3-2014

An epidemiologic profile of pediatric concussions: Identifying urban and rural differences

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BACKGROUND: The objective of this study was to describe the epidemiology of concussions presenting to the emergency department (ED).

METHODS: A retrospective cohort of concussions for pediatric (age < 18 years) patients treated in the ED of a regional pediatric Level 1 trauma center from 2006 to 2011 was examined. Descriptive and geographic analyses were completed, with comparisons by age groups and residence (urban/rural).

RESULTS: There were a total of 2,112 treated pediatric concussions. Two thirds of the concussions occurred in males (67%), with a median age of 13 years (interquartile range [IQR], 6). Nearly half of the pediatric concussions were sports related (48%); 36% of these concussions were from hockey. Significant differences were found in the distribution of the mechanism of injury across age groups ($p < 0.001$). Falls were most prevalent among young children, and sports concussions, for children 10 years and older. Two fifths of concussions occurred during winter months. Discharge disposition significantly differed by age ($p < 0.001$), with home discharge increasing with age up to 14 years. There were a total of 387 rural (19%) and 1,687 urban (81%) concussed patients, for a mean ED concussion visit rate of 2.2 per 1,000 and 3.5 per 1,000, respectively. Rural patients were older (14 [IQR, 6] vs. 13 [IQR, 6], $p = 0.019$] and sustained 2.5 times more concussions from a motor vehicle crash compared with urban youth patients ($p < 0.001$).

CONCLUSION: Males in early adolescence are at highest risk for concussion, particularly from sport-related activities. Urban and rural children have differences in their etiology and severity of concussions. Concussions are predictable, and their prevention should be targeted based on epidemiologic and environmental data. (*J Trauma Acute Care Surg*. 2014;76: 736–742. Copyright © 2014 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Epidemiology–injury; concussion; mild traumatic brain injury; urban; rural.

Traumatic brain injury (TBI) is a major public health concern of epidemic proportions, with an annual incidence of 1.6 to 3.2 million in the United States.[1,2] In Canada, there are 34,000 hospitalizations every year for TBI.[3] Mild TBI (mTBI), of which concussion is a subset,[4] is the most common form, representing nearly 75% of all TBIs.[1] These less severe forms of TBI disproportionately affect youth, with more than half of mTBIs occurring in children and adolescents.[2,5] While concussions are common in the pediatric population, they are not without concern because there is the potential for significant acute symptoms and long-term consequences for a child's functioning and ongoing neurologic development.[6,7]

A concussion has been defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."[8] Typically, concussions result in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously. Concussions can result from a direct blow to the head, face or neck or a hit somewhere else on the body with an "impulsive" force that is transmitted up to the head and may or may not involve a loss of consciousness (LOC). It has been noted that while a concussion may result in microscopic neuropathologic changes, it is largely a functional disturbance of clinical symptoms rather than a structural injury.[4,7,8]

The recent media attention over concussions has increased awareness of this important pediatric health issue and has resulted in a heightened interest to better understand the epidemiology, pathophysiology, and sequelae from sustaining a concussion. It is only through a complete understanding of concussion occurrence, its causes, and who is at risk that targeted interventions to prevent concussion can be implemented.

The objective of this study was to describe the epidemiology of concussions presenting to the emergency department (ED) of a Level 1 pediatric trauma center. A comparison of concussions by age groups and a subgroup analysis for comparing concussions sustained by urban and rural children were undertaken.

PATIENTS AND METHODS

This study examined a retrospective cohort of concussions with or without other intracranial computed tomography (CT) finding for pediatric (age < 18 years) patients treated in the ED of a regional pediatric Level 1 trauma center (Children's

Submitted: June 19, 2013, Revised: September 6, 2013, Accepted: September 6, 2013.
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DOI: 10.1097/TA.0b013e3182aafdf5

Hospital, London Health Sciences Centre in London, Ontario) from 2006 to 2011. The National Ambulatory Care Reporting System was used for any International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA).[9] Diagnosis codes for concussion within code S06 and coded for amnesia and unspecified coma (R40.29, R41.1, R41.2, R41.3, R41.8), along with any of the following trauma codes: S00-T98, injury and certain other consequences of external causes; U98.0–U98.9, place of occurrence codes; and V01–Y98, external causes of morbidity and mortality codes. This list of concussed patients was cross-referenced with severely injured (Injury Severity Score [ISS] > 12] patients within our trauma registry to confirm that the initial in-hospital Glasgow Coma Scale (GCS) score was greater than 12, in accordance with the definition of mTBI.[10] Penetrating head injuries were excluded.

