ranks 2nd (after falls) for all injury admissions (ages 0–24) in Canada (Public Health Agency of Canada, 2012; Transport Canada, 2015). Road traffic injuries in children 0–14 years, resulted in 70 deaths and 9000 reported injuries in 2013 and cost the Canadian health care system 60 million dollars annually (Transport Canada, 2015; Parachute, 2015).

Although child pedestrian hospitalizations and deaths in Canada have declined over the past 20 years, the burden remains high (Safe Kids Canada, 2007; CIHI, 2008). Child pedestrians are overrepresented in road user fatalities, with 33% being pedestrian deaths (ages 0–14), as opposed to 13% in adults (Transport Canada, 2013). Many believe the decline in child pedestrian-motor vehicle collisions (PMVCs) is due to children walking less, thereby reducing

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their exposure to motor vehicles (Roberts, 1993; Unicef, 2001; DiGuiseppi et al., 1997). In the 2004 Canadian National Transportation Survey, 50% of children reported never walking to school (Cragg et al., 2006). From 1986–2011, walking mode share for trips to school in 11–13 year olds in the City of Toronto decreased from 59% to 45%, with auto mode share increasing from 12% to 29% (Smart Commute School Travel in the City of Toronto, 2015). The 2013 Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth indicated 24% of Canadians 5–17 years use active school transportation only (AST, i.e. walking, cycling, scooters etc.) and 14% use a combination of active and inactive modes (e.g. vehicles) for transportation (Active Healthy Kids Canada, 2013).

Almost 40% of pedestrian-motor vehicle collisions involving children ages 4–12 years in Toronto occur during school travel times (Warsh et al., 2009; Rothman et al., 2015a). More than 1/3 of collisions have been found to be within 300 m of a school, with the highest density of collisions among children occurring within 150 m of a school (Warsh et al., 2009). Peak times for child pedestrian-motor vehicle collisions appear to be in the morning (7:00–9:00) and the afternoon (15:00–18:00); school start and finish times and also peak times for overall traffic volume (Yiannakoulias et al., 2002).

There are many initiatives to increase AST in children to combat obesity and other related health conditions throughout Canada and other places in the Global North (Mammen et al., 2014; Buliung et al., 2011). Road traffic exposure; however, remains poorly understood and conflicting evidence exists on pedestrian volume and collisions (Routledge et al., 1974; Rao et al., 1997; Macpherson et al., 1998; Jacobsen, 2003; Rothman et al., 2014). Depending on the mix of walking and driving and environmental conditions, walking promotion could either increase or decrease injury risk. Optimal conditions for safe walking to school must be defined, because if planned poorly, increased walking has the potential to increase injury risk in children. Conversely, injury risk, real or perceived, may be a barrier to successfully increasing children's active transportation.

Previous studies have examined built environment correlates of walking in children and child PMVC separately (Rothman et al., 2013a). These studies are observational, with the majority using a cross-sectional design. Correlates of walking include traffic calming, playgrounds, crosswalks, higher pedestrian volume and population densities, land use mix, urban areas and schools. Correlates of PMVC include crosswalks, higher pedestrian/population volumes, land use mix, urban areas, more schools, higher traffic speeds and crossing busy roadways (Rothman et al., 2013a). It is essential to examine walking and child PMVC together to determine whether there is an increased risk of child PMVC with more walking to school exposure and to identify the effect of the built environment on this relationship. To our knowledge, there is only one previous study examining both walking to school and child PMVC rates together, This cross-sectional study found that there was no relationship between more walking to school and child PMVC once features of the built environment was controlled for (Rothman et al., 2014).

