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# Where to start? Injury prevention priority scores in Canadian children☆,☆☆

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ABSTRACT

*Purpose:* Given limited resources, it is essential to determine which Mechanisms of Injury (MOIs) to prioritize for injury prevention policy and research. We developed objective, evidence-based Injury Prevention Priority Scores (IPPSs) for Canadian children across three prevention perspectives: mortality, injury severity, and resource utilization.
*Methods:* We performed a retrospective cohort study of all injuries in Canada in individuals aged 0 to 19 years old from 2009 to 2014. For each MOI, an IPPS was calculated as a balanced measure of frequency and either mortality rate, median ICD-10 derived Injury Severity Score (ICISS), or median cost per hospitalization.
*Results:* Of 87,017 injuries, 83,112 were nonfatal hospitalizations, and 3905 were deaths. Overall mortality rate was 0.04 deaths/injury, median ICISS was 0.994 (IQR 0.75–0.996), and median cost per hospitalization was CAD$3262 (IQR $2118–$5001). The top three mechanisms were falls (IPPS 72), intentional self-harm (IPPS 68), and drowning (IPPS 65) for mortality, falls (IPPS73), drowning (IPPS 61), and suffocation (IPPS 61) for injury severity and falls (IPPS 70), fires (IPPS 65), and intentional self-harm (IPPS 60) for resource utilization.
*Conclusion:* Falls, if prevented, would provide the most benefit to the largest proportion of the Canadian pediatric population and should be targeted for injury prevention.
*Level of evidence:* Level III.



Injuries are the leading cause of death for individuals aged from 1 to 20 years old in Canada [1] and worldwide [2]. As force is applied to the body at varied speeds, vectors and periods of time, the impact on an individual sustaining an injury can be substantially different depending on the mechanism of said injury. To produce effective injury prevention policy, mechanisms of injury must be identifiable, quantifiable and prioritized according to the highest burden. Many metrics exist for measuring disease burden from injuries, including mortality indices, morbidity indices and cost metrics [3]. As each of these metrics has respective limitations, using a single metric would only provide a partial understanding of the burden of injury. Therefore, injury prevention policy is best planned through examination of multiple injury metrics in combination, thus addressing all domains of an injury. Haider et al. proposed the "Injury Prevention Priority Score" (IPPS) which provides a simple, objective and quantitative method for ranking injury mechanisms by combining both the relative frequency of a mechanism of injury and a priority metric [4]. This tool can be employed to examine different domains of injuries, including mortality, morbidity and cost. This analysis has been conducted in the American pediatric population to rank mechanisms of injury according to priority for prevention [5], but has yet to be applied in Canada. The objective of our study was to calculate objective injury prevention priority scores for mechanisms of traumatic injury in children aged 0 to19 years old in Canada, from 2009 to 2014 across three domains: mortality, injury severity and resource utilization.

## 1. Methods

### 1.1. Cohort selection and data sources

After review and approval from local Ethics Review Board (project number 1022463), we performed a retrospective cohort review of all

*Abbreviations:* CIHI, Canadian Institute for Health Information; CMG+, Case Mix Group; CPI, Consumer Price Index; CSHS, Cost of Standard Hospital Stay; ICD-10, International Classification of Disease, 10th edition; ICISS, ICD-10 derived Injury Severity Score; IPPS, Injury Prevention Priority Score; RIW, Resource Intensity Weight; SSR, Specific Survival Risk Ratio.

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traumatic injuries in Canada aged 0 to 19 years old from April 1st 2009 to March 31st 2014. Our data sources included the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) and Statistics Canada Vital Statistics (VS) database. The DAD is the most comprehensive database for Canadian in-hospital information and contains demographic, administrative and clinical information concerning all inpatient hospitalizations in Canadian provinces, except Quebec. In addition to basic demographic data (sex, date of birth, province of admission), the DAD contains up to 25 admitting diagnoses and cost information including Case-Mix Group (CMG+) and Resource Intensity Weight (RIW), used to estimate the cost of a hospital admission, further detailed below [6]. VS contains demographic and underlying cause of death on all fatalities (including Canadian residents and non-residents) occurring in Canada. Each death has an associated underlying cause of death, coded by ICD-10 codes [7,8]. As registration of death is a legal requirement in each Canadian province, reporting is virtually complete and overcoverage is avoided by identification of duplicates [7].