Analysis included all first-time visits to the ED for treatment of a concussion. Return visits for reevaluation of the same concussion were excluded. Subsequent ED visits by the same patient for new concussion incidents were included. A subanalysis of repeat concussion was undertaken.

Descriptive analyses were completed. Data analyzed included age, sex, year of ED visit, place of occurrence, disposition from ED, type of concussion, etiology based on major ICD-10-CA groupings, with the exception of "sports and recreation-related," which was a new category created that also included struck by or against animate or inanimate objects W codes (W51.00–W51.07; W21.00–W22.07) and sports and recreation-related falls (i.e., falls related to sports, W02.00–W02.08; falls from playground equipment/swings/trampolines, W09.00–W09.09; diving, W16; struck against/bumped into person in sports, W51; and struck against/by object in sports, W21–22). Data were compared for the five pediatric age groups (<1 year, infants; 1–4 years, toddlers; 5–9 years, school age; 10–14 years, early adolescents; 15–17 years, late adolescents)[11] up to the age of 17 years, the definition of "pediatric" at our institution, using χ^2 for proportions of categorical data and nonparametric Mann-Whitney U-test for continuous variables. All continuous variables were checked for normality with the Shapiro-Wilk test. Because data were all nonnormally distributed, medians and interquartile ranges (IQRs) were presented. A subanalysis of urban versus rural pediatric patients was undertaken. A $p < 0.05$ was considered statistically significant. All analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corporation, Armonk, NY).

Data on home address of concussed patients were entered into a Geographic Information System (ArcGIS 10.1, Environmental Systems Research Institute, Redlands, CA) to allow for the patients' home address mapping and the identification of selected demographic and geographical characteristics of patients' home neighborhoods to examine potential rural and urban differences.[12] Neighborhoods were defined by dissemination areas (DAs), the smallest geographical unit for which Statistics Canada releases the population data required for this study. Data on the number of children (age < 18 years) and the total population (all ages) for each DA in Southwestern Ontario were extracted from the 2011 Canadian Census (Statistics Canada, 2011). Geographic analysis involved identifying each DA as urban or rural, as defined by Statistics Canada. Urban DAs were identified as having a minimum population concentration of more than 1,000 people and a population density of more than 400 people/km^2; otherwise, the area is classed as rural. Population-based admission rates were calculated for every DA in Southwestern Ontario by dividing the number of children admitted for concussions who reside in a given DA by the total number of children living in that DA. A map of ED visits per 1,000 children by DA was created. The data used for mapping were aggregated and presented at a level of detail small enough as to not be able to identify any individual, to maintain patient privacy. This study was approved by the Western University, Health Sciences Research Ethics Board.