The purpose of this study was to build on the previous cross-sectional study, by using an innovative and more rigorous case control study design and identifying schools as cases and controls based on collision rates. Multivariate logistic regression modelling was utilized to determine if the proportion of children observed walking to school was a potential PMVC risk factor and identify modifiable built environment and social risk factors associated with historically higher child PMVC rates within school attendance boundaries controlling for walking exposure

2. Methods

A case-control study was conducted in the City of Toronto, Canada, in May–June 2015. Cases were identified as kindergarten to grade 6 schools, within the highest quartile of historical child PMVCs within school attendance boundaries. Control schools were those within the lowest quartile of historical child PMVCs. Attendance boundaries were defined by the Toronto District School Board (TDSB) (Toronto District School Board, 2016). Collision rates were calculated from City of Toronto police-reported pedestrian collision data from 2000 to 2013 for children ages 4–12 years. The collision dataset includes location, time of day, date, and child age. Collisions were mapped onto attendance boundaries and PMVC rates were calculated using the 2011 Canadian census population, ages 4–12 years, conflated to each of the school attendance boundaries. Exclusion criteria included schools with: (1) grade combinations that included grades ≥7; (2) special programs that accept children from outside the school's attendance boundaries (e.g., French immersion) and; (3) involvement in other walking studies. Ethics approval was obtained from the TDSB, the Hospital for Sick Children Research Ethics Board and the Toronto District School Board, External Research Review Committee.

2.1. Risk and protective factors

Table 1 presents each of the potential risk and protective factors tested for inclusion in the models by conceptual category (where appropriate) and data source.

2.1.1. Walking to school

Mode of school transportation, including walking, cycling, other active transportation (i.e., scooters, rollerblades, skate-long boards), strollers, wagons and vehicles were counted by trained observers outside of the schools for 20 min before and 5 min after the morning arrival bell on a single day in the spring. The proportion of children walking to school was calculated from the total number of children observed. Children arriving by school bus were excluded as generally they had met TDSB busing eligibility criteria (grades JK-5 living ≥1.6 km, grades 5+ who live ≥ 3.2 km), or had mobility needs related to a medical condition or disability (Toronto District School Board, 2005).

2.1.2. Built environment

Potential built environment risk factors for child pedestrian injury were identified from a literature review and from a previous cross-sectional study (Rothman et al., 2014, 2013a). These factors were organized conceptually according to Cervero and Kockelman's 3 D's, Density (population), Design (roadway) and Diversity (land use) (Cervero and Kockelman, 1997). Density and design environment features were obtained from the City of Toronto, Transportation Services, and the 2006 Canadian census and Toronto Police Services and mapped onto school attendance boundaries. Variables obtained from the 2006 Canadian census were obtained at the Dissemination Area (DA) level of geography. DAs have approximately 400–700 residents, and are the smallest standard geographic area for which all census data are disseminated. DAs were mapped onto school attendance boundaries and census variables for each attendance boundary were estimated using area-weighted proportionate analysis (Braza et al., 2004; Falb et al., 2007). Population and design densities were calculated either per linear kilometer of roadway or per area of school attendance boundary. Two variables were created for crossing guards; the first indicating whether or not a guard was observed at the school site during the transportation mode observations and the other was a density of crossing guards throughout the school attendance boundaries. Only adult crossing guards which are employed

Table 1
Potential risk and protective factors according to conceptual domain and data source.