The inclusion criteria are any individual, aged from 0 to 19 years old that was either admitted to hospital or deceased with an associated International Classification of Disease (ICD) 10 diagnostic code consistent with external cause (V01-Y98) in either the DAD (hospital admission) or VS (death). Exclusion criteria included hospital admission or death secondary to poisoning (ICD-10 codes X40–X49, X70–X69, X85–X90, Y10–Y19 and Y35.2) or medical adverse events (ICD-10 codes Y40–Y59, Y60–Y84, Y88–89) and individuals without a valid health card number.

### 1.2. Variable definition

Our exposure of interest was traumatic mechanism of injury, defined as the fundamental physical process responsible for a given action, reaction or result [9] and grouped according to the Center for Disease Control (CDC) proposed framework for presenting injury data [10]. To adhere to confidentiality requirements, the CDC categories were adapted as shown in Supplementary Table 1.

The outcomes of interest are injury prevention priority scores, described below in the statistical analysis section, across three domains: mortality, injury severity and resource. Mortality is defined as the total number of deaths associated with a specific mechanism of injury category divided by the total number of injuries (hospitalizations and deaths) associated with said category. Because the Injury Severity Score (ISS) is unavailable is most databases, including the DAD and VS, injury severity is measured through the ICD-10 derived Injury Severity Score (ICISS). ICISS utilizes Specific Survival Risk Ratio (SRR) of each diagnostic code associated with trauma (ICD-10 codes S00–T78) [11]. The SRR represents the number of times an individual with the specific ICD-10 code survived, divided by the total occurrences of the ICD-10 code in a large pooled dataset of more than 4 million observations of all ages from 7 countries [11,12]. Thus, the SSR represents the probability of survival of each individual injury.

Resource utilization is defined as the sum of all charges associated with an injury and measured for hospitalizations only through CIHI's cost estimator. The DAD assigns a Case Mix Group (CMG+) to each hospital admission, representing a collection of admissions with similar characteristics, including diagnoses, interventions and resource use [13,14]. Each CMG+ in turn, is associated with a baseline Resource Intensity Weight (RIW) [15]. The base RIW represents the standardized estimate of resource consumption [16]. Each hospitalization is provided with a RIW which represents the relative resources used, adjusted on a case by case basis depending on age group, length of stay, comorbidity level and interventions received [16,17].

The baseline Cost of a Standard Hospital Stay (CSHS) is estimated by CIHI based on aggregate data across provinces and is supplied by CIHI. As the CSHS is not available for all territories, the territories and Yukon were combined into a single category and the CSHS of the Yukon was used as the category's CSHS. The cost of each hospitalization is estimated as the product of the CSHS multiplied by the RIW for that admission. For individuals with repeat hospitalizations, the cost of each hospitalization is calculated and summed, treating it as a single hospitalization with a cost of both hospitalizations combined. To adapt for inflation, each cost was adjusted according to the Consumer Price Index (CPI) for health published by Statistics Canada [18], using 2009 as a base year.