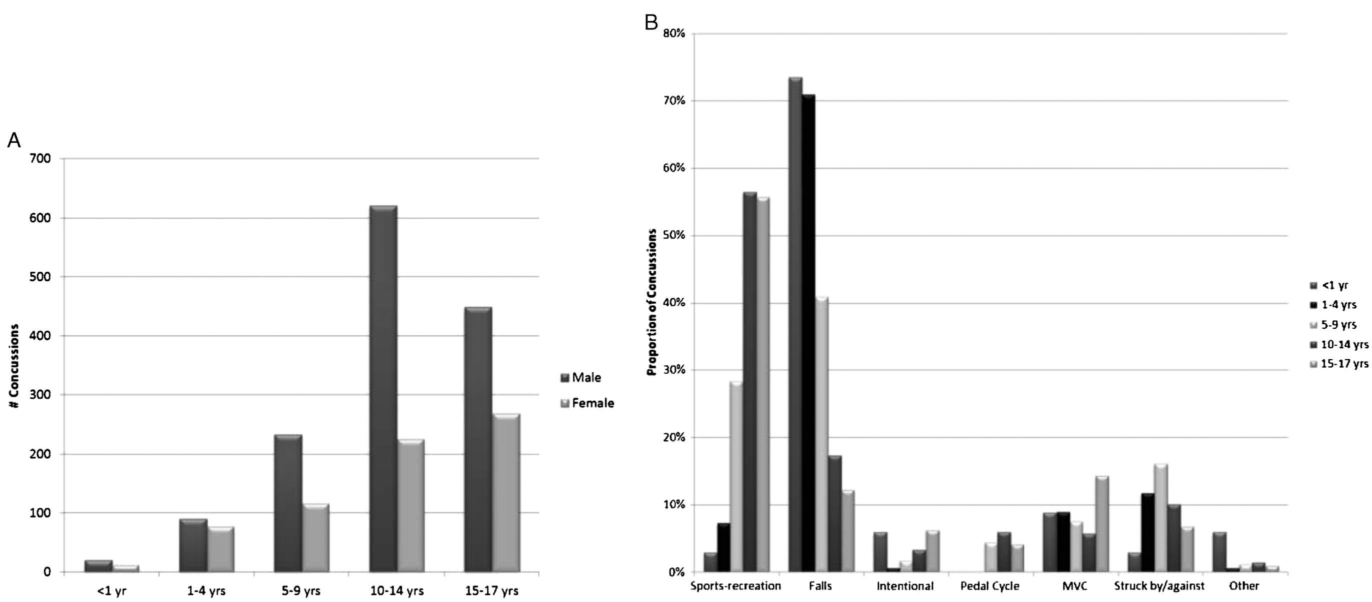

Figure 1. Age-sex distribution (*A*) and etiology by age group (*B*) for all pediatric concussions (n = 2,112).

RESULTS

All Pediatric Concussions

There were a total of 2,112 pediatric concussions during the 6-year period. Two thirds of the concussions occurred in males (67%). The median age was 13 years (IQR, 6). An age-sex distribution is presented in Figure 1*A*.

The etiology and place of injury occurrence are presented in Table 1. Nearly half of pediatric concussions were sports and recreation related (48%), with 37% occurring in a sports field or arena. The concussion etiology for the five pediatric age groups is depicted in Figure 1*B*. Significant differences were found in the distribution of the mechanism of injury across age groups ($p < 0.001$). The specific mechanism of injury for each etiologic category is presented in Table 2, with hockey as the leading mechanism.

A subgroup analysis of mechanism of injuries by age group revealed significant proportional sex differences in motor vehicle crash (MVC) (9% for females vs. 4% for males, $p = 0.016$) and pedal cycle injuries (4% for females vs. 7% for male, $p = 0.016$), for patients 10 years to 14 years of age. For adolescents 15 years to 17 years of age, there were significant sex differences in concussion mechanism, in particular falls (19% for female vs. 9% for males, $p < 0.001$) and intentional injury (4% for females vs. 8% for males, $p < 0.001$).

The number of concussions increased each year from low of 289 in 2007 up to a maximum of 488 concussions in 2011 or a 69% increase in concussions treated in the ED during the past 5 years. The temporal analysis of concussions by month found November to have the most concussions (n = 240, 11%), August the lowest (n = 111, 5%). Overall, the winter months (November–February) accounted for 40% of concussions. There were more sports-related concussion in the winter (59% vs. 41%, $p < 0.001$), primarily related to the more than double the number of hockey-related concussions [248 [50%] vs. 120 [23%], $p < 0.001$].

Overall, 10% of concussed patients reported an LOC. A total of 490 patients (23%) had a head CT scan as part of their assessment. Only 7% (149 of 2,112) of all concussed patients had an acute intracranial abnormality identified by CT scan (Fig. 2).