Risk and Protective Factors	Domain	Data Source
Proportion walking to school		Observational counts
Built Environment		
Multi-dwelling (apartments, duplexes) (#)/1000 m^2	Density	2006 Canadian Census
Entropy Index	Diversity	Derived
Commercial land use area/boundary		MPAC
Residential land use area/boundary		MPAC
Industrial land use area/boundary		MPAC
Institutional land use area/boundary		MPAC
Park land area/boundary		MPAC
Recreational facilities (#)/km^2		City of Toronto
Adult school crossing guard observed at school site	Design	Site Survey
Adult crossing guards (#)/1000 m road		Toronto Police Services
Dead end (#)/1000 m road		City of Toronto
Flashing lights (#)10/km road		City of Toronto
Intersection (#)/km road		City of Toronto
Major roads km/km road		City of Toronto
Minor roads km/km road		City of Toronto
Local roads km/km road		City of Toronto
Collector roads km/km road		City of Toronto
One way streets km/10 km road		City of Toronto
Other schools within school boundary (#)/km^2		TDSB/TCDSB
Pedestrian crossover (#)/1000 m road		City of Toronto
Sidewalk (one) missing km/10 km road		City of Toronto
Sidewalks (both) missing km/10 km road		City of Toronto
Traffic calming segment km/10 km road		City of Toronto
Traffic signal #/10 km road		City of Toronto
Trails km/km^2		City of Toronto
Urban School		City of Toronto
Old Housing (pre 1946) (#)/1000 m^2		2006 Canadian Census
School Social Environment		
English not primary language (%)		TDSB
New immigrants ($\leq$ 5 years) (%)		TDSB
Total school population (#)		TDSB
School learning opportunities index (LOI) (0–1)		TDSB
After Tax below Low Income Cut-Off (school DA) (%)		2006 Canadian Census

TDSB, Toronto District School Board; TCDSB, Toronto Catholic District School Board; DA, Dissemination area; Municipal Property Assessment Corporation, MPAC

by Toronto Police Services were included; student safety patrollers were not included in these analyses. Toronto's urban areas consist of older, pre-World War 2 straight grid street patterns, and inner suburban neighbourhoods with newer, car-oriented post-World War II, long winding streets and cul-de-sacs (City of Toronto, 2001). These areas were politically amalgamated into the City of Toronto in 1998. A school with over 50% of its attendance boundary within the urban core of Toronto was designated an urban school.

Diversity of land use was assessed using parcel level land use data obtained from the Municipal Properties Assessment Corporation (MPAC), which classifies properties in Ontario (MPAC, 2013). Individual land use was calculated as a percentage of the school boundary. An entropy index was used to measure the mix of residential, commercial, industrial, institutional, and vacant land use (including parks and walkways) within school boundaries (Larsen et al., 2009; Frank et al., 2004). The entropy index ranges from 0 0(single land use) to 1 (equal distribution of land use classifications):

$$\text{Land use mix} = -\Sigma_u(pu \times \ln pu)/\ln n$$

u = land use classification, p = proportion with specific land use, n = total number classifications. Scores of 0 = single land use, 1 = equal distribution of all classifications (Larsen et al., 2009; Frank et al., 2004).

Recreational land use was calculated as the number of facilities per school boundary.

2.1.3. School social environment

The TDSB uses a Learning Opportunities Index (LOI) to indicate a schools' level of social disadvantage. It is a composite index, measured on a scale from 0 (low disadvantage) to 1 (high disadvantage) constructed from variables reflecting parent education, income, housing and student immigration status (Toronto District School Board, 2014). The socioeconomic status of the area surrounding each school was measured using the proportion of households, according to the 2006 Canadian census, falling below after tax, low income cut-offs in the school dissemination area (DA) as defined by Statistics Canada (Statistics Canada, 2009). This measure was used as a proxy measure for the school neighbourhood SES. The low income cut-off is an income threshold below which a family devotes a larger share of its income, than the average family, on necessities; i.e., food, shelter and clothing (Statistics Canada, 2009). The total number of public schools within the school attendance boundary was calculated including schools from the TDSB and the Toronto Catholic District School Board. The proportion of each school's population whose primary language was other than English and who had immigrated to Canada within 5 years was obtained from the TDSB.

2.2. Statistical analysis

School attendance boundaries were the unit of analysis. All features were mapped onto school attendance boundaries using ArcMap v.10 (ESRI, 2015). Statistical analysis was conducted using SAS, v.9.3 (SAS, 2012). Multicollinearity was assessed using Variance Inflation Factors (VIF); where there were two highly correlated variables (VIFs > 10), the more significant variable in the univariate analysis was retained (Kleinbaum et al., 1998). Bivariate correlations were investigated using Pearson's correlation coefficients. Descriptive comparisons were made between case and control schools on selected features and tested for significance using two sample *t*-tests or Pearson's chi-square tests. Univariate logistic regression was conducted to examine potential correlates of being a case school with higher collision rates.

