Where to Start? Developing Injury Prevention Priority Score for Traumatic Injury Resulting in Hospitalization or Death Among Canadians

by

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Abstract

Background: Given limited resources, it is essential to determine which mechanisms of injury (MOI) should be prioritized for injury prevention. We developed objective, Injury Prevention Priority Scores (IPPS) for the Canadian population across four priority metrics: mortality, severity, resource utilization, and societal cost.

Methods: A retrospective cohort study was performed examining Canadians with traumatic injuries from 2009-2014 resulting in hospitalization or death, from the Canadian Institute of Health Information's Discharge Abstract Database and Statistics Canada Vital Statistics database. For each MOI, an IPPS was calculated by balancing both the standardized relative frequency of the injury and a secondary metric: mortality rate; severity [ICD10-derived Injury Severity Score (ICISS)]; resource utilization (hospitalization costs); and societal burden [Years of Potential Life Lost; (YPLL)]. The ICISS represents the probability of death from the specific injury. Separate IPPS were computed across each domain at the provincial level and in three separate age groups: young (0-19 years old), middle-aged (20-59 years old) and elderly (over 60 years old). IPPS across each priority metric were also compared in provinces with inclusive trauma systems and provinces without.

Results: 694,535 injuries were identified: 629,490 non-fatal hospitalizations and 65,045 deaths. The top three most frequent MOI included falls (56.3%), motor vehicle collisions (10.5%) and other (9.2%). The overall mortality rate was 0.09 and was highest in intentional-self harm (0.72), drowning (0.66) and suffocation (0.32). The overall median ICISS was 0.019 and was highest in drowning (0.148), suffocation (0.101) and pedestrian incidents (0.037). The overall median hospitalization cost was $6099 per injury and was highest in fires ($9500), suffocation ($9100) and falls ($7800). The overall median potential years of life lost was 0 and was highest in legal interventions (38 years), assault (38 years) and firearm incidents (38 years).

The top three MOI for mortality were falls (IPPS 75), self-harm (IPPS 67) and drowning (IPPS 66). The top three MOI for injury severity were falls (IPPS 77), drowning (IPPS 70) and suffocation (IPPS 61). The top three MOI for resource utilization were falls (IPPS 81), fires (IPPS 61) and suffocation (IPPS 60). The top three MOI for PYLL were falls (IPPS 72), assault (IPPS 62) and firearms (IPPS 59).

The top three MOIs are consistent across provinces in all priority metrics examined, except Prince Edward Island and the Yukon/Territories. There are marked differences in IPPS rankings in different age groups. The presence or absence of an inclusive trauma system did not change the IPPS rankings across each domain.

Conclusion: IPPS provides a useful tool to evaluate the relative burden of mechanisms of injury. Falls consistently demonstrate a high IPPS across all domains of injury prevention, and if prevented, would provide the most benefit to the largest population in Canada.

List of Abbreviations Used

AIS	Abbreviated Injury Score
CDC	Centre for Disease Control
CIHI	Canadian Institute of Health Information
CMG+	Case Mix Group
CSHS	Cost of a Standard Hospital Stay
DAD	Discharge Abstract Database
DALY	Disability Adjusted Life Years
GCS	Glasgow Coma Scale
ICD10	International Classification of Diseases – 10th edition
ICISS	ICD-10 derived Injury Severity Score
IPPS	Injury Prevention Priority Score
ISS	Injury Severity Score
NISS	New Injury Severity Score
PYLL	Potential Years of Life Lost
RIW	Resource Intensity Weight
RTS	Revised Trauma Score
SSR	Specific Survival Ratio
TRISS	Trauma and Injury Severity Score
YLD	Years Lived with Disability

Chapter One: Introduction

1.1 Introduction

Unintentional injuries are the leading cause of death for individuals under 44 years of age[1,2], account for approximately 4.8 million deaths, and affect 973 million individuals each year worldwide[3]. This represents 16% of the global burden of disease and 9% of global mortality [4]. In Canada, unintentional injuries represent the leading cause of death for individuals aged 1-35 years of age[5]. In Canada in 2010, injuries represented 15,000 deaths, 231,000 hospitalizations and over 3 million emergency room visits[6].

Injury is traditionally defined as a bodily lesion at the organic level, resulting from acute exposure to energy (mechanical, thermal, electrical, chemical, or radiant) in amounts that exceed the threshold of physiologic tolerance[4]. The main distinguishing factor between injury and disease is the acuteness of exposure and the short duration between exposure and manifestations of injury[7]. For example, acute smoke inhalation would cause a lung injury compared to chronic smoke exposure which would cause a lung disease[8,9]. Injuries are most commonly categorized with reference to the presumed underlying intent (intentional vs unintentional) and mechanism[10]. Although several etiologies for injuries exist, we will focus on traumatic injuries, both intentional and unintentional, defined as injuries secondary to external causes with mechanical force applied. 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. The mechanism of injury is defined as the fundamental physical process responsible for a given action, reaction or result[11]. These include, amongst others, road traffic incidents, falls, drowning and burns. Mechanisms and intent of injury, rather than consequences of injury, are perceived as a modifiable risk factor for injury, and therefore are commonly the target of injury prevention policy and research.

The public health approach to injury prevention involves four key steps, similar to an epidemiologic approach to any health problem[12]. The first is to determine the magnitude, scope and characteristics of the problem through data collection and surveillance. The second is to identify the risk factors that increase the likelihood of injury or disability and to determine which factors are potentially modifiable. The third step is to assess what measures can be taken to prevent the problem, and the final step is to implement the most promising and cost-effective interventions on a broad scale[4,12].

To produce effective injury prevention policy, therefore, 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[13]. Each of these domains has respective advantages and limitations. For example, a focus on mechanisms of injury that produce the highest mortality may fail to account for injuries that result in severe disability without loss of life[13] or injury mechanisms that result in more minor injuries but are so frequent that the magnitude of events constitute a significant burden. In the same way, a focus on severity of an injury alone may fail to account for the duration that a disability impacts an individual's function[13]. Finally, cost or quality-of-life measures rely on a high degree of assumptions and subjectivity[14-16]. Injury prevention policy is best planned through examination of multiple injury metrics in combination, thus addressing all domains of an injury.

Although well meaning, many injury prevention initiatives are not based on empirical evidence. For example, occupational therapy home visits to improve home safety are often promoted to decrease the incidence of falls. However, a recent systematic review has not found any evidence of fall reduction as a direct result of home visits[17]. Similarly, some injury prevention initiatives do not produce the desired preventative effect. For example, a study has found an increase in injury severity and no change in injury frequency in pediatric all-terrain vehicle injuries before and after the introduction of restrictive policy aimed at increasing all-terrain vehicle safety in children[18].