In total, 93% of these patients were discharged home following assessment and treatment in the ED. Five percent of the concussions with acute intracranial abnormalities and injuries to other body regions were admitted to the hospital, and 2% were admitted to a special care unit.

TABLE 1. The Etiology and Place of Occurrence for the ED Pediatric Concussions

Data Element	n (%) n = 2,112
Etiology	
Sport and recreation related	1,009 (47.8)
Falls	526 (24.9)
Struck by/against object/person	212 (10.0)
MVC	165 (7.8)
Pedal cycle	92 (4.4)
Intentional	82 (3.9)
Other	26 (1.2)
Place of occurrence	
Sports and athletic arena	784 (37.1)
School and public place	268 (12.7)
Home	215 (10.2)
Street and highway	156 (7.4)
Other specified place	133 (6.3)
Unspecified place	556 (26.3)

TABLE 2. Specific Mechanism of Injury for Each Etiologic Category for All Pediatric Concussions

Mechanism of Injury	n (%)
Sports and recreation related	
Hockey	368 (36.3)
Football/rugby	114 (11.3)
Ice skates/inline/roller/skateboard	111 (11.0)
Baseball	86 (8.5)
Soccer	80 (7.9)
Snowboard/Skiing	67 (6.6)
Playground Equipment	42 (4.1)
Toboggan	23 (2.3)
Other sports and recreation	122 (12.0)
Falls	
Fall—same level	270 (51.4)
Fall—1 level to another	77 (14.6)
Fall—stairs and steps	56 (10.6)
Fall—furniture	55 (10.5)
Fall—other and unspecified	68 (12.9)
Struck by/against object/person	
Inanimate	
Struck by/against, non–sports related*	120 (56.6)
Struck by thrown/falling object	25 (11.8)
Animate	
Struck/hit/bit by person/animal	40 (18.9)
Struck against, non–sports related*	27 (12.7)
MVC	
MVC—occupant	69 (41.8)
MVC—recreational vehicle**	30 (18.2)
MVC—pedestrian	27 (16.4)
Motorcycle	20 (12.1)
MVC—other vehicle†	19 (11.5)
Pedal cycle	
Pedal cycle—noncollision	69 (75.0)
Pedal cycle vs. car	13 (14.1)
Pedal cycle—collision stationary object	10 (10.9)
Intentional	
Assault	78 (95.1)
Child abuse	3 (3.7)
Intentional self-harm	1 (1.2)
Other	
Exposure to factors causing injury‡	26 (100)

*The child was struck by or against an object or person in a non–sports-related activity.

**MVC—recreational vehicle includes ATVs, snowmobile, sailboat, and powered watercraft.

†MVC—other vehicle includes rider or occupant of animal/animal drawn vehicle, agricultural vehicle, and other vehicle.

‡Exposure to factors causing injury includes cause of injury/concussion unspecified or not documented.

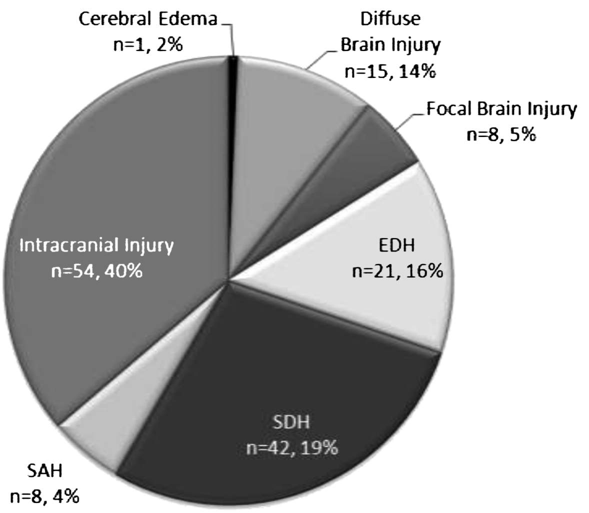

Figure 2. Intracranial abnormalities in concussed patients (n = 149).