### 1.3. Statistical analysis

Each priority metric is summarized in a single measure: mortality rate, median ICISS and median hospitalization cost. Median was chosen as the summary statistic for ICISS and hospitalization cost as their respective distributions were skewed toward the left. IPPSs are calculated for each outcome measure, combining both the incidence and the priority outcome of interest [4]. Two Z-scores are created: one for frequency of the mechanism of injury and one for the priority metric, based on their respective distributions. The two respective Z scores obtained are then summed (Zsum) and a new composite Z score is created by dividing the difference between the sum of Z scores and the mean of the Z score sum by the standard deviation of the Z score sum. Finally, the IPPS is derived by calculating a T score for each mechanism of injury where $T = 50 + 10\,Zsum$. An IPPS has by definition a mean of 50 and a standard deviation of 10. The higher the IPPS, the higher the mechanism of injury should be prioritized for prevention. As the IPPS requires an ordinal structure in ascending order and the ICISS is in descending order, the ICISS was modified to 1-ICISS in the calculation of the IPPS for injury severity. Missing data were treated by case wise deletion and all analyses were performed using STATA version 14 (College Station, TX).

## 2. Results

As seen in the flow chart in Fig. 1, after excluding medical adverse events (51,319), poisoning (17,610), missing health card numbers (1454) and repeat hospitalizations (6794) our hospitalization cohort consisted of 86,641 unique hospitalizations for traumatic injury. Similarly, after excluding medical adverse events (15) and poisoning (335), our mortality cohort consisted of 3905 deaths from traumatic injury. After removing duplicates of in hospital deaths that are counted in both data sources (529), our final cohort consists of 87,017 unique traumatic injuries in Canada from 2009 to 2014.

As shown in Fig. 2, the most frequent mechanism of injury was falls (35.9%), followed by cut/pierce/struck by (13.0%) and motor vehicle collisions (12.5%). The overall mortality rate is 0.004 deaths per injury. As shown in Fig. 3, the mechanisms with the highest mortality rate are intentional self-harm (0.45 deaths per injury), drowning/submersion (0.42 deaths per injury) and suffocation (0.21 deaths per injury). The overall median ICISS is 0.994 (IQR 0.750–0.996). As shown in Fig. 4 the mechanisms with the highest injury severity are drowning/submersion (ICISS 0.852), suffocation (0.899) and pedestrian incidents (0.965). The overall median cost per hospitalization is CAD $3262 (IQR $2118–$5002). As shown in Fig. 5, the mechanisms with the highest cost per hospitalization were fires ($6649), intentional self-harm ($5911) and legal interventions ($5155). Legal interventions include any mechanism of injury related to law enforcement activities. Injury frequency, mortality rate, median ICISS and median hospitalization cost by mechanism of injury are summarized in Table 1 and the corresponding IPPSs are presented in Table 2. In the mortality domain, the top three mechanisms of injury for prevention were falls (IPPS 72), intentional self-harm (IPPS 68) and drowning (IPPS 65). In the severity domain, the top three mechanisms were falls (IPPS73), drowning (IPPS 61) and suffocation (IPPS 61). In the resource utilization domain, the top three mechanisms were falls (IPPS 70), fires (IPPS 65) and intentional self-harm (IPPS 60).

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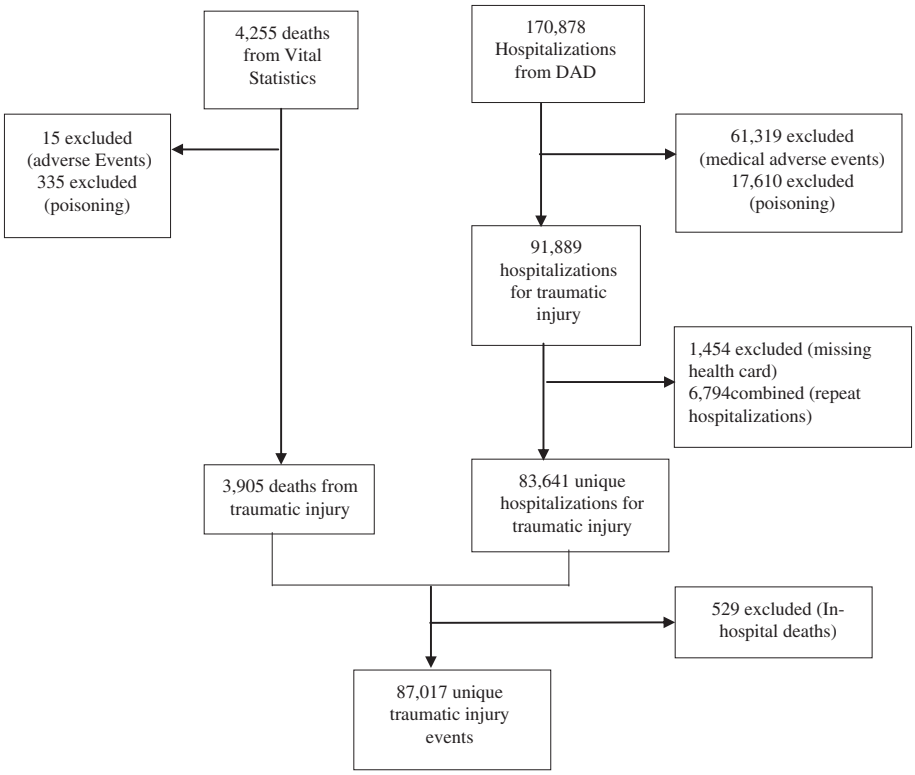