2.2.1. Logistic regression

The logistic procedure in SAS, fits linear logistic regression models for binary outcomes using the method of maximum likelihood (SAS, 2011). This procedure was used due to the binary outcome of the case-control study design. If x is a vector of explanatory variables, the response probability to be modelled is:

$$3\pi = PRY = 1/X$$

The linear logistic model is:

$$\text{logit}(\pi) = \log\pi/(1\text{-}\pi) = \alpha + \beta' \text{x}$$

where α is the intercept parameter and $\beta = (\beta_1 \ldots\ldots \beta_s)\,'x$ is the vector of *s* slope parameters. For continuous variables, the odds ratio approximates the amount one unit change in the explanatory variable affects the likelihood of the outcome. For a binary explanatory variable the odds ratio compares the odds for the outcome between one level of the explanatory variable and the other (SAS, 2011).

Forward manual stepwise multivariate logistic modelling was then conducted to investigate the relationship between the discrete response and variables that had $p \leq 0.2$ in the univariate analysis (Hosmer and Lemeshow, 2004). This threshold p value indicated whether the variable was associated with an increased (OR > 1.00) or decreased (OR < 1.00) odds of higher collision rates. Variables were entered into the multivariate model according to the magnitude of the p-values in the univariate analyses. Variables were re-examined and dropped at each stage of the modelling if not significant at the $p \leq 0.05$ level. The exception to this was walking proportion, which was kept in the model as a measure of exposure. Hosmer and Lemeshow recommend the use of forward stepwise techniques to achieve parsimony. Inclusion of greater numbers of variables increases instability, and the results are less generalizable as they are more dependent on the observed data (Hosmer and Lemeshow, 2004).

Adjusted odds ratios and 95% confidence intervals (CI) comparing case and control schools were calculated for walking proportions, and built and social environment variables. Model fit was assessed using the likelihood ratio test and the efficient score test which test the joint significance of the explanatory variables with small p-values used to reject the hypothesis that all slope parameters are equal to 0. The Akaike's information criteria (AIC) was used to compare the final stepwise model to the full model including all variables significant at the $p \leq 0.2$ level, with a smaller value indicating a better model fit (SAS, 2011).

$$\text{AIC} = -2\log(\text{L}) + 2\text{p}$$

where p is the number of parameters in the model. The AIC adjusts the −2 log likelihood statistic for the number of observations used and the number of terms in the model (SAS, 2011).

A stratified analysis was conducted by urban versus inner suburb location to determine whether there were different risk factors for being a case school in these two geographically different areas.

3. Results

A total of 601 collisions occurred 2000–2013, with 277 (46%) during school travel times (Table 2). There were a total of 198 eligible schools. There were more schools in the inner suburbs compared to urban (n = 75 versus n = 25), with almost double the number of case schools (n = 17 versus n = 33). Within the downtown urban core; however, there was a much higher proportion of case schools (17/25 = 68%), as compared to the inner suburbs (33/75 = 44%). The mean collision rate was almost 8 times higher in case versus control schools and the walking proportions were 12% higher. No significant differences in mean child population or mean school boundary sizes were found.

Older housing, proportion below after tax low income cut-off by school DA and intersection density were dropped from further analyses due to multicollinearity. Variables associated with higher collision rates in the unadjusted analysis are presented in Table 3. Higher proportions of students walking to school were associated with increased collision odds in the unadjusted analysis.