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 secondary metric of interest[19]. This tool can be employed to combine different domains on injuries, including mortality, morbidity and cost, and has been employed to rank mechanisms of pediatric injuries in the United States[20]. This type of ranking for injury prevention has yet to be completed in adults or in Canada. We seek to use this technique to better understand the state of injuries in Canada and derive objective priority rankings of each mechanism of injury, drawing on mortality, injury severity, resource utilization and societal cost.

This information will help us develop injury prevention measures that can target the mechanisms of injury that have the highest mortality, injury severity, resource utilization and societal cost, ultimately assisting in decreasing the burden of injury in Canada.

1.2 Research Objectives

This thesis has three objectives:

1) To calculate Injury Prevention Priority Scores across mechanisms of injury for the traumatically injured population in Canada from April 1st 2009 to March 31st, 2014 across four separate domains: mortality, severity, resource utilization and societal cost.

2) To subdivide IPPS by provinces and by age groups (young, middle-aged and senior).

3) To compare IPPS rankings from provinces with an inclusive trauma system to provinces without.

1.3 Thesis Overview

This thesis begins with an introduction to injuries and a review of the relevant literature in Chapter Two. Specifically, Chapter Two reviews the global and Canadian burden of injury, trauma systems, measures of trauma, variations in trauma at the demographic and regional levels and injury prevention. Chapter Three details our research methods and statistical analysis, explaining the creation of our population cohort, our exposures and outcomes of interest and a detailed description of the IPPS. Chapter Four presents the results of our main analysis related to objective one, while Chapters Five and Six present the results of our subgroup analyses related to the second and third objectives. Finally, Chapter Seven provides a discussion of key results, a review of the implications of findings for policy and practice, review of strengths and limitations of the thesis, and a thesis summary.

Chapter Two: Background and Literature Review

2.1 Global Burden of Injury

Injuries represent a significant proportion of the disease burden in the world[4] and Canada[21]. In the most recent Global Burden of Disease report in 2013, over 973 million injuries were reported that required healthcare. Of these, 4.8 million were fatal[22]. The most common causes of fatal injuries were road injuries (29.1%), self-harm (17.6%) and falls (11.6%)[22]. Injuries represent 10.1% of the global burden of disease[23]. Injuries disproportionately affect younger populations when compared to other diseases[4] and in addition to contributing to global fatalities, are a significant cause of disability. In 2013, injuries were responsible for 36.8 million Years of Life lived with Disability (YLD) and 247.6 million Disability-Adjusted Life Years (DALYs)[22]. Similar to fatalities, the mechanisms that contribute the most DALYs are road injuries (73.3 million DALYs), self-harm (35.2 million DALYs) and falls (27.5 million DALYs)[22].

Compared to 1990, when the first Global Burden of Disease report was produced, significant improvements in injury mortality and morbidity have occurred. In 1990, injuries were responsible for 5 million deaths worldwide[24]. Between 1990 and 2013, there has been a decline in Years of Life Lost (YLL) secondary to injury of 29.6%, and a decline in injury related DALYs by 30.9%[22]. YLLs are calculated by multiplying the remaining life expectancy at the age of death from a standard life table chosen as the norm for estimating premature mortality in the Global burden of Disease study[22]. These improvements since 1990 are believed to be secondary to injury prevention measures such as road safety, gun control, and occupational safety[3].

2.2 Burden of Injury in Canada

Although the burden of traumatic injuries is higher in low income countries[2], traumatic injuries represent a significant proportion of the disease burden of high income countries, including Canada. In 2010, injuries represented 15,866 deaths, 231,696 hospitalizations and over 3 million emergency room visits[21]. This resulted in $26.8 billion in cost, of which $15 billion are considered direct costs and $11 billion are considered indirect costs[6]. The three main mechanisms of injury fatality were unintentional falls (25.7%; 4,071 deaths), self-harm (24.9%; 3,948 deaths) and transport accidents (16.5%; 2620 deaths). In that same year, the National Trauma Registry reported 15,190 Canadians were hospitalized with major trauma, defined as an Injury Severity Score (ISS) >12[25]. The ISS is a numerical scoring system from 1 to 75 that quantifies the severity of an injury and is used commonly in injury research. It is further detailed below. These injury statistics reflect significant global increases from 2004, where injuries represented 13,667 deaths, 211,768 hospital admissions and 3 million emergency room visits and a total cost of $19.8 billion[26].

2.3 Mechanisms of Injury

The mechanism of injury is defined as the fundamental physical process responsible for a given action, reaction or result[11]. These include, amongst others, road traffic incidents, falls, drowning and burns. Worldwide in 2013, the most frequent mechanisms of injury mortality were road injuries (29.1%), self-harm (17.6%), falls (11.6%) and interpersonal violence (8.5%)[2]. In Canada, in 2010, the three most frequent mechanisms of injury resulting in a fatality were unintentional falls (25.7%), self-harm (24.9%) and transport incidents (16.5%)[21]. This has changed since 2004 in Canada when the most frequent mechanisms of injury resulting in a fatality were self-harm (26.5%), transport incidents (22.4%) and unintentional falls (16.3%)[26].

In Canada, in 2010, the three most frequent mechanisms of injury resulting in hospitalization were unintentional falls (55.4%; 28,389 hospitalizations), transport incidents (12.2% - 28,350 hospitalizations) and self-harm (7%; 6,131 hospitalizations)[21]. This ranking remains unchanged from 2004, when they were: falls (49.8%; 105,565 hospitalizations), transport incidents (14.6%; 30,932 hospitalizations) and self-harm (17.2%; 18,210 hospitalizations)[26].

2.4 Measuring trauma

Depending on which metric is observed, the impact of trauma can vary widely. As traumatic injuries disproportionately affect younger populations[4], measuring only mortality would not account for loss of productivity or non-fatal consequences of trauma. As such, different metrics have been developed to better understand the full effect of traumatic injuries on society. We summarize below some of the commonly used metrics when studying injuries.

2.4.1 Mortality Measures

Mortality can be easily measured and is unambiguous, however its value to trauma assessment is controversial. Much of the mortality in traumatically injured is not necessarily related to the immediate consequences of the injury, but rather an indirect consequence. For example, a patient may suffer a fall and fracture their ribs and survive; however, consequently, they can succumb to a pneumonia that developed secondary to poor expiratory efforts and clearance of secretions due to the ensuing pain[27,28].

