Trends in child pedestrian motor vehicle collision injury rates by neighborhood deprivation score in Toronto, Canada

N. Schwartz a,*, L. Rothman a,b,c, A. Howard b, T. To b, C. Macarthur b

a School of Occupational and Public Health, Ryerson University, 350 Victoria St, Toronto, ON M5B 2K3, Canada
b Child Health Evaluative Sciences, SickKids Research Institute, 686 Bay St, Toronto, ON MSG 0A4, Canada
c Dalla Lana School of Public Health, University of Toronto, 155 College Street, 6th Floor, Toronto, ON M5T 3M7, Canada

ARTICLE INFO

Keywords: Social inequalities in health Road injury Child and youth Trends

ABSTRACT

We examined trends from 2000 to 2019 in child pedestrian motor vehicle collision (PMVC) injury rates in Toronto, Canada, to see if injury trends varied by neighbourhood deprivation. This 20-year period was associated with major road safety policy changes in the City. A Poisson regression analysis examined police-reported data on children (age 1–19 years), killed or seriously injured (KSI) PMVC rates, by deprivation status (using the Ontario Marginalization Index), over the period 2000–2019. Models controlled for location (urban core v. inner suburbs) and evaluated potential interactions. There were 523 child pedestrian KSI collisions from 2000 to 2019. Over this period, KSI rates decreased by more than 50 % across all neighbourhood deprivation levels. Steep declines from 2000 to 2010 were followed by level or increasing child PMVC rates from 2010 to 2019. Higher deprivation was associated with slightly elevated KSI rates; although not statistically significant. It is important to learn from road safety policy “successes” and ensure that future road safety interventions are applied equitably across areas, accounting for deprivation and location.

1. Introduction

In Canada, unintentional injury is the leading cause of death and disability among children (1–19 years), with traffic injury making up the largest portion (45 %) of injury fatalities (Yao et al., 2019). While road injuries have decreased over time, pedestrian injuries have not decreased in proportion and currently constitute a significant share of such injuries (Transport Canada, 2021). Across Canada, on average 43 deaths and 3,000 serious child pedestrian injuries occur each year (Transport Canada, 2021).

Many studies have shown inequalities in child pedestrian motor vehicle collision (PMVC) injury rates based on socioeconomic status (SES) (Birken et al., 2006; Morency et al., 2012; Rothman et al., 2019). Studies of trends in SES-related inequalities in childhood PMVC, however, have found conflicting results (Adams et al., 2005; Birken et al., 2006; Coupland et al., 2003; Roberts and Power, 1996; Rothman et al., 2019). While some have shown widening inequalities (Roberts and Power, 1996; Rothman et al., 2019), others have demonstrated no differences in trends or decreasing gradients over time (Adams et al., 2005; Birken et al., 2006; Coupland et al., 2003). Variation in road safety policy implementation may contribute to diverging trends. The period from 2000 to 2019 in Toronto Canada included major road safety policy changes, including city-wide changes to speed limits and traffic calming policies (City of Toronto Transportation Services Division, 2016).

The objective of this study was to examine whether child PMVCs resulting in death or serious injury declined during this 20-year period and whether trends differed by neighbourhood deprivation status.

2. Methods

2.1. Outcome

All police-reported child (ages 1–19 years) pedestrians killed or seriously injured (KSI) in motor vehicle collisions in Toronto, from 2000 to 2019, were mapped onto Toronto’s 140 neighbourhoods (City of Toronto, 2021a). Collision coordinates are reported by the Toronto Police at the time of collision and later validated (Toronto Police Service, 2022). Killed or serious injury collisions are coded by police as collisions resulting in admission to hospital or death within 30 days (Toronto Police Service, 2022).
Denominator: Neighbourhood child (0–19 years) population data by year were derived from the Canadian census to estimate KSI collision rates for each 5-year time interval (City of Toronto, 2021a).

Time Interval: The time frame of the study was 2000–2019 inclusive. Because of small numbers of KSI collisions, 5-year time intervals (2000–2004, 2005–2009, 2010–2014, 2015–2019) were used.