The resulting equation for the multivariate analysis was as follows:

Logit(p) = −0.1512 + −0.7089*proportion walking + 1.3861*one way street density + 3.1747*learning opportunities index + −0.5741*residential density + 1.2960*school crossing guard

Walking to school was not a risk factor for higher PMVC rates (Table 4). One way street density (OR = 4.00, 95% CI = 1.76, 9.08), the presence of a school crossing guard (OR = 3.65, 95% CI = 1.10, 12.20) and higher school disadvantage (OR = 1.37, 95% CI = 1.11, 1.70,) were associated with schools with higher collision rates whereas higher residential densities were protective for collisions (OR = 0.56, 95% CI = 0.37, 0.86). Significant p-values for the likelihood ratio (< 0.0001) and the score statistic (0.0005), indicate that the fit of this model reduced by the forward manual selection process was good. The AIC in the reduced model was also substantially lower than in the full model indicating better model fit (106.2 versus 118.2).

The estimates for specifically, the inner suburbs resulted in the following equation:

Logit(p) = −3.0662 + 01.0910*proportion walking + 0.3835*one way street density + 0.4631*traffic signal density + 1.2697*traffic calming density

In the inner suburbs, one way street (OR = 1.47, 95% CI = 1.13, 1.90), traffic light (OR = 1.59, 95% CI = 1.17, 2.15) and traffic calming densities (OR = 3.56, 95% CI = 1.03, 12.26) were risk factors for PMVC collision rates. Goodness of fit statistics indicated good model fit (p < 0.0001,likelihood ratio, p = 0.0001, score statistic).

The estimates for specifically, the urban downtown schools resulted in the following equation:

Logit(p) = 2.3674 + −0.6525* proportion walking + 0.9370*learning opportunities index

The only significant risk factor for higher collision rates in the urban downtown schools was higher school disadvantage (OR = 2.55, 95% CI = 1.28, 5.09) when controlling for proportion walking. Goodness of fit statistics indicated good model fit (p = 0.0009 likelihood ratio, p = 0.0034, score statistic).

4. Discussion

This study identified environmental risk factors for higher historical child PMVCs in areas surrounding elementary schools in Toronto. One-way streets were a modifiable risk factor related to urban design. School crossing guards and school disadvantage were also associated with higher collision rates. Higher residential land use density was protective for child PMVCs. The proportion walking to school was not a risk factor for higher rates of child PMVCs once other risk factors were controlled for.

The results support those found in a cross-sectional study conducted in 2011 in Toronto elementary schools; specifically the associations between historical PMVC rates and one way streets, school crossing guards, traffic calming, traffic lights, population

Table 2
Descriptive comparison of case and control schools.

	Totals	Case (n = 50)	Control (n = 50)	p-value (T test, Chi-Square)
Number of collisions	601	513 (85.4%)	88 (14.6%)	<0.0001
School travel time collisions[1]	278	230 (82.7%)	48 (17.3%)	<0.0001
Inner suburb schoolUrban school	75 25	33 (44%) 17 (68%)	42 (56%) 8 (32%)	0.004
Mean collision rate/10,000/year	–	18.8 (s.d. 7.2)	2.5 (s.d. 1.7)	<0.0001
Mean walking proportion	–	69.8% (s.d. 0.15)	61.2% (s.d. 0.18)	0.012
Mean child population	–	565 (s.d. 244)	646 (s.d. 278)	0.180
Mean school boundary size (m^2)	–	1,300287 (s.d. 824,252)	1,644,009 (s.d. 1,063,496)	0.078

Table 3
Unadjusted odds ratios (95% CI) for child PMVCs (p≤.2) for multivariate modelling.