Furthermore, the scope of mortality as a measure of the burden of injury is limited. Simple counts of mortality do not address age difference and may underestimate the burden of traumatic injuries by failing to adjust for premature death and lost time[29]. Consequently, the Potential Years of Life Lost (PYLL) metric was developed to account for the duration of time lost due to premature death. It is calculated by defining a potential limit to life (usually life expectancy at birth) and subtracting the age at death from said limit[30]. This metric is appealing both for its simplicity, adding a temporal aspect to the measure, and because it treats all deaths at a given age equally.

2.4.2 Morbidity Measures

Both mortality rates and PYLL do not account for non-fatal outcomes of injury. Some studies attempt to measure morbidity in terms of hospital resources, assessing how many hospital admissions, emergency department visits and days in hospital are associated with traumatic injury[13]. Other models have focused on injury severity as a metric of morbidity, where an injury is translated into a score, based either on anatomical or physiological parameters. Scoring systems are used clinically, as a hospital triage tool and for predicting outcomes from trauma (including mortality or other). They are also used in research, providing clinicians and researchers with a common language to assess trauma severity[31]. Of the anatomic indices, the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) are the most widely used[13]. The AIS is calculated by classifying each body region (head, neck, thorax, abdomen, spine, upper and lower extremity) on a 6-point scale from 1 (minor injury) to 6 (fatal) [13,32]. To calculate the ISS, the highest AIS for each body region is squared, and the top three highest values are summed [33]. For example, an individual with a non-depressed skull fracture (AIS=2), open tibial fracture (AIS=3) and single rib fracture (AIS=1) would have an ISS of 14 ($ISS=2^2+3^2+1^2=14$)[34]. Unfortunately, the AIS and ISS are subjective, not readily available in all databases and are labour intensive to calculate.

Physiologic scoring systems rely on biological derangements caused by a traumatic injury. The most commonly used scores are the Glasgow Coma Scale (GCS) and the Revised Trauma Score (RTS), adapted from the original trauma score[35], often used in triaging trauma patients in the clinical setting. The GCS is the sum of three coded values for eye opening (1-4), motor (1-6) and verbal (1-5) response for a total of 15[36]. The GCS has been criticized however for its low inter-rater reliability, its subjectivity and low predictive value in trauma[37-39]. The RTS combines coded values for respiratory rate, systolic blood pressure and GCS and sums them with different weights applied to each parameter[40]. The RTS was found to be predictive of mortality, however studies assessing its ability to predict non-fatal outcomes of trauma (such as injury severity and disability) have yielded mixed results[41]. The Pediatric Trauma Score (PTS) is a similar scoring system that encompasses weight, patency of airway, systolic blood pressure, level of consciousness, presence of wounds and fractures to estimate the severity of injuries in the pediatric population and is predictive of mortality[42].

Finally, the Trauma Score and Injury Severity Score (TRISS) is a mathematical regression model incorporating the RTS, ISS, age of the patient and whether the injury was blunt or penetrating and provides a probability of survival [40]. The survival probability, compared to actual survival is often used in quality of care evaluations of trauma centres. As the TRISS relies on the RTS and the ISS, it incorporates the disadvantages of both, specifically, its subjectivity, labor intensive calculations and lack of availability in most databases. Also, although empirically derived, the coefficients associated with each component of the TRISS are often debated, with up to 67 publications identified suggesting coefficient revisions[43].

One of the major limitations of morbidity metrics is that they are not readily available in most databases, especially if a database was not specifically created for trauma related research. Such a problem exists with the database used in this research, the Discharge Abstract Database (DAD). Several solutions exist, including an estimation of the ISS based on International Classification of Disease diagnostic codes 10th edition (ICD-10). The ICD-10 derived ISS (ICISS) utilizes specific survival risk ratio (SRR) of each diagnostic code associated with trauma (ICD-10 codes S00-T78)[44]. 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 over 4 million observations from 7 countries[44,45]. Thus, the SSR represents the probability of survival of each individual injury. A full list of ICD-10 codes and their associated SRRs is provided in Appendix 3.

The main advantages of ICISS include ease of use, reliability and that it is based on objective measures and empirical data. ICISS was shown to outperform ISS in predicting survival from traumatic injury[45-47] and has outperformed other resource utilization metrics in predicting length of hospital stay and hospital charges[47]. Furthermore, a recent systematic review identified the ICISS as the most accurate prediction tool for in-hospital mortality after an injury[48]. Like many morbidity scores, ICISS is scaled to mortality and consequently should be considered a measure of mortality rather than morbidity. Compared to simple mortality counts, however, it does incorporate a measure of non-fatal outcomes of injury.

Although injury severity is correlated with mortality, if the ICISS could be scaled to disability instead of mortality, it would provide a more complete picture of morbidity associated with an injury. Another limitation of ICISS is that it does not accurately predict survival for uncommon disorders. For example, the SRR of ICD-10 37.5 "Injury to fallopian tube" is based on a single observation. This limitation is minimal in population research as rare diagnoses will be unlikely to impact the overall burden of injury severity at the provincial or national level. Another limitation of ICISS is that it underestimates the severity of multiple injuries, especially if a single injury is coded with multiple ICD-10 codes. For example, if a fractured ankle is coded as ICD-10 code S92, the corresponding SSR is 0.995. If the injury is coded as both S92 and S90 (superficial injury of ankle, foot and toes) with associated SSR 0.981, the resulting SSR would be the product of both, i.e 0.995*0.981=0.976, which is lower than if an single ICD-10 code was used. Furthermore, although the SSR database the ICISS depends on includes adults and child injuries[44], the ICISS has yet to be validated in a purely pediatric population.

Another limitation of ICISS is its dependency on ICD-10 coding. The ICD-10 causes of injury and poisoning from the WHO are the most widely used coding form for categorising the circumstances of injury and poisoning [49]. It classifies each injury according first to intent and subsequently by mechanism of injury[50]. Although accuracy of ICD-10 codes for all diagnoses averages 87%[51], some limitations arise from using ICD-10 codes for injury assessment. Errors in attribution of ICD-10 codes can occur at several stages. The patient may be misdiagnosed by the treating team, which is more likely for conditions that are not amenable to definitive testing, for example an ankle sprain[52]. An ICD-10 code may also be misattributed by the coder, depending on their attention, level of training and persistence[52].