Area-level Deprivation: Toronto neighbourhoods are designated social planning areas organized by SES. Neighbourhoods have an average population of 19,500 (range 6,500–65,000) and size of 4.5 km² (range 0.4–36.9 km²). Neighbourhood boundaries were stable between 2000 and 2019 (City of Toronto, 2021a). Area-level deprivation was measured using the 2006 and 2016 Ontario Marginalization (On-Marg) Index, material deprivation score (Matheson and van Ingen, 2018). The On-Marg is calculated using factor scores of six indicators of marginalization from each Canadian Census cycle (population below the low-income cut-off, lone-parent families, unemployed, receiving government transfer payments, without a high-school diploma, living in a dwelling needing major repair) (Matheson and van Ingen, 2018). On-Marg scores by Toronto neighbourhood were first calculated and made available in 2006 (van Ingen and Matheson, 2021). Scores for 2006 were applied to periods before 2010 and 2016 scores applied afterwards. On-Marg scores remained relatively consistent over time (van Ingen and Matheson, 2021). In 2006, Toronto neighbourhood On-Marg scores ranged from –1.2–3.4 and in 2016 scores ranged from –1.5–3.1. Tertiles were used to designate low, medium, and highly deprived neighbourhoods. Between 2006 and 2016 tertiles remained consistent; 84 % of neighbourhoods did not change tertile (n = 118), while 15 % (n = 21) changed by one tertile. Those neighbourhoods that became more deprived (n = 11) were exclusively located in the inner suburbs, mostly in the north of the City, while those neighbourhoods becoming less deprived (n = 10) were mainly (7/10) in the urban core. The On-Marg deprivation score was also analysed as a continuous variable in models to evaluate the validity of tertile groupings.

Covariates: Analytic models controlled for location of collision (urban core versus inner suburbs), thus accounting for areas with higher levels of motor vehicle traffic and pedestrian activity (Toronto Public Health, 2012). In 1998, the City of Toronto was amalgamated with surrounding suburban municipalities. The pre-amalgamated Toronto boundary (“urban core”) includes the downtown core and surrounding dense suburbs. Outside this boundary, are mainly suburban neighbourhoods (“inner suburbs”) (Toronto Public Health, 2012).

Statistical Analysis: The rate of child pedestrian KSI by neighbourhood deprivation tertile was calculated for each time interval. A Generalized Linear Mixed Model Poisson regression analysis measured child KSI rates by neighbourhood deprivation and time interval with neighbourhood (a unique id) included as a random effect to account for repeated measures across time periods. The offset variable was the log of neighbourhood child population. Model 1 included time interval and deprivation as covariates. An interaction term was included for deprivation and time interval to estimate whether trends differed based on neighbourhood deprivation. Model 2 additionally controlled for location (urban core/inner suburbs). An interaction term was included to examine if KSI trends were modified by location. Univariate and adjusted incident rate ratios (IRR) and 95 % confidence intervals (CI) were calculated. Over-dispersion was not found (Model 2 generalized chi² divided by degrees of freedom = 0.98). Moran’s I was calculated on model residuals for each time period using inverse distance weights. Significant spatial autocorrelation of model residuals was not found. Analyses were conducted in SAS v.9.4 and ArcGIS v.10.4.

3. Results

There were 523 child pedestrian KSI collisions between 2000 and 2019. The five-year KSI rate decreased in all three neighbourhood tertiles (Fig. 1a). Crude KSI rates decreased by at least 50 % in all deprivation tertiles over the study period. This decrease mainly occurred from...
2000 to 2010. From 2010–2019 there was little change, with even a slight increase in KSI rates. The lowest rates were consistently seen in Toronto’s least deprived neighbourhoods. The urban core had higher KSI rates compared to the inner-suburbs, though lower rates were seen most recently, in 2015–2019 (Fig. 1b).

Univariate data showed significantly fewer KSI collisions over time, with the largest decrease seen in 2010–2014 compared to 2000–2004 (Table 1). Increased deprivation was associated with higher KSI rates compared to the least deprived tertile, although this was not statistically significant. Modelling using a continuous deprivation score showed no significant association, with large variation within deprivation tertiles (Supplementary Fig. 1). The urban core was associated with a higher KSI rate compared to the inner suburbs, though not significantly.