**Fig. 1.** Flow chart of traumatic injuries resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014. A total to 4355 deaths from Vital Statistics (VS) and 170, 878 hospitalizations from the Discharge Abstract Database (DAD) were combined for a total of 87,017 unique traumatic injuries after exclusions.

## 3. Discussion

This study has identified objective, quantifiable injury prevention priority scores for mechanisms of injury in Canadian children and youth. As resources for prevention are finite, it is critical to match prevention efforts with public health needs. Different priorities emerge for prevention depending on the domain examined. Falls were consistently the top mechanism to be prioritized, even though they were not associated with the highest mortality, injury severity or cost. This is likely a function of the high frequency of falls, representing 35.8% of all injuries. Falls are the most common cause of pediatric hospital admission for trauma in the United States and represent 34% of the mechanisms of injury in the National Trauma Bank [19]. In a recent review of hospitalized trauma patients less than 14 years old for falls,

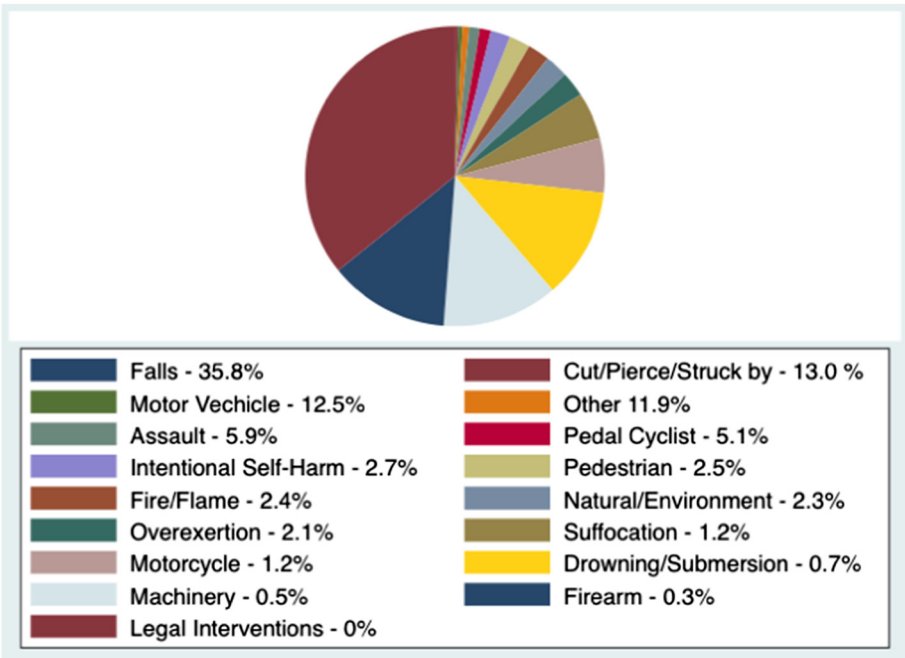


**Fig. 2.** Distribution of mechanisms of injury resulting in hospitalization or death in 0 to19 year olds in Canada, 2009-2014. The most common mechanism of injury is falls (35.8%), followed by cut/pierce/struck by (13.0%) and motor vehicle collisions (12.5%)

