The Spatial and Temporal Dimensions of Child Pedestrian Injury in Edmonton

Niko Yiannakoulis, MA¹

Karen E. Smoyer-Tomic, PhD¹

John Hodgson, PhD¹

Donald W. Spady, MD, MSc, FRCP(C)²

Brian H. Rowe, MD, MSc, CCFP(EM)³

Donald C. Voaklander, PhD⁴

ABSTRACT

Objectives: This paper describes the temporal and spatial distribution of child pedestrian injury within Edmonton, Alberta for four fiscal years (1995-96 through 1998-99), and compares this pattern to temporal and spatial data on traffic volume.

Methods: We used injury data obtained through an ongoing emergency department (ED) surveillance system involving all hospitals in Alberta's Capital Health Region. We identified peak times of injury occurrence and the location of high injury incidence as indicated by census tract of residence. Empirical Bayes estimation procedures were used to calculate stable injury incidence ratios. Cartographic and correlation analyses identified the relationship between traffic volume and injury incidence.

Results: Child pedestrian injury occurred most frequently during morning (0700-0900 hrs) and late afternoon (1500-1800 hrs) which corresponds with peak periods of vehicular traffic flow. The highest incidence rates occurred in or near areas of high traffic volume, notably in the central and west-central parts of Edmonton.

Discussion: These findings emphasize the importance of considering spatial and temporal patterns in pedestrian injury research, as well as the need to incorporate these patterns in prevention strategies. Changing the times that children attend school may reduce the convergence of pedestrian and vehicular traffic.

La traduction du résumé se trouve à la fin de l'article.

1. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB

2. Department of Pediatrics, University of Alberta

3. Division of Emergency Medicine, University of Alberta

4. British Columbia Rural and Remote Health Research Institute

Correspondence and reprint requests: Dr. M. John Hodgson, Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, AB T6G 2E3, E-mail: john.hodgson@ualberta.ca

Acknowledgements: This research was funded by the Social Sciences and Humanities Research Council (SSHRC) of Canada. The authors acknowledge the Alberta Centre for Injury Control and Research (ACICR) for providing injury data and helping to make this research possible. In addition, we are grateful for the thoughtful comments of the two anonymous referees.

Pedestrian injury is a leading cause of death in children. In 1996, 183 children aged 0-14 years died in Canada as a result of motor vehicle-related collisions, 63 of which involved pedestrians.¹ When compared to 1996 data on other major causes of death within this age group (208 deaths from cancer, 79 deaths associated with respiratory illness and 126 deaths related to diseases of the nervous system and sense organs), pedestrian injury fatalities are seen to be a significant public health concern.¹

Interest in the environment as a key component of injury risk and prevention has been growing, most likely as a result of the inconsistent success of educational prevention strategies that focus on behaviour modification.² Of the many environmental risk factors that have been investigated, the volume and density of traffic show a consistent relationship with increased risk of child pedestrian injury.³⁻⁶ Research in Edmonton, Alberta, has shown that more modern neighbourhood planning types have lower pedestrian injury rates.⁷ Children are typically injured in the morning and in the mid-afternoon,⁸ which for many children, coincides with periods of travel to and from school. The specific role that traffic volume has on risk, and the interaction between time of peak pedestrian traffic and peak automobile traffic, remains largely unexplored, however. Traffic volume varies by time and place in most cities, and understanding the relationship between vehicular and pedestrian traffic density may offer unique opportunities for prevention.

A two-pronged approach, considering both time and space, is needed to minimize the interaction between child pedestrians and automobile traffic. Before this type of intervention can be designed and implemented, it is necessary to identify when and where child pedestrians are being injured. We hypothesize that injury incidence varies throughout the course of the day, as well as throughout the city of Edmonton, and that this variation coincides with variation in traffic density. Thus the primary purposes of this paper are to 1) describe the temporal and spatial distribution of child pedestrian injury within Edmonton for four fiscal years (1995-96 through 1998-99), and 2) relate this pattern to temporal and spatial data on traffic volume.

METHODS

The Alberta Centre for Injury Control and Research provided four fiscal years (1995-96 to 1998-99) of injury data through an ongoing emergency department (ED) surveillance system involving all hospitals in the Capital Health Region, an administrative health unit located in central Alberta. Since the data come from emergency departments, the final case count excludes fatalities that occurred prior to arrival in the ED as well as minor injuries that were either unreported, or reported only to physicians outside the ED setting. We assume that there are no temporal or spatial biases in this under-counting.