In multivariable models, lower KSI rates by time interval were found with significant decreases compared to 2000–2004 at all time periods. Higher rates in higher deprivation tertiles were observed but were not significant with and without controlling for urban core location (apart from significance for medium deprivation, in Model 2). No association was found with deprivation as a continuous score in multivariable models (IRR: 1.06; 95% CI: 0.90–1.25). In multivariable models, urban core was significantly associated with KSI rates (IRR: 1.38, 95% CI: 1.04–1.83). Interaction terms were all non-significant for time interval and deprivation, indicating that trends did not differ significantly by deprivation status. Significant interactions were found for urban core and time interval, with collisions decreasing faster in Toronto’s urban core in 2005–2009 (p = 0.035, reference 2000–2004) and 2015–2019 (p = 0.0099, reference 2000–2004) compared to the inner suburbs.

4. Discussion

Between 2000 and 2019 there were large declines in child pedestrian KSI rates in Toronto, Canada, though from 2010 to 2019, the decline has levelled. These declines were seen uniformly by neighbourhood deprivation. However, the absolute number of injuries continues to be excessive with, on average, 26 child pedestrian KSI per year. Elevated KSI rates were consistently seen in more deprived neighbourhoods, however, differences by deprivation were generally not significant.

This analysis used police reports to examine disparities based on location of collision, thereby allowing an assessment of the potential environmental impacts of neighbourhood deprivation. While this study is specific to Toronto, trends in Canada’s largest urban centre may be generalizable to other urban areas in high-income countries.

Reduced injury on the road may be related to declines in child pedestrian activity, including continued declining trends in walking to school from 1986 to 2016 in the Greater Toronto Area (Smart Commute, 2018). A number of traffic calming strategies were also initiated in 2002 in Toronto, including a city-wide lowering of speed limits, that could, in part, explain dramatic decreases in collisions from 2000 to 2010 (City of Toronto Transportation Services Division, 2016). Toronto’s Vision Zero road safety plan was adopted in 2017 with a goal to dramatically reduce serious injuries and deaths. Dramatic changes in traffic volumes and decreases in collisions in 2020/2021, attributed to the COVID-19 pandemic, meant that trends related to Vision Zero could not be assessed over a longer timeframe (Amberber et al., 2021). Additionally, it is possible that early Vision Zero strategies in Toronto were not ambitious enough, with a focus on signs and education, rather than enforcement or changes to road engineering (Rothman et al., 2022). In 2019, Vision Zero 2.0 was adopted with plans for widespread lowering of speed limits among other measures, which may have greater impacts (City of Toronto, 2019).

Higher KSI rates in more deprived neighbourhoods (though non-significant) may be related to the higher percentage of high-speed roads and lower number of speed humps in Toronto’s most deprived neighbourhoods (Rothman et al., 2020). Walking rates could potentially explain differences. However, no consistent relationship has been found between Toronto neighbourhood deprivation and walking to school (Kunaratnam et al., 2022). Toronto’s urban core showed higher rates of child pedestrian KSI, though, with faster declining rates. Higher collision rates in the urban core (seen from 2000 to 2014), are likely related to higher levels of walking to school in Toronto’s denser neighbourhoods (Kunaratnam et al., 2022). From 2000 to 2019, the urban core has seen a greater density of traffic calming and speed limit reductions which may have contributed to faster declines (City of Toronto, 2021b). The “urbanization” of KSI may lead to inequalities by deprivation as just 12% of Toronto’s urban core population live in highly deprived neighbourhoods, compared to 48% in the inner suburbs (City of Toronto, 2021a). This calls for more attention to traffic safety in the inner suburbs where cars dominate and fast moving traffic is found along major arterial roads (Toronto Public Health, 2012). Some of these arterial roads are seen as a linear pattern of collisions on the city map (Supplementary Figure 2). While most neighbourhoods remained at a similar deprivation level throughout the study period, decreasing deprivation occurred mostly in the urban core neighbourhoods, at a time when pedestrian collisions were also decreasing. Gentrification may be related to road safety improvements, particularly when the processes required to achieve road safety, e.g., community requests for installation of speed humps, may not be equitable (Rothman et al., 2020).