	Variable	Unadjusted OR(95% CI)
Exposure	Walking to School (X10)	1.37 (1.06, 1.76)
Built Environment		
Density	Multifamily dwelling density #/1000 m^2	2.39 (1.44, 3.98)
Design	Traffic signal density/10 km	1.29 (1.10, 1.51)
	All schools density/km^2	1.61 (1.15, 2.26)
	Crossing guard #/10 km roads	1.41 (1.01, 1.97)
	School crossing guard near school (y/n)	2.13 (0.94, 4.79)
	Pedestrian crossover #/10 km roads	1.55 (1.05, 2.28)
	Dead end #/km roads	1.09 (1.00, 1.19)
	Intersection #/km road	1.92 (1.37, 2.69)
	Traffic calming km/10 km roads	1.68 (0.90, 3.14)
	One way streets km/10 km roads	3.43 (1.68, 7.00)
	Both sidewalks missing km/10 km roads	0.68 (0.51, 0.90)
	Recreation facilities #/km^2	2.88 (1.23, 6.76)
	Minor arterial roads km/10 km roads	2.41 (1.24, 4.65)
Diversity	Commercial land use km/10 km^2	1.92 (1.03, 3.55)
	Residential land use km/10 km^2	0.62 (0.45, 0.86)
	Park area/boundary km/10 km^2	0.79 (0.56, 1.10)
	Entropy index (mixed land use) (X10)	1.64 (1.13, 2.39)
Social Environment	Higher school disadvantage (X10)	1.24 (1.08 1.44)
	After tax low income cut-offs (school DA)	1.33 (1.03, 1.72)

Table 4
Adjusted odds of higher child pedestrian-motor vehicle collisions for all schools, in the preamalgamated City of Toronto and in the inner suburbs.

	Variable	Adjusted OR (95% CI) All schools	Adjusted OR (95% CI) Inner Suburbs	Adjusted OR (95% CI) Downtown Urban Core
Exposure	Walking to School	0.49 (0.02, 13.72)	0.34 (0.008, 14.56)	0.52 (0.16, 1.71)
Built Environment				
Design	One way streets km/ 10 km roads	4.00 (1.76, 9.08)	1.47 (1.13,1.90)	–
	School crossing guard	3.65 (1.10, 12.20)	–	–
	Traffic lights #/km roads	–	1.59 (1.17, 2.15)	–
	Traffic calming km/10 km roads	–	3.56 (1.03, 12.26)	–
Land Use Diversity	Residential land use km/10 km^2	0.56 (0.37, 0.86)	–	–
Social Environment	Higher school disadvantage (*10)	1.37 (1.11, 1.70)	–	2.55 (1.28, 5.09)

densities and school social disadvantage and the lack of association with walking to school proportions once the environment is controlled for (Rothman et al., 2014). By conducting a case-control study, we were able to determine risk and protective factors for schools with high versus low PMVC rates. Results of this study also provided new information regarding the differences in the influence of built and social environments in the newer more car-oriented inner suburbs versus the older downtown urban area.

These design and social environment features have also been associated with higher child PMVCs in previous cross-sectional studies. In the City of Hamilton, Ontario, Canada, collisions involving child pedestrians were 2.5 times higher on one-way compared to two-way streets, which may be due to higher traffic speeds, drivers paying less attention as there is no conflicting traffic flow and children having difficulty crossing one-way streets (Wazana et al., 2000). There has been a growing movement to convert one-way to two-way streets in many North American cities to increase safety. In Louisville, Kentucky, the conversion from one-way to two-way streets demonstrated significant decreases on two roadways in all motor vehicle collisions (36% and 60%) in addition to slower traffic and slight increases in traffic volumes (Riggs and Gilderbloom, 2015).

School crossing guards have also been related to higher collision rates in a study in Montreal, Quebec (Cloutier and Apparicio, 2008). It has not been definitively established; however, if school crossing guards are true risk factors for collisions, but are instead indicators of schools with higher historical collision rates (Rothman et al., 2014). A recent pre-post intervention study done in Toronto, Canada, found a null effect of school crossing guards on child PMVCs (Rothman et al., 2015a). There is also conflicting evidence regarding whether or not the implementation of school crossing guards is associated with more children walking (Rothman et al., 2013b; Gutierrez et al., 2014). In the absence of good pedestrian and vehicle volume denominators, it is impossible to determine if there is a true negative or positive effect of crossing guards on child PMVCs.