Furthermore, ICD-10 has evolved from ICD-9, which was a much simpler coding system. The added codes allow a much more detailed description of an injury, however the added complexity invites more errors in coding[53] For example, asphyxiation was coded with a single ICD-9 code (994.7) and has evolved to include more than 40 diagnostic codes with the transition to ICD-10 coding (T71.0 to T71.9)[49]. Furthermore, ICD-10 has been criticized for being non-modular, in that each code represents an individual injury. A modular coding system would allow for the combination of two separate codes into one, allowing a multiplication of possibilities. For example, one character could represent the mechanism of injury (crash/drowning/fall etc…) and another character could represent the vehicle involved (car/truck/bicycle), allowing for finer determination of injury[53]. Another limitation of ICD-10 coding is that it places intent ahead of mechanism of injury, thus adding logistical barriers if one wishes to analyze injury mechanisms irrespective of intent[53]. In the context of injuries, Davie et al. found inaccuracies in 26% of injury related ICD-10 codes[54], Langley et al. found the average age adjusted usage of unspecified mechanism codes was between 3% and 11% [55], while Finch et al. found that 30% of admissions for leisure activities were associated with either a missing or unspecified ICD-10 code and believe the use of ICD-10 codes for reporting injury data leads to underrepresentation of injury mechanisms [56]. When comparing two databases of the same patients with head injuries, Deb et al. found that ICD-10 coding underrepresented head injuries by 50%[57]. Significant heterogeneity was noted in studies examining the accuracy of ICD-10 codes.

2.4.3 Temporal measures

One shortcoming of morbidity measures is that they do not assess the temporal dimension of consequences to a trauma, i.e. the time lived with a disability after an injury. For example: two injuries of equal severity, one from which a patient can fully recover and the other from which a patient is permanently disabled, would carry equal weight if only injury severity is measured. To address the temporal dimension of duration of time lived after a traumatic injury, some frameworks have focused on the time lived with a disability following an injury. The most popular include the Disability Adjusted Life

Years (DALY) metric and the Quality Adjusted Life Years (QALY) which measure time lived with disability. The DALY is the cumulative number of years lived with a disability and years of life lost secondary to a disease[13]. A QALY is a year of life adjusted for its quality, with 1.0 equalling a year lived in perfect health. Each year lived with a disability is weighted differently depending on the severity of the disability[30]. For example, an amputated thumb has a relative weight of 0.165 for long term disability compared to an injured spinal cord which has a relative weight of 0.725[58]. These metrics are advantageous in combining fatal and non-fatal outcomes and include a temporal dimension. However, they rely on underlying societal value-based assumptions, which may not be applicable to individuals[59]. The weights used incorporate social value judgements which may change depending on the setting, and may be difficult to interpret[13].

2.4.5 Cost Measures

Cost is often utilized as a measure of disease burden. The economic burden of a disease is defined as the sum of all costs associated with a condition that would not be incurred if that disease did not exist[60]. There are three aspects to the cost of an illness or injury: direct costs, indirect costs, and intangible costs[61]. Direct costs are the sum of all charges associated with an injury, including the goods and services used in the diagnosis, treatment, continuing care, rehabilitation and terminal care of injured individuals[21]. These are usually calculated by adding all hospital charges associated with an injury. Indirect costs relate to the productivity losses due to morbidity and mortality that are borne by the individual, family, society or the employer and resources used in connection with the healthcare system that do not fall under the medical sector[61]. These include for example transportation to and from the hospital, renovations in a home to accommodate for disability and loss of productivity from the injured individual or their families both in the paid and unpaid domains [61]. Indirect costs can be calculated through two approaches: the human capital approach that estimates the loss of productivity as equal to a person's lost earnings from date of injury until retirement, or the friction cost method which estimates the cost of absence of a worker and the cost of replacing them[62]. The loss of unpaid productivity such as household work can be estimated by the cost of hiring someone to perform these tasks[60]. Most studies underestimate the indirect costs of an injury as they fail to incorporate the loss of productivity of family/supporting members surrounding the injured individual. Finally, intangible costs are the non-monetary costs that are associated with the sequelae of an injury, such as functional limitations, pain, psychological distress and decreased social interactions[63,64]. By definition, intangible costs cannot be counted in monetary units and are rarely included in cost studies[60], however they should not be completely ignored. Injury costing research may measure costs through two basic methods: the top-down method allocates claims from databases to specific injuries whereas the bottom-up method uses person level data and measures individual costs based on interviews and diaries of healthcare use[60].

2.4.6 Injury Prevention Priority Score

The previously mentioned metrics only assess injuries from a single perspective, and to date, no combined metric allows trauma programs or governing bodies to objectively evaluate which mechanisms of injury require increased attention for prevention.

Depending on which aspect one wishes to prevent, either mortality secondary to injury, hospital-associated costs or societal impact, it is essential to incorporate not only the measure of interest (mortality/cost/etc…) but also the relative frequency at which a particular mechanism of injury occurs.

The Injury Prevention Priority Score (IPPS) was first devised by Haider et al[19]. It was designed for trauma centers to differentiate which mechanisms of injury to prioritize and of special importance when planning and assessing injury prevention initiatives. It was initially constructed and validated through two large pediatric trauma databases. Its exact calculation is described below in the Statistical Analysis section. It provides a region-specific objective and quantitative injury prioritization scheme with the additional benefits of being simple and based on the true magnitude of injury rather than national benchmarks or political pressures. The IPPS is specific to whichever metric one wishes to prioritize by. For example, if one wishes to reduce resource utilization specifically, the IPPS can rank mechanisms of injury per hospital charges. If, however, one wishes to focus on mortality, the IPPS can rank mechanisms according to which is associated with the most fatalities. One could theoretically calculate multiple different rankings of mechanisms of injury, one for each metric of interest. For example, Wiebe et al. developed four separate rankings of IPPS for injured children in the US according to mortality, injury severity, hospital charges and PYLL[20].

The IPPS is analogous to the methods used in estimating disease burden in The Global Burden of Disease Study[24]. The Global Burden of Diseases estimates health burden by incorporating both the disease's incidence and its weighted disability. By incorporating both a measure of relative frequency and of a secondary metric of interest, they estimate which diseases are the most disabling to the highest number of people. The diseases are then ranked in order of disability. The IPPS can be considered analogous, whereby incidence and the secondary metric are combined to provide a raking of mechanisms of injuries. The various measures of trauma are summarized in Table 2.1.