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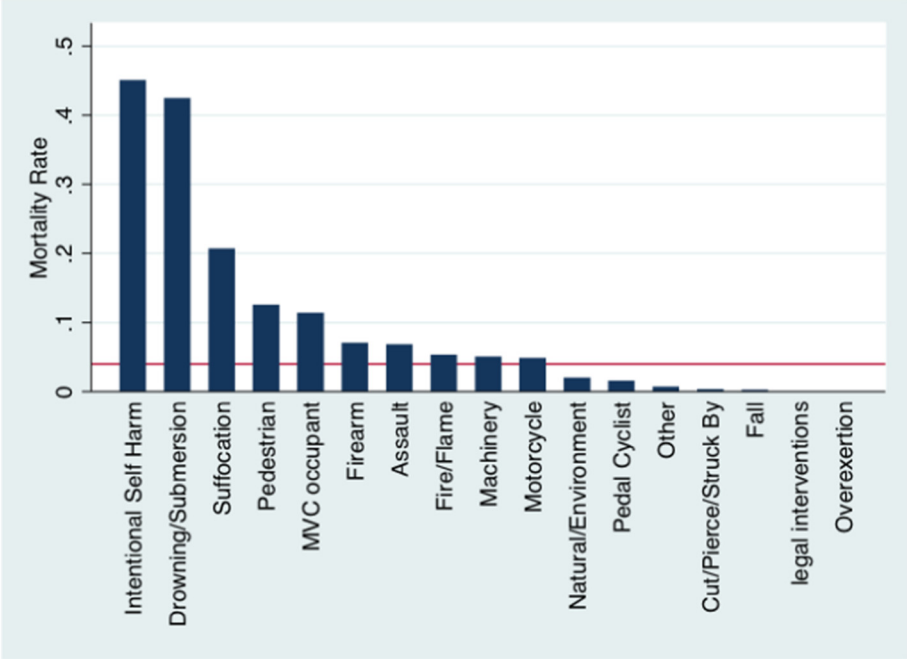


**Fig. 3.** Mortality rate by mechanism of injury resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014. The mechanisms of injury with the highest mortality are intentional self-harm (0.45 deaths per injury), drowning/submersion (0.42 deaths per injury) and suffocation (0.21 deaths per injury). The red line indicates the overall mortality rate (0.004 deaths per injury).

the most common injuries were head injuries (55.6%), and abdominal injuries (18%), with an associated mortality of 3.6% [20]. Falls are often considered a problem of the elderly, and falls in children are often seen as a consequence of "kids being kids." Although fall prevention programs in Canada exist, including Parachute Canada [21] and ALTER, [22] no study exists examining interventions specifically geared toward decreasing childhood falls.

Intentional self-harm represented the second highest IPPS for mortality and third for resource utilization, underlying its prominence in pediatric injuries. About two and a half percent of American high school students injure themselves through intentional self-harm annually and suicide represents 12% of deaths in adolescent and young adults in the United States [23]. Compared to other reports, our study observed a high mortality (45.2%) from intentional self-harm [24]. This is likely secondary to our exclusion of poisoning from our sample and our focus on traumatic injury, whereby a traumatic mechanism increases the probability of completed suicide [25,26]. Furthermore, our exclusion of patients not admitted to hospital would further bias our population

