

ORIGINAL ARTICLE

A population based investigation of head injuries and symptoms of concussion of children and adolescents in schools

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Objective: To examine the incidence of head injury and symptoms of concussion among children at school and to determine the relationship of age, gender, and cause to incidence rates.

Design: Incident reports involving head injury for schools in the Province of Ontario, Canada during the year 2000 were evaluated.

Participants: The population base for the schools represented was 1 372 979 children aged 6 to 16.

Setting: 95% of schools in the province of Ontario, Canada participated in the injury reporting system.

Main outcome measures: A head injury was defined as any injury to the head that came to the attention of a school official. Head injuries accompanied by symptoms of concussion became a secondary outcome measure.

Results: There were 11 068 unduplicated head injury reports for the year 2000 of which 1861 qualified as producing signs or symptoms of concussion. Young children were more likely to have a head injury than older children, but slightly less likely to experience concussive symptoms. The primary cause of injury to young children was falls. Older children were more likely to receive head injuries and symptoms of concussion from sports activities.

Conclusions: Overall rate of injury (3.98 per 100 children) was consistent with previous studies using prospective injury reporting systems. Probability of a head injury with symptoms of concussion among schoolchildren was only 1.9% for boys and <1% for girls during the course of their school years. There is ample justification for prevention efforts in schools.

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Concussion is defined by the American Academy of Neurology as a traumatically induced alteration in mental status that may or may not be accompanied by a loss of consciousness.¹ Physicians and researchers diagnose acute concussion on the basis of signs and symptoms.² Signs and symptoms include confusion, amnesia, loss of consciousness, sensitivity to light or sound, headache, dizziness, nausea, unsteadiness, feeling "dazed", seeing stars, double vision, sleepiness, impact seizure, slowed response time, poor concentration, inappropriate affect, vacant stare, and slurred speech.³ The diagnosis of concussion remains difficult even when a physician is immediately available such as at sports events.⁴ Not surprisingly, with the inherent difficulties of diagnosis, there are no population based studies of concussion. The Centers for Disease Control and Prevention (CDC) estimates that there are more than 300 000 sports related concussions every year in the United States,⁵ and this estimate only includes concussions accompanied by a loss of consciousness. Recent research demonstrates that children can have a concussion without a loss of consciousness⁶ and loss of consciousness is not an especially good predictor of outcome.^{2 7}

The CDC study produced a number of important observations of concussion in sports.⁵ The highest risk group is adolescents; males are at greater risk than females; and less than one third of concussions are seen by a physician. Interestingly, the recovery period after concussion is greater for adolescents than adults, suggesting that adolescents are not only at higher risk for injury, but at higher risk for more serious injury.⁸ Surveys of high school students in Canada⁹ and New Zealand¹¹ indicate that approximately 30% of high school students report at least one concussive event before their graduation from high school. The average

age for the reported concussion event was 10 years. Only 25% of reported concussions were seen by a physician. Neither study revealed any detail on the location (school, playground, non-school activities) or features of the concussive event so efforts to develop prevention initiatives for head injuries are unaided.

There are a number of studies of the epidemiology of injuries to children while at school that provide an important backdrop for the current study of head injury/concussion symptom rates in schools. Each of these studies used prospective injury reporting systems for a defined population. Boyce *et al* reported an annual overall injury rate of 2.5 per 100 children in Tuscon, Arizona (USA) but did not separate head injuries from injuries to other parts of the body.¹² They reported that boys are twice as likely to be injured as girls. Hammarstrom and Janlert reported a similar rate of injury at 2.4 per 100 in schools of northern Sweden.¹³ Schuller and Kopjar reported an annual incidence rate of 2.9 per 100 students for Norway.¹⁴ Sheps and Evans reported an injury rate of 2.8 per 100 in Vancouver, British Columbia (Canada) schools.¹⁵ The Vancouver study reported a head injury rate of 1.8 per 100. Although these authors did not focus on concussion, they reported a rate of 0.09 per 100 for a category of injuries that included nosebleed, whiplash, eye injury, and concussion. Lenaway *et al* studied schools in Boulder, Colorado (USA) and found an unusually high injury rate of 9.2 per 100.¹⁶ However, the reported rate of injury to the head was 1.3 per 100, which is similar to the Vancouver rate. Finally, Junkins *et al* reported an injury rate of 1.4 per 100 children in the State of Utah.¹⁷ The Junkins *et al* study only

Abbreviations: CDC, Centers for Disease Control and Prevention; OSBIE, Ontario School Boards Insurance Exchange

included injuries that resulted in a physician visit or a minimum loss of a half day of school. None of these population based studies report rates of concussion or concussion symptoms in school settings.