2.5 Demographics of injury

When compared to other diseases, injuries tend to affect younger populations[4]. The age distribution of major trauma (ISS>12) absolute numbers of injuries in Canada displays two peaks, one in the 20-24 year old group and one in the 45-54 year old group[65]. Rates of injury vary by sex and age. According to the Canadian Community Health Survey, in 2010, 30% of males aged 12-19 were injured compared to 17% of males aged 20-64 and 9% of males aged 65 and older[66]. In the same year, 23% of females aged 12-19 were injured, compared to 12% of females aged 20-64 and 10% of females aged 65 and older[66].

2.5.1 Sex

Females, in addition to being less frequently injured compared to males, tend to have lower mortality rates after traumatic injury[67,68]. This association does not persist when adjusting for pre-existing conditions[69], and sex is believed to be a proxy for pre-existing conditions, which are the true cause of the association seen between sex and mortality.

2.5.2 Pediatric Trauma

Traumatic injury is the leading cause of death amongst Canadian children[70] and individuals aged under 20 years old. Children on average are twice as likely to become injured compared to adults[66,71]. Male children are twice as likely to become injured compared to females[72 73]. The most common mechanism of injury in children is motor vehicle incidents[20,71,74], compared to falls in adults[21]. Although crude survival is higher in children compared to adults, this survival advantage does not persist when adjusting for physiologic criteria and injury severity [71,74 73]. In a large series, mortality rates for injured children are much lower than adults, ranging from 0.9-2.4% for all patients and 4.9-9.1% for patients with an ISS>15 [73].

2.5.3 Trauma in the Elderly

The elderly, although proportionally less likely to become injured[66], have a decreased physiologic reserve and are less able to withstand traumatic injury compared to their younger counterparts and have consistently been found to have higher risk of mortality after traumatic injury[67,75,76]. When adjusted for injury severity and co-morbidities, individuals over the age of 65 were found to have significantly higher mortality rates, higher intensive care resource utilization and longer hospital stays[76]. In that same study, female sex was associated with increased survivorship from traumatic injury when adjusted for injury severity[76]. Compounding this increased risk of mortality, elderly patients are less likely to undergo adequate triage after a traumatic injury despite having similar percentage of severe injuries compared to their counterparts[75,77-79]. In the under-triaged group, the mortality was significantly elevated[75].

2.6 Regional variations in Injury

Several regional differences exist in outcomes after an injury. Individuals who are injured in rural settings without a formal trauma system are more likely to die at the scene, and tend to be older [80]. In the United States in 2001, the unintentional injury mortality rate was two times higher than in large metropolitan areas[81]. It is difficult to distinguish if this is secondary to infrastructure (for example in road safety), to access to healthcare, to differences in injury mechanism or to host factors related to individuals living in rural areas (for example rural areas tend to have higher proportions of older individuals)[82]. In Canada, injury rates vary by province even when adjusting for age and sex differences[21,26]. For example, in 2010, the lowest age and sex standardized mortality rate for transportation related deaths was in Ontario (5.1 deaths per 100 000) compared to the highest in Saskatchewan (14.6 deaths per 100,000)[21]. For falls, Newfoundland had the lowest mortality rate with 1.5 deaths per 100,000 and Manitoba experienced the highest at 7.0 deaths per 100,000[21]. The explanation for these differences is likely multifactorial, including differences in geography, socio-economic status and access to care[83].

2.7 Canadian Trauma Systems

In Canada, health care is administered at the provincial level, with each province individually organizing and delivering trauma care to injured patients. All provinces have designated trauma centres in large urban settings[84] and four provinces had established inclusive trauma networks with established ministry-designated trauma centres in 2009-2013. These include British Columbia, Alberta, Quebec and Nova Scotia [84,85]. According to the Trauma Association of Canada, an inclusive trauma system is defined as a preplanned, organized, and coordinated injury control effort in a defined geographic area (province or region) which: has an identifiable lead agency, is publicly administered, funded and accountable; engages in comprehensive injury surveillance, reporting and prevention programs; delivers the full spectrum of trauma care from the time of injury to recovery including immediate access to emergency medical services, rapid transport to appropriate level of care, acute services including resuscitation, surgery, critical care and specialty services, rehabilitation and reintegration into the community and workforce; engages in research, training and performance improvement and establishes linkages with an all-hazards emergency preparedness program[86]. A trauma system, in addition to connecting trauma centers, coordinates care and utilizes higher level trauma centers for the most severely injured patients and acute care (regional) facilities for the less severely injured patients, thus optimizing the available resources, matching patient needs with care[87].

In the United States, injury mortality rates in regions have consistently decreased with the introduction of trauma systems [88-94]. Regions with trauma systems have also shown improved survival when compared to regions without trauma systems [95-97], and this benefit is more readily seen for severely injured patients [98,99]. Similar findings have been reproduced in several countries around the world [100,101]. In a meta-analysis of 14 original articles, trauma systems were associated with a significant reduction in mortality following a traumatic injury [odds ratio: 0.881 (95% CI 0.778-0.998)][102]. In Canada, trauma systems are associated with reduced mortality [103] and provinces with inclusive trauma systems have an adjusted odds ratio for mortality of 0.93 (95% CI 0.87-0.99) compared to those without [104]. For example, In Nova Scotia, establishment of an inclusive trauma system was associated with a 29% reduction in injury related mortality, although this did not reach statistical significance (95% CI 0.32-1.03) [105].

A Canadian study has also found decreased hospital associated costs with trauma centers[106], which has been validated in the United States for more severely injured patients (defined here as an ISS>16), where trauma centers were associated with a shorter length of stay and decreased cost of care[94]. Although trauma systems cannot change the injury severity on arrival, it is possible that they would lower mortality, resource utilization and societal cost differently for different mechanisms of injury.

2.8 Injury Prevention

Injury prevention is an effort to prevent or reduce the severity of bodily injuries caused by external mechanisms. This can be at the individual level, for example someone who chooses to wear a helmet while cycling and at the population level, for example bicycle helmet legislation. Haddon described a matrix for injury prevention, dividing an injury into three factors: host factors, agent/vehicle factors and environmental factors, as well as three phases: pre-event, event and post-event[107]. Haddon's matrix was introduced at a time of paradigm shift, where "accidents" were relabeled to be considered "injuries" and reframed in the realm of medical ecology[7]. This shift has changed our interpretation of injuries as the opposite of accidents, whereby they are non-random events that occur in distinct distributions, like infectious diseases. Injuries are caused by agents (for example burns are caused by heat), which is delivered to the host (the individual who is injured) via a vector/vehicle (for example via a flame). The host themselves can be more or less prone to injury depending on several characteristics (such as their age). An example of Haddon's matrix employed for analyzing motor vehicle incidents is provided in Table 2.2[108].