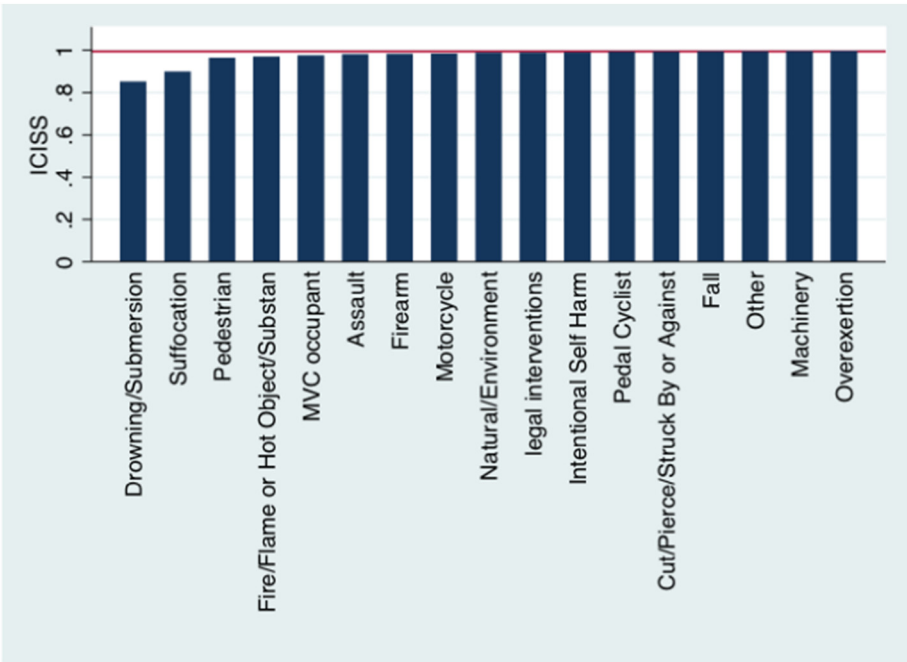


**Fig. 4.** Median injury severity by mechanism of injury resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014. The mechanisms of injury with the highest injury severity are drowning/submersion (ICISS 0.852), suffocation (0.899) and pedestrian incidents (0.965). The red line indicates overall median ICISS (0.994).

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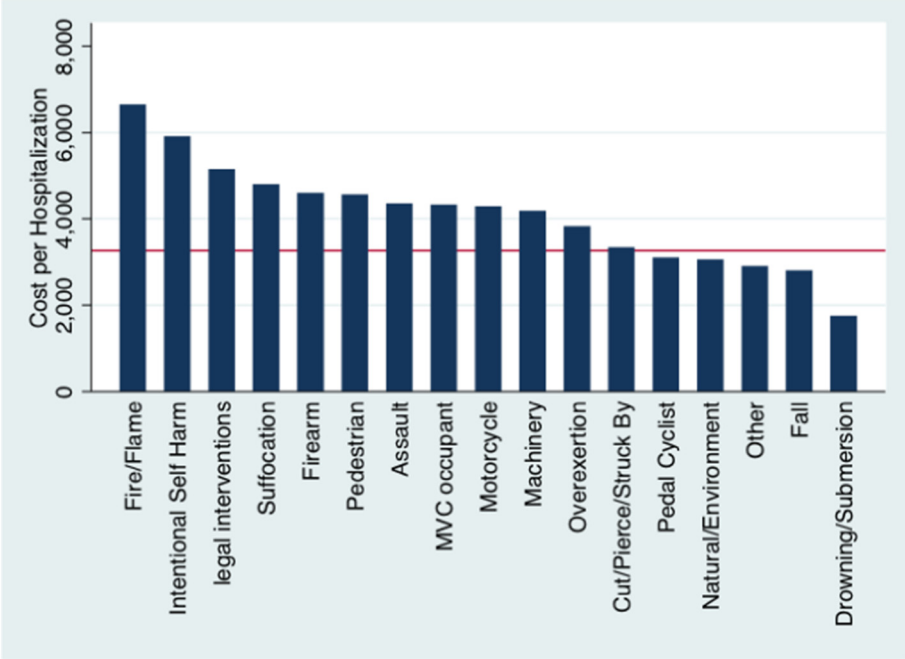