A few limitations of this study must be noted. First, the small number of KSI collisions during the study period reduced statistical power. Lack of statistical power might explain why these results differed from an Ontario-wide analysis that showed significant differences in childhood pedestrian injury by neighbourhood deprivation (Rothman et al., 2019). This analysis was also limited to the City of Toronto, which may have different social, demographic, and traffic environments compared with the rest of the province.

### Table 1

| Models | Univariate IRR, (95% CI) | Model 1 IRR, (95% CI) | Interactions Model 1 IRR, (95% CI) | Model 2 IRR, (95% CI) | Interactions Model 2 IRR, (95% CI) |
|--------|-------------------------|-----------------------|-----------------------------------|----------------------|-----------------------------------|
| Year Group (per increasing 5-year interval) | | | | | |
| 2000–2004 | | | | | |
| 2005–2009 | 0.62 (0.50–0.77) | 0.62 (0.50–0.77) | 0.63 (0.50–0.79) | 0.62 (0.50–0.78) | 0.54 (0.42–0.70) |
| 2010–2014 | 0.40 (0.31–0.52) | 0.40 (0.31–0.52) | 0.41 (0.31–0.53) | 0.41 (0.31–0.52) | 0.41 (0.31–0.54) |
| 2015–2019 | 0.45 (0.35–0.57) | 0.45 (0.35–0.57) | 0.45 (0.35–0.58) | 0.45 (0.35–0.57) | 0.36 (0.27–0.50) |
| Deprivation | | | | | |
| Least deprived | 1.00 | 1.00 | | | |
| Medium deprived | 1.32 (0.98–1.79) | 1.25 (0.92–1.70) | 1.30 (0.95–1.78) | 1.36 (1.00–1.86) | 1.36 (0.99–1.86) |
| Most deprived | 1.24 (0.91–1.69) | 1.19 (0.87–1.62) | 1.16 (0.84–1.60) | 1.30 (0.95–1.78) | 1.27 (0.93–1.75) |
| Deprivation (continuous) | | | | | |
| Urban core (v inner suburbs) | 0.96 (0.83–1.12) | | | | |
| Interaction Deprivation tertile/time interval | | | No significant interactions | | |
| (reference least deprived, 2000–2004) | | | | | Non-significant-eliminated from model |
| Urban core*Year Group (reference Inner suburbs, 2000–2004) | 1.29 (0.98–1.70) | | | | Significant interactions for 2005–2009 and 2015–2019 |
Police reports may under-report collisions in low-income communities, however, KSI collisions are likely reported more consistently (Sciortino et al., 2005). It is also possible that spatial patterns of collisions differ across child age groups. However, small sample sizes prevented further stratification by age. Other demographic data, such as sex and race, are not shared by Toronto police, and therefore, our analysis could not take into account these potentially relevant demographic characteristics. Detailed data on child walking rates, or active school transportation by Toronto neighbourhood were not available. Differences in collision rates are likely, in part, related to differences in walking rates. However, higher rates found in the inner suburbs, as recently as 2015–2019 indicate that road design may also play an important role.

This analysis was subject to the modifiable areal unit problem, where findings are influenced by the areal-unit of analysis (Wong, 2004). We chose neighbourhoods as the unit of analysis, given that neighbourhoods are relatively stable over time, used for planning purposes, and interpreting socioeconomic differences by neighbourhood is relatively straightforward (City of Toronto, 2021a). Because of the small sample of child KSI collisions and use of aggregated time periods, we did not use spatiotemporal methods that account for dependence across time and space. This was justified as analysis of model residuals did not find spatial autocorrelation (Moran’s I) and temporal data were averaged across years. Future research with larger datasets could consider autocorrelation across time and space.

5. Conclusion:

The first decade of the 2000s was associated with large declines in child KSI collisions across Toronto neighbourhood. However, these declines have since levelled off. It is important to examine the possible reasons (policy, behavioural, environmental) for this road safety success. Ongoing attention to equity, and particular attention to arterial roads in the inner suburbs is required to improve road safety at the population level.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2022.102050.

References

Adams, J., White, M., Heywood, P., 2005. Time trends in socioeconomic inequalities in road traffic injuries to children, Northumberland and Tyne and Wear 1988–2003. Injury Prev. 11, 125–126.