Of note, there were a total of 75 patients (3%) who returned to our ED for a repeat concussion during the study period. Of these, eight patients (11% of repeat concussions) returned for three different concussion incidents, and two patients (3%) sustained four concussions. For two patients returning to the ED (3%), they had sustained a more severe head injury for this second visit. Two additional patients visited the ED for concussions following a previous severe TBI.

Urban Versus Rural

There were a total of 387 rural (19%) and 1687 urban (81%) patients with concussion for a mean ED concussion visit rate of 2.2 per 1,000 (rural) and 3.5 per 1,000 (urban). Rural areas had more than double the maximum incidence rate at 300 per 1,000 compared with urban areas (140 per 1,000). A map depicting the ED concussion visit rates by home neighborhood is presented in Figure 3. A comparison of the patient demographics and etiologic variables is shown in Table 3. Rural patients were slightly older than the urban patient (14 [IQR, 6] vs. 13 [IQR, 6], $p = 0.019$), with the highest proportion of rural patients consisting of the late adolescence age group of 15 years to 17 years (41%) compared with the early adolescent age group (41%) for urban patients ($p = 0.046$).

The mechanism of injury differed with rural children sustaining 2.5 times more concussions from an MVC compared with urban youth (Table 3, $p < 0.001$). A subanalysis of the types of injury mechanisms by urban/rural groups found the specific types of MVCs to differ between groups. Occupant of a vehicle was the most common type of MVC occurring to urban and rural youth (41% and 39%, respectively; $p = 0.005$). The proportion of rural children injured in a motorized recreational vehicle, including an all-terrain vehicle (ATV), snowmobile or motorized water craft, was more than double the proportion in urban youth (31% vs. 12%, $p = 0.005$). In the urban environment, children had nearly 5 times the proportion of children sustaining concussions as a pedestrian in an MVC than rural youth (24% vs. 5%, $p = 0.005$). Both urban and rural had hockey as the most common sports-related injury at 36% and 41%, respectively ($p = 0.226$). More than half of the falls in both groups were on the same level (51% urban vs. 54% rural, $p = 0.141$), and the majority of pedal cycle injuries were a fall from bicycle (78% urban vs. 55% rural, $p = 0.252$). The temporal distribution of concussions by region was not significantly different ($p = 0.779$).

Rural children and teenagers had significantly more concussions with an LOC (12% vs. 10%, $p < 0.001$) and with acute intracranial abnormalities (10% vs. 6%, $p < 0.001$). In addition, more were admitted as an inpatient (7% vs. 4%, $p < 0.001$) and to a special care unit (3% vs. 1%, $p = 0.012$) compared with urban youth. The vast majority of patients in both groups were discharged home, but more of the urban children and adolescents went home directly from the ED (94% vs. 90%, $p < 0.012$).

DISCUSSION

Concussions have become a "hot topic" recently in both the media and medical literature. Attitudes have changed drastically of what was once considered a "ding," and young athletes were often told to "shake it off," to the recognition of the potential serious and long-lasting effects of concussions.[7,13,14] The symptoms following a concussion can be highly variable and range from short-lived disturbances to profound and persistent disabilities, cognitive impairments, behavioral changes, and in rare cases, death from second-impact syndrome.[7,14,15]

Concussions are of particular concern for youth because their brains are still developing and may be more susceptible to the effects of a concussion,[14–16] with several studies finding the rates of concussion and mean time to normalization to preconcussion baseline to be higher for adolescents, as compared with adults.[17,18] In addition, there is the potential for behavioral changes and loss of activities, such as sports and school, which can negatively impact a child's normal intellectual and social development.[14]

Our number of ED concussions increased annually, with a dramatic increase in 2011. This likely reflects an increase in diagnosis or the public coming to the ED for assessment, as a result of heightened media attention surrounding concussions. The incidence of concussions in our cohort increased with age up to 10 years to 14 years, with late adolescents consisting of the second largest age group, as was found in reports from other North American EDs.[19,20]