Our study was restricted to cases living in urban Edmonton, the largest city in the region. Cases were defined as children 15 and under who were admitted to an ED with a pedestrian injury diagnostic code (ICD9-CM E814.7). In addition to diagnostic information and age and gender of the case, the data set includes information on the place of residence and the time of admittance to the emergency department. We used time of ED admittance as a proxy for time of injury, as this was the only time-specific information available. We used the six-digit postal code to locate residence of injury cases, and a postal code look-up file developed by Statistics Canada to aggregate postal codes into their respective census tracts (CT). We thus aggregated our cases based on CT of residence rather than CT of collision. Previous Canadian research has suggested that most children involved in pedestrian-automobile collisions are injured in the census tracts in which they live.⁹ Our rate calculations are based on tract populations from the 1996 Canadian Census.

Generating incidence rates in small areas (like census tracts) can be complicated by the fact that the number of outcomes and the underlying population are small. Frequently, such maps reveal very high rates in areas with small populations. This occurs because rates generated in areas with low counts of events are more affected by small variations in the number of events than those in areas with larger event counts. The resulting maps are not necessarily representative of underlying patterns of risk, and may even provide a misleading representation of spatial variability. To

Figure 1. Injuries for three age groups by time of day for FY 1995/96-1998/99 in urban Edmonton

Figure 2. Traffic density in urban Edmonton, 1996

Figure 3. Child pedestrian injury incidence ratio in urban Edmonton, FY 1995/96-1998/99.
TWMC = traffic weighted mean centre.

mitigate this problem, we mapped empirical Bayes estimates of child pedestrian injury incidence ratios as an alternative to mapping crude incidence rates/ratios. The technique is discussed in detail elsewhere.^{10,11} In short, for each ratio, an adjustment was made according to parameters that describe the distribution of the regional child pedestrian injury incidence ratio. For areas with smaller populations, the adjustment is greater. For areas with larger populations, the adjustment is smaller. The result is a 'smoothed' map in which incidence estimates contain both a measure of magnitude and a measure of certainty. Although empirical Bayes estimates may over-smooth spatial data, these estimates usually preserve spatial patterns, and provide good representations of overall spatial variation of risk.¹²

The City of Edmonton Department of Transportation provided data on city-wide

traffic flow for 1996, which were linked to a digitized map of the city street network provided by Statistics Canada. Volume data were not provided for low-traffic residential streets, so we restricted our focus to arterials and other higher volume roadways. High-volume freeways were excluded from analysis in cases where pedestrian-blocking berms prevent the roadways from being crossed on foot. We calculated traffic density for census tracts within urban Edmonton by multiplying the length of each arterial by its average daily traffic volume, summing this value for each CT, and then dividing this value by the area of the CT. The City of Edmonton Department of Transportation Information also provided data on traffic flow by time of day.

Since daytime traffic density in urban areas is typically high in and around the downtown core, we also investigated the relationship between distance from the city

centre and injury incidence. The distance of each residential CT to the city centre was estimated by calculating the Euclidean distance between the geometric centre of each CT and a point located in the traffic density weighted-mean centre (TWMC) of the study area. In this study, the TWMC is close to both the geometric centre of the city as well as the population-weighted mean centre. Pearson correlation was used to test the association between traffic density and injury incidence as well as the association between injury incidence and the distance from the TWMC.

RESULTS

Within the study period, a total of 258 children (0-15 years of age) were injured in motor vehicle-pedestrian collisions. The times that these cases were admitted to an ED peaked in frequency during two periods of the day (Figure 1). The morning peak is a narrow band of time between 0700 and 0900 hrs. During this time, most cases were over nine years of age, particularly between 0700 and 0800 hrs. The second peak occurred between the hours of 1500 and 1800 hrs; however this period of higher injury frequency is not as distinct as the morning period. Injuries continued to be reported fairly frequently between 1900 and 2000 hrs. Children over four years of age showed fairly constant frequency of injury reporting during the afternoon period.

Traffic density in Edmonton is higher in the central and west-central areas of the city and lower in most outlying areas (Figure 2). A corridor of census tracts running from the south toward the city centre also shows a higher traffic density. Traffic density is lowest in the southwest.

Child pedestrian injury incidence shows moderate variability within the study area (Figure 3). Incidence ratios are highest in several downtown CTs and in several CTs located in the west-central areas of the city. Visual inspection of the two maps suggests a possible association between traffic density and child pedestrian injury incidence as hypothesized. Visual comparisons can be misleading; Pearson correlation provides a more objective measure of association. Tract incidence ratios show a moderate negative association with distance from the TWMC ($r = -0.310$, $p = 0.0001$). There is also a positive correlation between tract

traffic density and tract child pedestrian injury incidence ratio ($r=0.381$, $p=0.0001$).