The current study examined the injuries reported on a prospective basis in Ontario, Canada schools during the year 2000. Approximately 95% of Ontario students attend schools that are insured by one liability insurer. All of these schools use the same injury reporting system. This study examined, in detail, those injury reports that indicated the injury to a student involved the head. The aim of the research was to determine the incidence of head injury and head injury accompanied by one or more symptoms of concussion. The study looks at a well defined, large population from both rural and urban locations. A secondary aim was to determine the types of activities that place students at greatest risk for head injury and symptoms of concussion.

METHODS

The Ontario School Boards Insurance Exchange (OSBIE) is the liability insurer for the vast majority (95%) of schools in the province of Ontario, Canada. In the year 2000, the number of children aged 6 to 16 inclusive represented by the schools insured by OSBIE was 1 372 979. Population statistics are based on school enrollments and were provided by the Ontario Ministry of Education. One requirement of OSBIE is the submission of a report to describe each incident when a child is injured in a school or school related activity, however minor the injury might be.

Each incident report includes the name and demographic information on the injured child (including date of birth and gender) and details of the incident (date, time, location within the school or school property). In the calendar year 2000 there were 67 647 reported injuries in the Ontario schools represented by OSBIE. The number of injuries reported for children aged 6 to 16 (or no reported age) is 58 769. This study examined the 13 853 head injuries reported during the year 2000. All duplicates (where the same incident had been reported more than once) were eliminated. In addition, we did not include incidents involving adults in the schools. The final tally was 11 068 unduplicated incidents involving injury to the head for a child aged 6 to 16.

Incident reports were completed by a teacher or staff member of the school and each report included a narrative description of the incident. For example, one incident description for a 10 year old read: "During a running tag game in gym class he tripped over another student's foot, fell and hit his head on the wall—he was disoriented—sick to his stomach". The recorder of each incident also classified the injury as (1) sports injury (including name of sport (2), assault, (3) slip or fall, (4) other (with explanation), or (5) rough play. We carefully reviewed the incident narratives to determine the relationship of the narrative description to the classification. Incidents classified as "slip or fall" included a wide range of events, such as running into walls or banging the head on an object. We collapsed the rough play category with the assault category because narrative descriptions were essentially indistinguishable. We also reclassified incidents that were classified as "other" but were better placed in one of the existing classifications. For example, most incidents that occurred in a sport were classified as "sports injury". However, there appeared to be occasional confusion as to the classification of an incident that occurred during unsupervised sports events. For example, the following incident was described for a 12 year old: "Playing soccer in grassy area of the school yard—fell and hit the back of his head—incident not reported to any staff member at the time it happened—when student went home complained of headache—vomited

and parents took him to hospital—mild concussion". In most cases this type of incident was reported as a sports injury but in some instances an incident was reported as "other" (perhaps because it was unsupervised). All incidents listed as "other" were reclassified when appropriate.

The narrative of each incident report was evaluated for the presence of key words that represent the symptoms of concussion: nausea, memory difficulties, fatigue, dizziness, vision difficulties, ringing in the ears, unconsciousness, incoherence, headache, vomiting, incoordination, disorientation, emotion(al), and convulsion. Any head injury description that included one or more of these key words (including any and all variations of these key words) were further evaluated by a research assistant (JD) and a psychologist (BW) familiar with concussion to determine if, based on the description of the incident, the signs and symptoms of a concussion were clearly a result of the head injury. Injuries that resulted in a diagnosis of concussion by a health care professional were also considered to have signs and symptoms of concussion. Thirty two children had symptoms that appeared to precede the head injury and therefore were not judged to be caused by the head injury. In these cases the child fainted first and hit his/her head.