Social disadvantage has been consistently associated with PMVC rates and there is a social gradient in injury risk that has not been fully explained, even after controlling for built environment features in this study (Laflamme and Diderichsen, 2000; Braddock et al., 1991; Rivara and Barber, 1985; Dougherty et al., 1990; Bagley, 1992; Roberts et al., 1996). Higher social disadvantage was not a risk factor for higher PMVC rates in the inner suburbs, but was in the older urban neighbourhoods of Toronto. There is no reason to expect social disadvantage and built environment effects to be the same everywhere, and these results demonstrate that, in fact, they are not. In the inner suburbs, the auto-orientation of design, and transport may simply overwhelm income effects and/or social difference, whereas in the older urban neighbourhoods, social difference seems to have a larger effect on injury, perhaps because higher income households have greater choice in the housing market and can self-select into protective places.

Higher collision rates were also associated with higher densities of traffic lights and traffic calming in the inner suburbs, where the majority of the study schools were located. These built environment features were also associated with higher collision rates in the previous cross-sectional study (Rothman et al., 2014). It is unsurprising that more traffic lights were associated with more collisions, in that the lights would represent more crossing locations and traffic exposure. The relationship with traffic calming; however, is likely indicative that calming is installed in areas with more collisions. Analysis of child PMVCs before and after traffic calming installation in Toronto, found a strong protective effect of speed humps for child PMVCs (Incident Rate Ratio = 0.56, 95% CI = 0.40, 0.79) (Rothman et al., 2015b). This protective effect of traffic calming on child PMVCs has been reported elsewhere (Tester et al., 2004; Jones et al., 2005).

Higher density residential land use had a protective effect on collisions, specifically in the inner suburbs Residential areas with local streets, slower posted speed limits and less traffic volume have been associated with fewer and less severe PMVCs (Dissanayake and Aryaija, 2009; Pasanen, 1990; World Health Organization, 2004; Pilkington, 2000).

Results also confirmed that the association between higher proportions of children walking to school and higher collision rates disappears when the model is adjusted for the built environment, as found in a previous cross-sectional study (Rothman et al., 2014). This reinforces that the promotion of walking to school will not lead to increased child PMVCs as long as the environment is safe. Moreover, as more walking occurs, conceivably neighbourhoods would see some decline in vehicle traffic on local streets and around the school. The problem of drive-through traffic to other destinations would; however, still exist. This is important when promoting walking promotion programs, which must include a safety evaluation component.

The strengths of the study include the large population-base, and the case control study design. Objective observational counts of walking to school were used with objective measures of the built environment from city databases. This study also included a multivariate analysis to identify risk factors for high rates of child PMVCs around schools. The limitations included the ecological nature of the data. Collisions occur at a specific locations, whereas the built environment data were measured at the school boundary level and may not accurately represent the environment at the collision locations (Rothman et al., 2014). Historical collision data was used over a 14-year period as collisions are relatively rare, and therefore assumptions were made that walking exposure remained unchanged over this period. In addition, total child walking exposure throughout the day was estimated by walking to school; therefore, the assumption was made that schools with high walking to school proportions have more children walking generally throughout the school attendance boundary. The school attendance boundaries were policy relevant spatial units of analysis, and the application of the school walking proportions to the school boundary was felt to be relevant as they are generally within walking distance to schools (Rothman et al., 2013b). Finally, the results related to the urban downtown schools should be interpreted with caution due to the smaller numbers of schools in the downtown core, and the low proportion of control schools.

Implications

This study identified several modifiable risk factors for child PMVCs consistent with previous studies. Most importantly, it reinforces that walking to school is not associated with child PMVCs as long as the built environment is safe. Schools should be centrally located within residential neighbourhoods surrounded by two-way local streets with low-posted speed limits, and road crossings for children should be limited. It is desirable that children walk to school for myriad individual and societal reasons, including the health benefits of physical activity and the reduction of traffic congestion. The results have implications for the design of roadways around schools considering area and school social disadvantage, as well as factors to consider when locating new school sites.

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Conflict of interest

The authors have no conflicts of interest to disclose.

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