Sports- and recreation-related concussions were the most common mechanism for concussion in our population, as demonstrated by many other studies.[7,13,19,21,22] Participation in sporting activities, both organized and not, is very common for youth, putting them at higher risk for sports-related injury.[22] Our proportion of sports-related concussions increased with age, with just more half of adolescent's (10–17 year olds) concussion the result of this mechanism, similar to a recent study in US EDs, which found 41% of adolescents' concussions to be sports related.[23] Our primary sports activity resulting in concussions was hockey, consistent with our Northern climate.[19] Having such a high number of concussions related with winter sporting activities accounts for 40% of our concussions occurring during the winter months.

Falls were the second leading cause of concussions, accounting for one quarter of the pediatric ED visits for concussions.

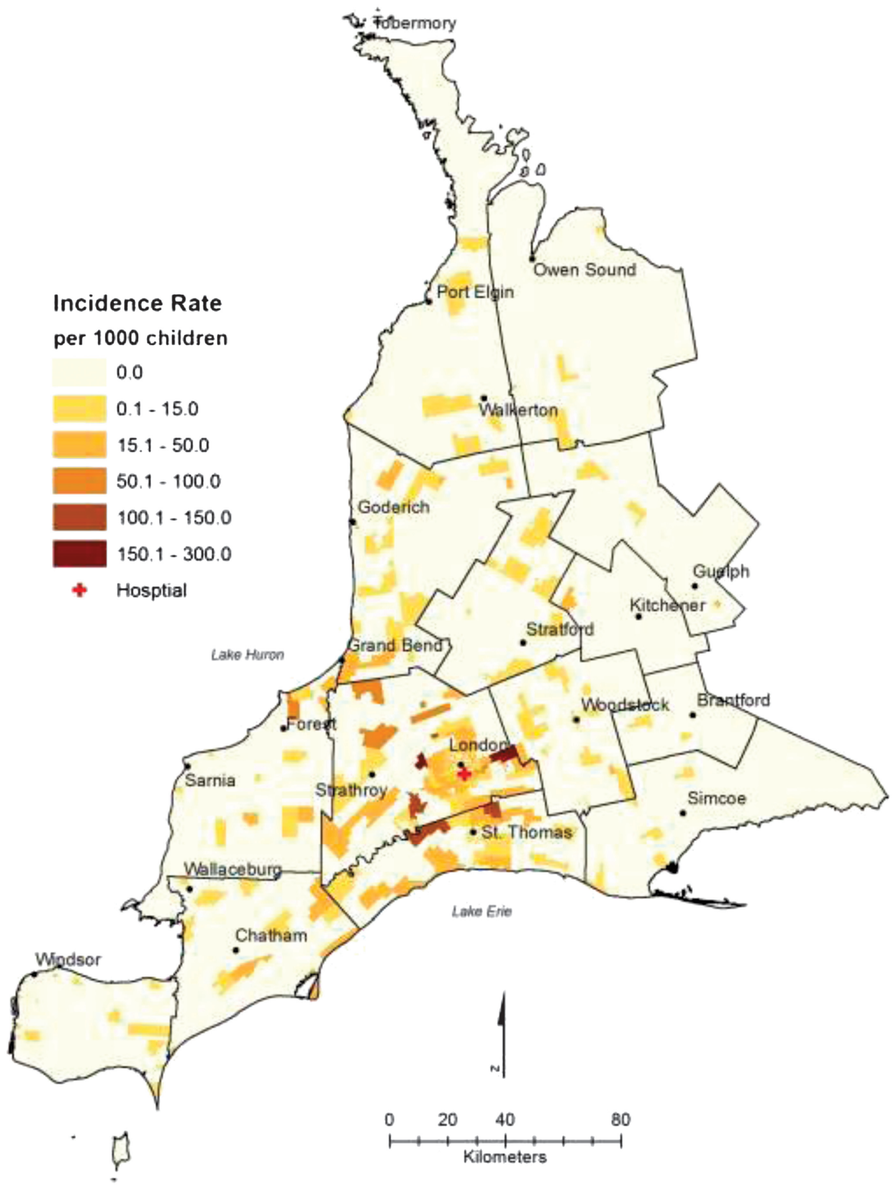

Figure 3. Map of the pediatric ED concussion visit rates by home neighborhood (DAs), Southwestern Ontario, Canada.