Amherber, N., Howard, A., Winters, M., Harris, M.A., Pike, L., Macpherson, A., Cloutier, M.-S., Richmond, S.A., Hagel, B., Fuselli, P., 2021. Road traffic injury during the covid-19 pandemic: Cured or a continued threat? Univ. Toronto J. Public Heal. 2.

Birken, C.S., Parkin, P.C., To, T., Macarthur, C., 2006. Trends in rates of death from unintentional injury among Canadian children in urban areas: influence of socioeconomic status. CMAJ 175, 867.

City of Toronto Transportation Services Division Traffic Calming Guide for Toronto 2016. Toronto ON.

City of Toronto, 2019. Vision Zero 2.0 - Road Safety Plan Update. Toronto, ON.

City of Toronto, 2021a. Neighbourhood Profiles [WWW Document]. URL https://www.toronto.ca/city-government/data-research-maps/neighbourhoods/n eighbourhood-profiles/ (accessed 11.4.21).

City of Toronto, 2021b. Vision Zero Mapping Tool [WWW Document]. URL https://www.toronto.ca/services/paying-roads-parking-transportation/road-safety /vision-zero/safety-measures-and-mapping/ (accessed 11.4.21).

Coupland, C., Hippiispy-Cox, J., Kendrick, D., Groom, L., Cross, E., Saveliyich, B., 2003. Severe traffic injuries to children, Trenz, 1992–7: time trend analysis. BMJ 327, 593–594.

Kunaratnam, V., Schwartz, N., Howard, A., Mitra, R., Saunders, N., Cloutier, M.S., Rothman, L., 2022. Equity, walkability, and active school transportation in Toronto, Canada: A cross-sectional study. TRD 108, 103336. https://doi.org/10.1016/j.tr e.d.2022.103336.

Matheson, F., van Ingen, T., 2018. 2016 Ontario marginalization index: user guide. Toronto, ON.

Morency, P., Gauvin, L., Plante, C., Fournier, M., Morency, C., 2012. Neighborhood social inequalities in road traffic injuries: the influence of traffic volume and road design. Am. J. Public Health 102, 1112–1119.

Roberts, I., Power, C., 1996. Does the decline in child injury mortality vary by social class? A comparison of class specific mortality in 1981 and 1991. BMJ 313, 784–786.

Rothman, L., Macarthur, C., Wilton, A., Howard, A.W., Macpherson, A.K., 2019. Recent trends in child and youth emergency department visits because of pedestrian motor vehicle collisions by socioeconomic status in Ontario, Canada. Injury Prev. 25, 570–573.

Rothman, L., Cloutier, M.S., Manaugh, K., Howard, A.W., Macpherson, A.K., Macarthur, C., 2020. Spatial distribution of roadway environment features related to child pedestrian safety by census tract income in Toronto, Canada. Injury Prev. 26, 229–233.

Sciortino, S., Vasan, M., Radetsky, M., Knudson, M.M., 2005. San Francisco pedestrian injury surveillance: mapping, under-reporting, and injury severity in police and hospital records. Accid. Anal. Prev. 37, 1102–1113.

Smart Commute. 2018. School Travel in the GTHA. A Report on Trends. Toronto, ON. http://www.publications.gov.on.ca/browse-catalogues/monthly-library-checklist/ch ecklist-november-2018/school-travel-in-the-gtha-a-report-on-trends (September 11, 2022).

Toronto Police Service. 2022. Public safety data portal: Open data documentation. Available from: https://data.torontopolice.on.ca/pages/ksi (September 2, 2022).

Toronto Police, 2012. The Walkable City: Neighbourhood Design and Preferences, Travel Choices and Health. Toronto, ON.

Transport Canada. 2021. National Collisions Database Online 1.0. [WWW Document], n. d. Available from: https://data.torontopolice.on.ca/pages/ksi (September 2, 2022).

Wong, D.W.S., 2004. The modifiable areal unit problem (MAUP). In: WorldMinds: Geographical Perspectives on 100 Problems. Springer, pp. 571–575.

Yao, X., Skinner, R., McFaul, S., 2019. At-a-glance-2015 injury deaths in Canada. Heal. Promot. Chronic Dis. Prev. Canada Res. Policy Pract. 39, 225.