**Fig. 5.** Cost per hospitalization by mechanism of injury resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014. The the mechanisms of injury with the highest cost per hospitalization were fires ($6649), intentional self-harm ($5911) and legal interventions ($5155). The red line indicates overall median cost per hospitalization ($3262).

toward more severe injuries. Death by intentional self-harm tends to be underreported, likely secondary to the underlying social stigma and, therefore, our IPPS for intentional self-harm may be an underestimate [27,28]. The relatively low injury severity (IPPS 43) associated with intentional self-harm may be explained by the high number of out of hospital deaths (1050 deaths versus 1278 nonfatal hospitalizations), which would not contribute toward our injury severity IPPS.

Finally, drowning figured prominently among our priorities with the third highest IPPS for mortality and second for injury severity. This coincides with trends from other jurisdiction; for instance, drowning accounts for 3800 deaths annually in the United States, 11.6% of unintentional injuries [29], and tend to occur more prominently in younger individuals compared to other mechanisms of injury [30,31].The poor survivability of drowning that requires medical attention is likely responsible for the high ranking of drowning in our mortality and severity domains and relatively lower ranking in the resource utilization domain.

Identification of mechanisms of injury remains a first step toward injury prevention. Further research is required to identify which interventions will yield the highest benefit, and should be the focus of further research. Although some research in interventions such as home visits and increased parental supervision has shown decreases in injury rates [32], severity and costs [33], this field remains largely

**Table 1**
Summary statistics by mechanism of injury resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014.

| Mechanism | Total Injuries | Mortality | ICISS (Median) | Cost per Hospitalization (Median in CAD$) |
|---|---|---|---|---|
| Falls | 31,163 | 0.003 | 0.995 | 2809 |
| Cut/Pierce/struck by | 11,299 | 0.004 | 0.994 | 3349 |
| Motor Vehicle Collision | 10,855 | 0.114 | 0.976 | 4334 |
| Other | 10,393 | 0.007 | 0.995 | 2910 |
| Assault | 5108 | 0.069 | 0.982 | 4361 |
| Pedal Cyclist | 4444 | 0.016 | 0.993 | 3105 |
| Intentional Self-Harm | 2328 | 0.452 | 0.99 | 5911 |
| Pedestrian | 2186 | 0.126 | 0.965 | 4568 |
| Fire/Flame | 2053 | 0.054 | 0.97 | 6649 |
| Natural/Environment | 1981 | 0.020 | 0.989 | 3061 |
| Overexertion | 1834 | 0.000 | 0.997 | 3831 |
| Suffocation | 1036 | 0.208 | 0.899 | 4802 |
| Motorcycle | 1022 | 0.049 | 0.984 | 4295 |
| Drowning/Submersion | 624 | 0.425 | 0.852 | 1758 |
| Machinery | 393 | 0.051 | 0.996 | 4190 |
| Firearm | 283 | 0.070 | 0.983 | 4603 |
| Legal Interventions | 15 | 0.000 | 0.989 | 5155 |
| Mean | 5119 | 0.098 | 0.974 | 3934 |
| Standard Deviation | 7704 | 0.140 | 0.961 | 1105 |

Each mechanism has a mortality rate, median ICISS and median cost per hospitalization. From these distributions, the respective means and standard deviations for each domain are computed and presented in the last two rows of the table.

**Table 2**
Mechanisms of injury prevention priority scores for mortality, severity and resource utilization resulting in hospitalization or death in 0 to19 year olds in Canada, 2009–2014.