Statistical analysis

Descriptive statistics consisted of cross classification tables of head injuries and head injuries accompanied by symptoms of concussion rates broken out by sex, age, and injury type. Injury rates, standardized per 10 000 were grouped by type and plotted by age. Logistic regression analysis was used to model probability of a concussion as a function of sex and age. Sex by age interactions were also examined within the logistic regression model. An indicator variable for sex was coded as 0 for females and 1 for males. The odds ratios generated from the logistic regression model were calculated along with their corresponding 95% confidence intervals. The odds ratio may be interpreted as a measure of the association between injury type and the covariates age and sex. An odds ratio equal to 1 implies no association. A limitation of this analysis was that we were not able to utilize the cause of injury category as a factor in the primary logistic regression model. This was due to the fact that we only had information on the number of injuries per cause and did not have the total number of participants per cause—for example, we knew the number of symptoms of concussion due to sports, but did not know the total number of sports participants in this cohort. We were, however, able to carry out a subanalysis by cause of injury (sports, falls, and assaults). In addition to the logistic regression modeling we also calculated the school lifetime cumulative probability of a head injury with symptoms of concussion by sex. Lifetime was defined as the time in school from age 6 to 16. These calculations were carried forth under the simplifying assumption that head injuries with symptoms of concussion are independent events. The only epidemiologic study to examine the issue of recurrent injuries in schools reported that <1% of children experience recurrent injuries in one year.¹⁸

RESULTS

The reported 58 769 injuries to children in the schools in this study represent an injury rate of 4.28 per 100 students. In our evaluation of head injuries we found that 6%–7% of injury reports were duplicated. That is, more than one teacher or staff member reported the incident. Thus, we estimate the injury rate to be 3.98 assuming an equal proportion of duplicate reports across all injuries. The 11 068 head injury reports examined in the current study represents a head injury rate of 0.81 per 100 students during the year 2000. A little less than one in five head injuries were classified as

Table 1 Head injury and symptoms of concussion (SoC, rate per 10 000) for boys and girls aged 6 to 16

Age	Boys				Girls				Total SoC rate
	Total	Head injury	SoC	SoC rate	Total	Head injury	SoC	SoC rate	
6	63381	818	116	18.302	60296	425	46	7.629	13.099
7	64583	815	113	17.497	61594	454	44	7.143	12.443
8	65029	762	103	15.820	62144	388	36	5.793	10.930
9	66350	844	124	18.689	62779	419	63	10.035	14.404
10	65106	762	126	19.353	61568	385	55	8.933	14.210
11	63209	790	155	24.522	60638	305	43	7.091	15.988
12	62209	688	148	23.790	59453	300	57	9.587	16.768
13	61989	581	128	20.649	58937	275	54	9.162	15.050
14	64224	381	80	12.456	61516	222	41	6.665	9.623
15	64972	257	97	14.930	61943	146	53	8.556	11.819
16	61756	205	40	6.477	59303	137	34	5.733	6.113
Missing		459	71			250	34		
All	702808	7362	1301	18.47	670171	3706	560	8.34	13.54

having concussive symptoms or signs. The probable symptoms of concussion rate was 0.135 per 100 students.

Table 1 presents the number of unduplicated reported head injuries for the year 2000 and the number of head injuries that qualified as having symptoms of concussion. The frequency of head injuries and symptoms of concussion are presented for each age group (6 to 16) and for boys and girls. Please note that some reports of injury did not provide the child's age. As a result, all reported rates of head injury and head injury with symptoms of concussion are low by approximately 5% (the percent of reports with age missing). There is a steady decrease with age in the frequency of head injuries. However, the rate of symptoms of concussion is highest for boys and girls aged 11 to 13. Boys are 2.23 times more likely to experience a head injury with symptoms of concussion than girls.

Table 2 presents the symptoms of concussion rates by cause for boys and girls. The cause categories of assault and rough play were combined because the descriptions of the events were quite similar. The leading cause of head injury with symptoms of concussion was falls. Head injuries with symptoms of concussion in younger children were much more likely to be associated with falls. Sports related symptoms of concussion rates steadily increase with the age of the children. For 15 and 16 year olds, sports accounted for the majority of head injuries with symptoms of concussion. Assaults (or rough play) accounted for a relatively small percent of head injuries with symptoms of concussion for all ages, especially for girls.

The sports associated with head injuries accompanied by symptoms of concussion represented a wide range.

Basketball accounted for 16.5% of symptoms of concussion and was the most frequently listed sport. Other sports of note are soccer (13.2%), gym/gymnastics (11.3%), football (7.7%), hockey/floor hockey (6.8%), baseball (6.4%), skating (3.0%), wrestling (2.2%), volleyball (1.8%), and lacrosse (0.8%). There is no indication of the extent to which students participate in each of these sports so a determination of injury to exposure is not possible. However, the following sports activities seemed surprisingly high given the likely exposure: skiing (5.8%), snowboarding (2.6%), and high jump (4.0%).