This proportion dramatically increases for children younger than 5 years, accounting for 73% of their concussions, with the majority occurring in the home. The primary type of fall for this age group was falls from furniture, highlighting the need for reinforcement of supervision as a prevention mechanism for infants and young children.

We found that 10% of our concussions were associated with an LOC consistent with previous reports.[15] Previous research suggests that pediatric patients with an LOC, even with a GCS score of 15, are reported to be at greater risk for intracranial injury, warranting neuroimaging.[24,25] Correspondingly, 23% of our population had a CT scan, and 7% of our patients had an acute intracranial abnormality identified. A previous study also found that 18% of patients arriving to the ED with a GCS score of 13 to 15 had an intracranial abnormality on initial CT.[26] In total, 93% of our patients were discharged from ED, similar to a report from American EDs,[27] providing support that our definition, population, and outcomes of pediatric concussions were similar.

Our finding that 11% of pediatric patients returned to our ED for repeat concussion was not surprising because it has been previously reported that individuals who have had a concussion are at an increased risk for additional concussions.[28,29] Our finding is likely an underestimation of the total number of repeat concussion because other patients may have sustained a subsequent concussion but did not seek medical attention in our ED.

Our analysis of pediatric urban and rural concussions is novel and important because it is well-established that the sociodemographic and environment issues for the urban and rural areas differ.[30,31] Urban children are at greater risk for concussion, based on our calculated mean ED concussion visit rates, with particular concern for pedestrian injuries. Previous

TABLE 3. A Comparison of Urban and Rural Children and Mechanism of Concussion*

Data Element	Rural n = 387	Urban n = 1,687	p
Age, median (IQR)	14 (6)	13 (6)	0.019
Age groups			0.046
Infants < 1 y	6 (1.6%)	24 (1.4%)	
Toddlers, 1–4 y	28 (7.2%)	136 (8.1%)	
School age, 5–9 y	58 (15.0%)	288 (17.1%)	
Early adolescents, 10–14 y	138 (35.7%)	693 (41.1%)	
Late adolescents, 15–17 y	157 (40.6%)	546 (32.4%)	
Male	250 (64.6%)	1,138 (67.5%)	0.281
Etiology			<0.001
Sports and recreation related	190 (49.1%)	804 (47.7%)	
Falls	82 (21.2%)	437 (25.9%)	
Struck by/against object/person	36 (9.3%)	171 (10.1%)	
MVC**	59 (15.2%)	101 (6.0%)	
Pedal cycle	11 (2.8%)	80 (4.7%)	
Intentional	6 (1.6%)	72 (4.3%)	
Other	3 (0.8%)	22 (1.3%)	
Place of occurrence			0.010
Sports and athletic arena	145 (37.5%)	628 (37.2%)	
School and public place	34 (8.8%)	229 (13.6%)	
Home	32 (8.3%)	179 (10.6%)	
Street and highway	38 (9.8%)	114 (6.8%)	
Other specified place	33 (8.5%)	99 (5.9%)	
Unspecified place	105 (27.1%)	438 (26.0%)	

*There were 38 patients (1.8%) for which type of residence could not be determined.
**MVC includes patients sustaining a concussion as a driver, passenger, pedestrian in a passenger vehicle, motorcycle, recreational vehicle or other vehicle, traffic, and nontraffic.

work has demonstrated an environmental and spatial relationships for pedestrian injuries with high-risk areas characterized by high population density, fast moving traffic, absence of parks, and socioeconomic aspect with significantly lower levels of education, income, and housing.[31,32]