All levels of factors and phases have been targets of injury prevention. Although little can be done to change the age of injured patients, policy has been devised to protect specific vulnerable populations. For example, the introduction of a Graduated Driver's Licensing System was associated with decreased crash incidents in North American youths in a recent systematic review[109]. Another example of successful interventions at the host level includes screening programs for falls in elderly populations, which have a risk reduction of 27%[110]. Both are examples of pre-event interventions. The introduction of seat belt and airbag safety are examples of interventions at the agent/vehicle level. They have been associated with a reduction in mortality by 72% for seat belts and 63% for airbags[111]. When combining seat belts and airbags, mortality is reduced by 80%[111]. Along with other safety improvements, this is an example of an event phase intervention. Setting road speed limits, through physical measures (such as speed bumps) and law enforcement are an example of environmental changes for injury prevention. In ecological studies, changes to speed limits have been associated with a 6-24% reduction in motor vehicle fatalities[112]. This is also a pre-event phase example.

A classic environmental and post-event phase example is the implementation of trauma systems, which aim to decrease the morbidity and mortality of injuries after a trauma has occurred. As previously mentioned, trauma systems have been associated with a mortality reduction[104,105].

To date, injury prevention in Canada has limited resources and lacks the data to adequately choose which mechanisms of injury, if prevented, will provide the greatest good to the largest number of people. Although a significant amount of research has been performed on injuries in Canada, there are no rankings of mechanisms of injury across various metrics. We propose to rank mechanisms of injury according to mortality, injury severity, resource utilization and societal cost.

2.9 Summary and Impact

Injuries represent a significant burden on the Canadian healthcare system. Different mechanisms of injury cause different mortality, injury severity, resource utilization and PYLL. Given our limited resources, we must identify which mechanisms of injury should be prioritized for policy drafting, funding allocations and further research. Our study will provide objective and quantifiable rankings for injuries in Canada and allow targeting of injury prevention efforts to specific mechanisms, depending on what aspect of the injury burden is being addressed, either mortality, morbidity, resource utilization or PYLL. By focusing on specific high-yield mechanisms of injury, these prevention programmes can be cost effective and have the most significant impact on the burden of injury.

2.10 Expected Contribution

Currently, no objective scores exist to identify which mechanisms of injury contribute the largest proportion of burden of injury in Canada. Our study will provide an objective ranking of mechanisms of injury with the highest impact on Canadian injuries. This information can then be used by policy makers to draft targeted policy to reduce injuries from the specifically identified mechanism of injury. This can be applicable to both federal and provincial policy as both estimates will be provided. The policies can also be tailored to the specific metric, mortality, injury severity, resource utilization and societal cost that is of interest. In addition to assisting with policy change, our results may help health researchers identify which mechanisms of injury warrant further research and analysis.

Overall, we aim to provide a paradigm by which to prioritize efforts for injury prevention, ultimately laying the foundation for reduced injuries and decreased associated disease and cost burden.

Chapter 3: Research Methods

The following chapter describes the research methods and statistical analysis used in this project. It details the study design, population, variables and analysis with specific description of the IPPS statistic.

3.1 Study Design

We performed a retrospective analysis of a cohort of the Canadian population who experienced a traumatic injury between April 1st, 2009 to March 31st, 2014. Data sources include the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database (DAD) and the Vital Statistics Database from Statistics Canada.

3.2 Data Sources

The DAD is the most comprehensive database for Canadian in-hospital information. It contains demographic, administrative and clinical information concerning all inpatient hospitalizations in Canada. In addition to basic demographic data (sex, date of birth, province of admission), the DAD contains up to 25 admitting diagnoses and information related to hospitalization (length of hospital stay, year and province of admission, disposition at discharge). More than 3.2 million abstracts of hospitalizations are submitted to the DAD annually from 581 acute care facilities across Canada[113,114]. It also contains cost information including Case-Mix Group (CMG+) and Resource Intensity Weight (RIW), used to estimate the cost of a hospital admission, further detailed below. In the DAD, admission diagnoses are classified according to International Classification of Disease (ICD)-10[115].

Statistics Canada maintains a Vital Statistics database which contains demographic and underlying cause of death on all fatalities (including Canadian residents and non-residents) occurring in the country. Each death has an associated underlying cause of death, coded by ICD-10 codes[5,116]. As registration of death is a legal requirement in each Canadian Province, reporting is virtually complete and over-coverage is avoided by identification of duplicates[116].

3.3 Study population

Our inclusion criteria included:

- Individuals who died with an ICD-10 code consistent with external cause (V01-Y98) as the cause of death in Vital Statistics from April 1st, 2009 to March 31st. 2014 inclusive.
- Individuals who were admitted to hospital with an ICD-10 code consistent with external cause (V01-Y98) as one of the 25 admitting diagnoses in the DAD, with admission date from April 1st, 2009 to March 31st, 2014 inclusive.

Our exclusion criteria included:

- Individuals who died or were admitted to hospital for poisoning, identified through ICD-10 codes X40-X49, X70-X69, X85-X90, Y10-Y19 and Y35.2 in admitting diagnoses (DAD) or cause of death (Vital Statistics).
- Individuals who died or were admitted to hospital for adverse events, identified through ICD-10 codes Y40-Y59, Y60-Y84, Y88-89 in admitting diagnoses (DAD) or cause of death (Vital Statistics).

- Individuals who were admitted to hospital in Quebec, as Quebec does not participate in the DAD.
- Individuals who do not have a valid health card number (including non-Canadian residents, individuals who do not have a health card or individuals for whom a health card is not recorded).

As age and sex significantly affect mortality from traumatic injury[67,68,71,73,75,76], when comparing provinces with and without inclusive trauma systems we performed direct standardization using the Canadian 2011 census as the standard population[117]. Each population cohort (with and without inclusive trauma systems) were stratified into age groups of base 10. The number of hospitalizations and deaths in each age group was multiplied by the proportion of individuals in the same age group from the standard population. The same procedure is then applied to sex, whereby the number of hospitalizations and deaths is multiplied by the proportion of males to females in each age group in the standard population. The IPPS were calculated as per the section 3.4.2.6 for all domains: mortality, severity, resource utilization and societal cost in both cohorts.