For boys the rate of head injuries with symptoms of concussion tended to increase and then decrease with age over the range from 6 to 16 years. For girls, the rate of symptoms of concussion was slightly more consistent across the ages. Within the logistic regression framework this suggests a non-linear association with age. The final model consisted of factors for age ($p < 0.0001$), age squared ($p < 0.0001$), and sex ($p < 0.0001$). The results of the logistic regression fit indicate that for boys and girls, combined, the predicted symptoms of concussion rate peaks at about 10 years of age and then declines. This differentiates only slightly from the empirical evidence presented in table 1 allowing for some smoothing. The odds ratio and 95% confidence interval of a head injury with symptoms of concussion relative to no concussion for boys as compared with girls was 2.23 (2.01 to 2.47). The odds ratio of symptoms of concussion for age₁ compared to age₂ is given by the formula: $\text{Exp}(0.41^*(\text{age}_1 - \text{age}_2) - 0.02^*(\text{age}_1^2 - \text{age}_2^2))$, where $\text{Exp}(\cdot)$ denotes the exponential function, for example, the odds ratio of symptoms of concussion for a 7 year old relative

Table 2 Rates of head injury with symptoms of concussion (SoC, per 10 000) by cause of injury

Age	Sports related SoC	Sports concussion SoC rate	Assault related SoC	Assault SoC rate	SoC from falls	Fall related SoC rate	Other causes of SoC
6	7	5.6	15	12.1	134	108.4	4
7	22	17.4	7	5.6	124	98.3	4
8	13	10.2	14	11.0	106	83.4	6
9	25	19.4	24	18.6	135	104.6	3
10	41	32.4	24	19.0	109	86.1	7
11	54	43.6	24	19.4	116	93.7	4
12	62	51.0	36	29.6	105	86.3	2
13	71	58.7	25	20.7	83	68.6	3
14	52	41.4	19	15.1	47	37.4	3
15	82	64.6	21	16.6	45	35.5	2
16	36	28.4	6	5.0	30	24.8	2
Missing	32		14		57		2
All	497	36.2	229	16.7	1091	79.5	42

to a 6 year old is $\text{Exp}(0.41-0.02*13) = 1.16$ and the odds ratio of symptoms of concussion for 10 year old relative to a 16 year old is 1.93.

Similar to the overall model described above, analyses were carried out for sport, assault, and fall related head injuries with concussive symptoms. For the subanalyses only the factors age and sex were considered. For the category of sports related head injury with symptoms of concussion the results of the logistic regression fit yielded odds ratios and 95% confidence intervals of 1.15 (1.11 to 1.18) and 2.10 (1.73 to 2.55) for age and sex, respectively, that is, for sports the risk of symptoms of concussion was opposite to the general trend and increased with age. For the category of assault related head injury with symptoms of concussion, the results of the logistic regression fit yielded odds ratios and 95% confidence intervals of 1.02 (0.98 to 1.07) and 4.31 (3.04 to 6.09) for age and sex, respectively. That is, there was no difference between age groups; however, males were 4.31 times more likely to suffer an assault related head injury with concussive symptoms compared with females. Finally, for falls the logistic regression fit yielded odds ratios and 95% confidence intervals of 0.88 (0.86 to 0.90) and 2.10 (1.83 to 2.40) for age and sex, respectively. Younger children are more likely to incur a head injury with symptoms of concussion from falls relative to older children and boys are twice as likely as girls to suffer a head injury with symptoms of concussion from falls.

The probability of sustaining a head injury with symptoms of concussion over the school lifetime of a child for females while in school is approximately 0.008 or 0.8% and for males the probability is 0.019 or 1.9%.

DISCUSSION

Annual injury rates for children in North American schools vary from 1.4 to 9.2 per 100. The current study reports an overall injury rate of 3.98 injured children per 100 for the year 2000. The threshold established for inclusion in the study accounts for some of the variance among reported injury rates. The lowest injury rate, reported by Junkins *et al.*,¹⁷ only included injuries that led to a doctor's visit or a minimum of a half day of school missed as a result of the injury. An examination of the reports in our study revealed that many of the injuries were very minor in nature. This observation of the minor nature of many injuries is reflected in the data on head injuries, where only one in five children with head injuries had signs or symptoms of concussion. Efforts to determine the best means to prevent injuries will benefit more from epidemiologic studies that focus on injuries that have greater significance for the injured child. Certainly, efforts to evaluate the effectiveness of prevention interventions will be enhanced if the criteria for inclusion of an injury to the reporting system are more precise.