The time of ED admittance overlaps considerably with the peak hours of automobile traffic flow (Figure 4). The morning and afternoon peaks match closely, as does the mid-day trough. In the mid to late afternoon, the trend in injuries slopes more gradually than the steep drop in traffic flow. The two vertical bands indicate the periods in which classes start and end for most Edmonton schools.

DISCUSSION

The bimodal pattern of times that children are injured as a result of collisions with automobiles has been noted elsewhere.⁸ These peaks correspond to the times of day that most of Edmonton's children start and finish school. Children in the older age group (10-15) were injured more frequently in the early morning than younger children. This may be explained by differences in times of school attendance or differences in pedestrian behaviour at these times of day. More detailed analysis might better identify a clear relationship between time of school attendance and risk of injury. Nevertheless, our results also reveal a notable temporal association between the hours of highest injury frequency and peak hours of traffic flow. Although our measure of time of injury is only a proxy derived from time of ED admittance, the pattern suggests that children are injured most frequently at times when automobile traffic flow is at its greatest.

Our findings confirm an association between child pedestrian injury incidence and traffic density. These results do not account for environmental confounders that may have a spatial distribution similar to traffic density – like visibility, availability and quality of crosswalks. Nor have we controlled for non-environmental factors (like low income and parental supervision) which may similarly confound our results. However, other research has established an independent relationship between traffic density and child pedestrian injury in Edmonton.¹³

We hypothesize a space-time interaction between peaks in traffic volume and time of school attendance. Since much of Edmonton's traffic flows towards the city

Figure 4. Hour-specific percentage of injuries and city-wide traffic volume, FY 1995/96-1998/99, urban Edmonton

centre in the morning,¹⁴ peak periods of traffic flow occur earlier in the morning in outlying regions of the city, and later in the morning in central regions. This pattern would be reversed in the afternoon when children are leaving school; traffic peaks earlier in the afternoon in central regions of the city, and later in the afternoon in outlying regions.

The sum of these observations suggests that slight changes in the times that some children attend school may reduce their risk of pedestrian injury. Several strategies have been considered to reduce the *spatial* convergence of children and vehicles, including eliminating visual obstacles near the road⁵ and reducing curb parking.⁶ However, there is a dearth of information about efforts to reduce the *temporal* convergence of children and vehicles. Offsetting times of school attendance could provide a simple and inexpensive method of reducing automobile-related injury to child pedestrians. The spatial variability of injury incidence combined with knowledge of the times of peak traffic flow in different regions of the city may identify focal points for such intervention.

For example, children living in west and central Edmonton, where both traffic volume and injury incidence is high, may benefit from slight changes in the times of school attendance. These passive strategies, which would reduce the physical intersection of children and traffic, could serve as highly effective components of ongoing active pedestrian injury prevention programs, augmenting such measures such as education and awareness.

Child pedestrian injury in Edmonton during the study period occurred most frequently during morning (0700-0900 hrs) and late afternoon (1500-1800 hrs) peaks in vehicular traffic flow. In addition to variation in the timing of injuries, we noted variation in the residential location of injured children, with the highest incidence rates occurring in or near areas of high traffic volume, notably in the central and west-central parts of Edmonton. These findings emphasize the importance of considering spatial and temporal patterns in pedestrian injury research, as well as the need to incorporate these patterns in prevention strategies. Further research is required to specifically quantify the space-

time process hypothesized here. Techniques developed for spatial and temporal cluster detection¹⁵ may provide more definitive conclusions about the relationship between times of peak pedestrian traffic, times of peak vehicular traffic and the variation of traffic density and injury over space.

REFERENCES

1. Statistics Canada. Causes of Deaths, 1996. Statistics Canada No. 92351XPE. Ottawa: Government of Canada, 1996.
2. Roberts IG. Why have child pedestrian death rates fallen? *BMJ* 1993;306:1737-39.
3. Lascaia EA, Gerber D, Gruenewald PJ. Demographic and environmental correlates of pedestrian injury collisions: A spatial analysis. *Accid Anal Prev* 2000;32:651-58.
4. Stevenson M. Childhood pedestrian injuries: What can changes to the road environment achieve? *Aust N Z J Public Health* 1997;21:33-37.
5. Stevenson MR, Jamrozik KD, Spittle J. A case-control study of traffic risk factors and child pedestrian injury. *Int J Epidemiol* 1995;24:957-64.
6. Roberts I, Norton R, Jackson R, Dunn R, Hassall I. Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: A case-control study. *BMJ* 1995;310:91-94.
7. Wang S. Residential Planning for Pedestrian Safety. PhD Dissertation, 1994.
8. Calhoun AD, McGwin G, King WD, Rousculp MD. Pediatric pedestrian injuries: A community assessment using a hospital surveillance system. *Acad Emerg Med* 1998;5:685-90.
9. Joly MF, Foggin PM, Pless IB. Geographical and socio-ecological variations of traffic accidents among children. *Soc Sci Med* 1991;33:765-69.
10. Clayton D, Kaldor J. Empirical Bayes estimates of age-standardized relative risks for use in disease mapping. *Biometrics* 1987;43:671-81.
11. Pringle DG. Mapping disease risk estimates based on small numbers: An assessment of empirical Bayes techniques. *Econ Soc Rev* 1996;27:341-63.
12. Kennedy-Kalafatis S. Reliability-adjusted disease maps. *Soc Sci Med* 1995;9:1273-87.
13. Yiannakoulis N. Child Pedestrian Injury in an Urban Environment: Risk in Space and Time. Masters Thesis, 2000.
14. City of Edmonton Transportation Department. Household Travel Survey Project Report. Edmonton: City of Edmonton, 1995.
15. Kulldorff M, Athas WF, Feuer EJ, Miller BA, Key CR. Evaluating cancer alarms: A space-time scan statistic and brain cancer in Los Alamos, New Mexico. *Am J Public Health* 1988;88:1377-80.