Our rural areas had more than doubled the maximum ED concussion visit rate of concussions compared with urban areas, likely owing to their environment and activities they undertake. For example, ATV-related injury has been shown to be overrepresented in rural areas, among the youth, because their use is increased in farming regions, whether for work or recreation.[33] Our previous research has demonstrated severe ATV-related injury to be predominantly rural (65%) for our region and that helmets were not commonly used.[12,34]

Based on our data, "targeted MVC and sports interventions" can be implemented in these locations, through education and enforcement of legislation[35,36] for ATV-related concussions and engineering interventions such as improved pedestrian crosswalks for the urban pedestrian problem. Moreover, we found a decline in concussion cases as the distance increased from our institution. While we are the only children's hospital in our region, as the patient's residence gets further away from our city, they may go to their local community hospital for assessment of their injury, resulting in a lowering of the mean ED concussion visit rate for our rural population and an underestimation of the effect of concussions in our rural areas.

As with other types on unintentional injuries, most concussions are considered to be predictable and preventable.[37–39] Prevention initiatives should be a priority for concussion research, as once a TBI is sustained; the effects can be debilitating and long lasting. For sports, modifications to protective gear, helmet use, rule change (i.e., checking in hockey), rule enforcement and education on the dangers of concussions and return to play guidelines are recommended, in addition to addressing the issue of violence in sports.[8,15] These prevention strategies are of particular importance for hockey-related injuries, which account for more than one third of our sports-related concussions. The early adolescent group is also at most risk for sports-related concussions and should be targeted for these interventions.

The geographic analysis in this study allows for the identification of specific urban and rural regions to be targeted with a combination of MVC-related interventions, particularly ATV use and pedestrian, using all of the Es of prevention—education, enforcement, engineering, based on our epidemiology, and environmental data.

The main limitation of this study was that the concussion data were retrospectively abstracted from the National Ambulatory Care Reporting System, which is an administrative database. As such, there are the inherent limitations of these types of databases in that not all the clinical data required to conclusively define "concussion" were available. To overcome this limitation, ED concussion patients were cross-referenced with patients in our trauma registry to confirm that patients in both databases met the GCS criteria for concussion,[10] and this allowed us to exclude all moderate-severe TBI. An additional limitation was that the calculated ED concussion visit rate underestimates the actual incidence rate because not all concussion patients go to the ED for treatment. Moreover, there are other hospitals in our region where youth may go for the assessment of injury and, therefore, would not be included in our data. We are the only Children's Hospital and Pediatric Trauma Centre for our region, so most children will come to our ED, but this may not be the case, especially for rural residents outside our city. A final limitation was that the exact location of injury was not available in the ED database. While it would be beneficial to have the incident location to alter the built environment of arenas or intersections that are a particular problem for sustaining concussions, we feel the issue of not having the exact injury location was minimal in terms of classifying urban or rural. In a previous trauma study, we found 67% of crashes occurred relatively close, within 15 km, of the child's home.[34] Using the home address will allow us to target our concussion prevention education or media campaigns to those specific higher risk populations that live within those regions.

CONCLUSION

Concussions are a common type of injury in the pediatric population. Males in early adolescence are at highest risk, particularly from sport-related activities. Urban and rural children have differences in their etiologic causes and severity of concussions. Concussions are often predictable and their prevention should be targeted based on epidemiologic and environmental data.

AUTHORSHIP

T.C.S. conceptualized and designed the study, performed the epidemiologic analyses, drafted the initial manuscript, and approved the final manuscript as submitted. J.G. performed the spatial analyses and interpretation of geographical results, critically reviewed and revised the manuscript, and approved the final manuscript as submitted. D.D.F. conceptualized and designed the study, supervised the project and medical interpretation of the data and results, critically reviewed and revised the manuscript, and approved the final manuscript as submitted.

ACKNOWLEDGMENT

Our sincere thanks go to Cynthia Dettloff and Joyce Williamson of the Trauma Program, LHSC, London, Ontario, for preparing the data for analysis.

DISCLOSURE

Financial support was provided by The Children's Health Foundation (www.childhealth.ca), London, Ontario, Canada.

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