Two of the previous population based studies presented head injury rates. Sheps *et al* in Vancouver (Canada) reported a head injury rate 1.0 per 100,¹⁵ and Lenaway *et al* in Boulder (United States) reported a head injury rate of 1.3 per 100.¹⁶ The current study found the rate of head injuries was 0.81 per 100. The overall rate of head injury with concussive symptoms was 18.5 per 10 000 for boys and 8.3 per 10 000 for girls. Head injury with concussive symptom rates appear to increase to a peak at around 10 years of age and then decrease as the child gets older. Younger children suffer head injuries with concussive symptoms primarily from falls while older children are more likely to suffer head injuries with concussive symptoms due to sports, albeit at a slightly lesser rate, with an intersection of the two causes at or around 10 years of age. A contributing factor is head injury with concussive symptoms due to horse play/assaults, which also follow an inverted U shape relationship with age. The types of

sporting activities that led to head injuries with symptoms of concussion are wide ranging, although basketball and soccer were the most frequent. Assaults (intentional or otherwise) accounted for a relatively small percent of head injuries with concussive symptoms, especially among girls. Greater specificity of causes of injury using advanced coding systems such as the International Classification of External Causes of Injuries is clearly required.

The probability of a boy sustaining a head injury with symptoms of concussion, at any time in his school career, is only 1.9%. The probability of a girl sustaining a head injury with symptoms of concussion is <1%. Research has demonstrated that students are much more likely to experience a head injury or concussion away from school than in school.¹⁹ However, efforts to prevent injury can justifiably be aimed at the school environment. The current study points to a number of conclusions regarding prevention activities. Head injury and head injury with concussive symptoms occurs at all ages with younger children being particularly vulnerable. Efforts to prevent head injuries among younger children need to focus on falls and the reasons for falls (for example, playground equipment), whereas efforts to prevent head injury with concussive symptoms among teens is best aimed at sports. Recent research has demonstrated that concussive effects are cumulative,^{20, 21} thus having one concussion puts a child at risk for greater cognitive impairment with subsequent concussions. Prevention could also focus on limiting the child's risk of a second concussion once identified as at-risk.

The current investigation looked at a large population of school aged children and relied on prospective reporting of injuries within a reporting system that has been consistently adhered to for more than a decade. However, the study has limitations. The study relies on the reports of teachers and staff that are not usually trained to assess concussive symptoms after a head injury. This clearly represents a threat to the external validity of the study, although the similarity of findings with other studies offers a moderate level of

Key points

- Previous population based studies of school injuries did not focus on head injury and did not offer any results on the incidence of head injury accompanied by symptoms of concussion.
- Rates of head injury and head injury with symptoms of concussion are higher for boys than girls and higher for younger children (elementary school) than older children (high school).
- The most common cause of head injury and head injury with concussive symptoms is falls. This is especially true for younger children.
- Sports related head injuries accompanied by symptoms of concussion were much more common among older children.
- Boys have slightly less than a 2% probability of sustaining a head injury with concussive symptoms during their school career, whereas girls have <1% probability of incurring such injuries.
- Schools are an ideal environment for prevention because of their emphasis on education. Efforts should be aimed at preventing falls for younger children and sports related injuries in older children.

confidence in the results. To improve the system for the future we developed an educational DVD for teachers and students about concussion. If documentation of injury is a first step toward identification of injuries, then education is perhaps a first step toward prevention.

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LACUNAE

Nun over the eight

A Polish Benedictine nun is facing jail for driving a tractor into a car while drunk outside her convent in south-western Poland, police said. The 45 year old nun will be charged with drunk-driving and causing an accident, which carries a prison sentence of up to two years. Dariusz Waluch, police spokesman in the south western Polish town of Dzierzoniow, said the nun was 17 times over the country's legal alcohol limit for driving, according to the local news agency PAP (submitted by Ian Scott; from *Sydney Morning Herald*, March 2004).

Electrifying New York

In January 2004 a student walking her dogs was killed by an electrified metal plate set in the ground in the east village area of Manhattan. In checking other sites the power company Con Ed found that 280 service box lids, manhole covers, and lamp posts had stray electric current in them. The amount of current varied from single digits to a lethal 140 volts on a lamp post in Queens. Con Ed is now checking 550 000 sites. *The New York Times*, in reporting this story noted that potentially deadly hazards has existed for an unknown period of time in some of the world's busiest intersections (submitted by Ian Scott).