Received: September 13, 2001
Accepted: June 19, 2002

RÉSUMÉ

Objectifs : Notre étude décrit la répartition spatiale et temporelle des blessures survenues chez les enfants circulant à pied à Edmonton (Alberta) pendant quatre années financières (1995-1996 à 1998-1999) et compare ce schéma aux données spatio-temporelles sur le débit routier.

Méthode : Nos données sur les blessures provenaient du système de surveillance continue des services d'urgence des hôpitaux de la région sanitaire de la capitale albertaine. Nous avons cerné les périodes de pointe pour les blessures et les endroits où elles se produisaient le plus par secteur de recensement. En établissant des estimations empiriques par la méthode de Bayes, nous avons calculé les rapports d'incidence stables des blessures. Des analyses cartographiques et de corrélation ont mis au jour un lien entre le débit routier et l'incidence des blessures.

Résultats : Les blessures aux enfants circulant à pied étaient les plus fréquentes le matin (entre 7 h et 9 h) et en fin d'après-midi (entre 15 h et 18 h), ce qui correspond aux heures de pointe de la circulation routière. Les taux d'incidence les plus élevés ont été constatés à l'intérieur ou à proximité des zones de fort débit, tout particulièrement dans le centre-ville et le centre-ouest d'Edmonton.

Question à débattre : Ces résultats soulignent l'importance de tenir compte des schémas spatio-temporels dans la recherche sur les blessures aux piétons et de les intégrer dans les stratégies de prévention. En modifiant les heures d'école, on pourrait aussi réduire la convergence de la circulation des piétons et des véhicules.

BOOK REVIEW

World Report on Violence and Health

*Edited by Etienne G. Krug, Linda L. Dahlberg,
James A. Mercy, Anthony Zwi and Rafael Lozano.
Geneva: World Health Organization, 2002*

This World Report will likely cause readers to think seriously about taking action against global violence. The hook is not only in the horrifying statistical profile of violence, but in the evidence-based approach that convinces readers that reducing global violence is possible. The Report brings together academics and practitioners working in public health and asks them to create as seamless a link as possible between research findings, interventions/policy responses, and recommendations/action plans to eradicate world violence. Although the World Report states that eradication is possible, the magnitude and impact of violence, key risk factors, and the effectiveness of various interventions and policy responses do not fill readers with confidence that we can wipe out global violence. Potential readers should not allow such clichés as eradication of violence to turn them away from reading this document – the report presents a scientific and practical approach that, if implemented and appropriately supported structurally and financially, will likely significantly reduce global violence.

This World Report is peer-reviewed with each chapter undergoing an assessment of its scientific merit and its relevance to the specific culture(s). An advisory committee with membership from all WHO regions and representatives from WHO staff provided guidance to the Editorial Committee. In all, over 160 world experts participated in this document.

The scope of the Report is wide. There are nine chapters that address violence as a global public health issue, youth violence, child abuse/neglect, intimate partner violence, elder abuse, sexual violence, self-directed violence, collective violence and recommendations for action that cut across all these types of violence. The public health surveillance methods employed and the data interpretation are excellent and authors clearly identify data and study limitations.

The World Report is comprehensive and although it is technically complex, the information is translated into clear messages and recommendations, widening its appeal and usefulness. Public health and health professionals, policy-makers, ethicists, rights advocates, and political scientists will benefit from reading it. However, the general public is an important audience – it is, after all, a statement about all of our lives and times, and the need for action.

*Lorraine E. Ferris, PhD., C.Psych., LL.M.
Associate Professor, Department of Public Health Sciences,
Faculty of Medicine, University of Toronto, Toronto, Ontario*