3.4 Variable Definition

3.4.1 Exposure

3.4.1.1 Mechanism of Injury

The main exposure of interest is mechanism of injury. Mechanism of injury will be grouped according to the Centre for Disease Control (CDC) proposed framework for presenting injury data[118]. This classification provides a universal language when examining mechanisms of injuries and divides injuries by general mechanism and intent. We have adapted the mechanism division to accommodate our database requests into the following 16 categories:

- Falls
- Drowning/Submersion
- Pedestrian
- Motor Vehicle Collision, Occupant
- Motorcycle
- Pedal Cyclist
- Suffocation
- Firearm
- Fire/Flame or contact with Hot Object/Surface
- Assault
- Intentional Self Harm
- Cut/Pierce or Struck By/Against
- Natural/Environmental

- Machinery
- Overexertion
- Legal Interventions
- Other

The corresponding ICD-10 codes for each mechanism can be found in Appendix 1. The combination of some mechanisms from the CDC categories were necessary to satisfy privacy concerns from some of our databases and ensuring no patients could be identifiable through unique combinations of mechanism of injury, year of injury and age group. Of note, because our mechanisms are irrespective of intent, a same action may be classified differently depending on intent. For example, if an individual receives an intentional firearm injury, the mechanism would be "assault", however if that same action was unintentional, it would be classified as "firearm." Each hospitalization or death will only be present in a single mechanism category. If more than one mechanism of injury was found from the 25 ICD-10 codes provided with each admission, the first diagnostic code with a classifiable mechanism of injury was used. For example, if an individual were to fall on the ice and was admitted with diagnosis 1 W-00 "fall at the same level involving ice or snow" and diagnosis 2 W22 "Striking against or struck by other objects", the individual would be classified according to diagnosis 1, i.e. a fall.

3.4.1.2 Inclusive Trauma System

The presence or absence of an inclusive trauma system was the secondary exposure of interest. As per the Trauma Association of Canada, an inclusive trauma system is defined as a preplanned, organized, and coordinated injury control effort in a defined geographic area (province or region) which: has an identifiable lead agency; is publicly administered, funded and accountable; engages in comprehensive injury surveillance, reporting and prevention programs; delivers the full spectrum of trauma care from the time of injury to recovery including immediate access to emergency medical services, rapid transport to appropriate level of care, acute services including resuscitation, surgery, critical care and specialty services, rehabilitation and reintegration into the community and workforce; engages in research, training and performance improvement and establishes linkages with an all-hazards emergency preparedness program[86]. Provinces that had an integrated trauma system during the period of study include British Columbia, Alberta, Quebec and Nova Scotia[85,119]. Provinces without an inclusive trauma system include Newfoundland, Prince Edward Island, New Brunswick, Ontario, Manitoba, Saskatchewan, the Yukon and The Northern Territories. Ontario and New Brunswick have recently developed trauma systems; however, they were not fully in place from 2009 to 2014 and therefore are considered to not have a fully integrated trauma system in our study.

3.4.2 Outcomes

Outcomes of interest include injury frequency, mortality, injury severity, resource utilization and societal cost.

3.4.2.1 Frequency

Injury frequency was calculated by summing the unique hospitalizations from the DAD and the deaths from Vital Statistics. The in-hospital deaths are then subtracted from the total to remove the overlap between hospitalizations and deaths. This represents the number of unique traumatic injuries resulting in death or hospitalizations in Canada from 2009-2014.

3.4.2.2 Mortality

Mortality counts for each mechanism of injury are obtained from Vital Statistics. An individual mortality is counted if the cause of death on the death certificate corresponds to the included ICD-10 codes. Any individual who meets the inclusion criteria will be counted as a single instance. Each instance of mortality will then be classified into the appropriate mechanism of injury as per their cause of death diagnosis from Vital Statistics.

3.4.2.3 Injury Severity

Injury Severity Score (ISS) is a widely used metric of injury severity[13]. It translates an injury into a scalable score based on anatomical criteria[33]. Unfortunately, it is highly subjective and not readily available in most databases, including our data sources. As an alternative, we opted to use an estimation of the ISS based on International Classification of Disease diagnostic codes 10th edition, the ICISS. The ICISS utilizes specific survival risk ratio (SRR) of each diagnostic code associated with trauma (ICD-10 codes S00-T78)[44]. 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 over 4 million observations from 7 countries[44,45]. Thus, the SSR represents the probability of survival of each individual injury. A full list of ICD-10 codes and their associated SRRs is available at http://links.lww.com/TA/A346. The main advantages of ICISS include ease of use, reliability and that it is based on objective measures and empirical data. ICISS was shown to outperform ISS in predicting survival from traumatic injury[45-47] and has outperformed other resource utilization metrics in predicting length of hospital stay and hospital charges[47]. Furthermore, a recent systematic review identified the ICISS as the most accurate prediction tool for in-hospital mortality after an injury[48].

The DAD supplies ICD-10-CA codes, which are one digit longer than regular ICD-10 codes. To match our ICD-10 to SSR database, all ICD-10-CA codes from DAD were trimmed to 4 digits. If multiple injuries were found in a single admission, the ICISS will be the product of each injury's SSR, as described by Osler et al[45]. An ICISS ranges from 0 to 1, with 0 being the most severe injuries and 1 being the least severe. Because of the manner in which our IPPS are constructed, as further described in section 2.4.2.6, we require the ICISS to have an ordinal structure with 0 being least severe and 1 being most severe. As such, we have transformed our ICISS by subtracting it from 1, thus creating a mirror imaged scoring system with 0 being least severe and 1 being most severe injuries. For example, if the calculated ICISS was 0.8, the adapted ICISS used is 0.2.

3.4.2.4 Resource utilization

Resource utilization, or the direct costs of injury, are the sum of all charges associated with an injury, including the goods and services used in the diagnosis, treatment, continuing care, rehabilitation and terminal care of injured individuals[21]. Resource utilization will be calculated from the perspective of the healthcare payer. 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[120,121]. Each CMG+ in turn, is associated with a baseline Resource Intensity Weight (RIW)[122]. The base RIW represents the standardized estimate of resource consumption[123]. Each hospitalization is provided with a RIW which represents the relative resource use, adjusted on a case by case basis depending on age group, length of stay, comorbidity level and interventions received[123,124]. The baseline Cost of a Standard Hospital Stay (CSHS) is estimated by CIHI based on aggregate data across provinces. The cost of each hospitalization becomes the CSHS multiplied by the RIW of that admission. This methodology has been validated in both simple and medically complex hospital admissions[125].

For individuals with repeat hospitalizations, the cost of each hospitalization will be calculated and summed, treating it as the same as a single hospitalization with a cost of both combined. Everyone is identified in the data obtained from the DAD with a unique identifier code, thus allowing easy calculation for repeat hospitalizations.