| Mechanism | IPPS Mortality | IPPS Severity | IPPS Resources |
|---|---|---|---|
| Fall | 72 | 73 | 70 |
| Intentional Self-Harm | 68 | 43 | 60 |
| Drowning/Submersion | 65 | 71 | 27 |
| MVC occupant | 57 | 56 | 58 |
| Suffocation | 52 | 61 | 50 |
| Cut/Pierce/Struck By | 51 | 52 | 52 |
| Other | 50 | 51 | 47 |
| Pedestrian | 49 | 48 | 50 |
| Assault | 48 | 48 | 52 |
| Fire/Flame | 44 | 47 | 65 |
| Pedal Cyclist | 44 | 45 | 41 |
| Firearm | 43 | 43 | 48 |
| Motorcycle | 43 | 43 | 47 |
| Machinery | 42 | 40 | 45 |
| Natural/Environment | 42 | 43 | 39 |
| Overexertion | 41 | 42 | 44 |
| Legal Interventions | 39 | 41 | 52 |

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understudied compared to similar research in older cohorts.

### 3.1. Strengths and limitations

This study has many strengths, namely the comprehensive dataset and large population allow a near-complete picture of the Canadian traumatically injured population. Furthermore, to our knowledge, it is the first to examine the relative burden of mechanisms of injury while accounting for both for injury frequency and a secondary priority metric (mortality, injury severity or resource utilization) in Canadian children. It does, however, have several limitations. (1) The retrospective nature of administrative datasets has inherent limitations, mainly the inability to adjust for variables that are not measured. For example, quality of life and patient perspectives of injury would be valuable to assess; however, these are unavailable in our datasets. (2) The 0 to 19-year-old population is very heterogeneous and policy recommendations applicable to infants and preschool children would be very different to ones for young adults. Classification according to more granular age groups may assist in specific policy recommendations. (3) Classification of mechanisms of injuries was adapted from the CDC's proposed framework for presenting injury data [10]; however, this classification has not been prospectively validated. (4) Social stigma may affect coding of intent, which would affect our mechanism of injury categorization. For example, assault or intentional self-harm may be underrepresented in our population and may in consequence have underestimated IPPS. (5) Errors in outcome measurement may also have affected our results. Although the ICISS is based on a database including children [11], it has not been formerly validated in the pediatric population. Furthermore, our study may have underrepresented the cost of patients treated at multiple hospitals as it only accounted for the hospitalization costs and not the added costs of transferring individuals between facilities. Also, our cost estimates were restricted to hospitalizations costs and do not account for out of hospital deaths as well as costs associated with disability and loss of productivity. (6) There are several patients not captured in our databases. These include hospitalizations from Quebec as the province does not submit to the DAD. However, fatal traumas in Quebec are captured in VS. (7) Traumatic injuries that are seen in the outpatient setting and not admitted to hospital would not be captured in our study population. This would not affect our mortality measures and one could postulate that injuries treated exclusively in the outpatient setting are likely to be less severe and cost less per injury compared to ones requiring hospitalization. However, such injuries could occur at such overwhelming frequency that their associated IPPS would be elevated. Further examination of both inpatient and outpatient injuries could help elucidate such possibilities.

## 4. Conclusion

Injury prevention priority scores provide an objective, quantifiable metric for identifying which mechanisms of injury to target for specific prevention initiatives. Efforts to prioritize injury mechanisms by using such methods will help allocate limited time, resources, and efforts to obtain the most benefit to the largest proportion of the population. Falls, if prevented, would provide the most benefit to the largest population of Canadian children. Our research identifies which mechanism of injury to prioritize for prevention; however, it does not identify which interventions would be most effective. Although much research has been performed in elderly injury prevention, little exists in the pediatric population. We hope our study invites further examination into interventions aimed at reducing the burden of falls among children.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2019.01.030.

IPPSs more than 70 are displayed in orange, those more than 60 are displayed in yellow and those more than 50 are displayed in blue. The IPPS by definition has a mean of 50 and a standard deviation of 10. The higher the IPPS the greater priority for injury prevention.

## CRediT authorship contribution statement

**Samuel Jessula:** Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft. **Mark Asbridge:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Rodrigo Romao:** Formal analysis, Writing - review & editing. **Robert Green:** Formal analysis, Writing - review & editing. **Natalie L. Yanchar:** Conceptualization, Methodology, Formal analysis, Writing - review & editing.

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