Each year, the cost of hospital resources will be adapted according to the Consumer Price Index (CPI) [126]. We will use 2009 as a base year, and multiply each hospital admission cost by the corresponding adjusted CPI for health, obtained from Statistics Canada[127]. For example, the cost of a hospitalization in the fiscal year 2014 will be divided by the CPI for health of 2014 and multiplied by the CPI for health for 2009. Unfortunately, at time of writing, the CSHS for each province is not available for the years 2012-2013 and 2013-2014. As such, the CSHS from 2011-2012 were used for the years 2012-2013 and 2013-2014. Furthermore, as the CSHS is not available for the Canadian Territories, the CSHS for Yukon is used as an estimate for the Northern Territories and Yukon.

3.4.2.5 Societal Cost

Societal cost reflects the indirect costs of injuries and represents the loss of productivity from the injured individual or their families, both in the paid and unpaid domains [61]. These are often complex and incorporate elements that are non-calculable, such as psychological distress and decreased social interactions[63,64]. We will estimate the societal cost of each mechanism of injury by calculating Potential Years of Life Lost (PYLL). PYLL is a metric developed to account for the duration of time lost due to premature death. We calculate it by deducting an individual's life expectancy by the age at death. Life expectancy at birth was obtained through Statistics Canada[128] from which age at death was deducted from the data obtained from Vital Statistics. The PYLL per death were then multiplied by the number of deaths in each age group and summed for each mechanism of injury. As the data from Statistics Canada is categorized in 10-year strata, the age at death is assumed to be the midway point of the strata. For example, if a certain mechanism had 5 individuals die in the age category 50 to 59 years old and life expectancy for that stratum at birth was 69, we would assume a total of PYLL for that age group to be 5*(69-55) =70.

3.4.2.6 IPPS

Injury Prevention Priority Scores will be calculated for each outcome measure, combining both the incidence and the secondary metric of interest, as devised by Haider et al[19]. This is computed in the following manner:

- The metric of interest is summarized in a single statistic (mean/median/other).
    - The four metrics of interest will be: mortality rate, median ICISS, median hospitalization cost and PYLL.
- Two separate Z scores are created: one for the frequency of a mechanism of injury and one for that mechanism's associated metric of interest. A Z score is calculated by dividing a value's distance from its mean by its standard deviation.
- The two respective Z scores obtained are then summed 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. A T score is similar to a Z score; however, it is more appropriate when your sample population is under 30 observations.

An IPPS has by definition a mean of 50 and a standard deviation of 10. The mechanisms of injuries are then sorted by descending IPPS values, thus providing a rank list of the most significant injury mechanisms across four separate domains. The creation of Z scores equalizes the variability across injury mechanisms with respect to frequency and the metric of interest, thereby reducing the possibility that the final score would be primarily a function of frequency[20]. Within each domain (mortality, injury severity, resource utilization and cost), missing data points were treated by case wise deletion.

3.5 Sensitivity Analyses

We performed two separate sensitivity analyses to ensure the validity of our dataset. First, we grouped together motor vehicle collisions, pedestrian, motorcycle and pedal cycle incidents into a single "traffic" mechanism to ensure that results were not related to an artificial decrease in frequency by separating these traffic related mechanisms into several. We then recomputed our IPPS with traffic as a unique category. Second, we wanted to ensure the PYLL data was not affected by the controlled rounding methodology employed by Vital Statistics. In controlled rounding, each individual cell is rounded either up or down to the closest integer by base 5, however the total for the category remains rounded to the closest integer base 5. The overall results would not be affected by rounding, however the individual PYLL with each combination of mechanism and age group may be. We therefore transformed our mortality data and assumed each cell to have a midpoint value for each cell range. For example, if a cell displayed 5, the midpoint value of 2.5 was chosen and if a cell displayed 10, the midpoint of 7.5 was chosen. Because this would only potentially affect our IPPS calculation for PYLL, we did not re-compute the IPPS for the other domains.

3.6 Subgroup analyses

3.6.1 Provincial subgroups

Provincial level data was available for the severity and resource utilization domain for all provinces except Quebec. We therefore computed injury severity and resource utilization IPPS for each province (except Quebec). The Yukon and the Northern Territories were treated as a single “province”.

3.6.2 Age-related subgroups

Our study population was subdivided into three distinct age groups: young (0-19 years old), middle-aged (20-59 years old) and elder (60 years or older). We then computed IPPS across all four domains for each age group, specifically looking for any variation in injury priority rankings.

Chapter Four: Development of Injury Prevention Priority Scores in Canada

Chapter four presents the results related to the first objective. It describes the study cohort, the demographics of injuries in Canada over the study period and the national IPPS for the overall cohort.

4.1 Study Cohort

As seen in the flow chart in Figure 4.1, after excluding patients missing a health card (11,871), medical adverse events (1,079,952), poisoning (101,847) and repeat hospitalizations (139,875) our hospitalization cohort consisted of 661,631 unique hospitalizations. After excluding adverse events (815) and poisoning (16,925) our mortality cohort consisted of 65,045 deaths. When combined and the in-hospital deaths removed (32,141), our total cohort consisted of 694,535 unique traumatic injury events between April 1st, 2009 and March 31st, 2014 in Canada.

4.1.1 Demographics

The distribution of mechanisms of injury is displayed in Figure 4.2. The most common mechanism of injury was falls (56.3%), followed by MVC occupant (10.5%) and then by other (9.2%). The age distribution of absolute numbers injuries, as seen in Figure 4.3, indicates a trimodal peak, with observed peaks at ages 20-29, 70-79 and a highest peak at ages 80-89 years old. The age distribution was highly variable across mechanisms of injury, with drowning/submersion being highly skewed toward younger age groups and falls being highly skewed toward older age groups. The sex distribution overall and by mechanism of injury is seen in Figure 4.4. Although the total sex distribution was roughly equal (52% female), most mechanisms of injury had a higher proportion of males, except for falls. The provincial distribution of hospitalizations is displayed in Figure 4.5. As shown, Yukon and Territories had the highest injury rate per capita, followed by Saskatchewan and Prince Edward Island. Of note, provincial level data was not available for the mortality cohort, therefore only hospitalizations are reported. Figure 4.6 displays the temporal changes in injury rate by mechanism of injury and overall. Although total injury rate had not changed significantly, motor vehicle collisions, assault and cut/pierce/struck by/against appear to be decreasing over time.

4.2 Outcomes

4.2.1 Mortality

The distribution of deaths by mechanism of injury is summarized in Figure 4.7. The overall mortality rate was 0.09 deaths per injury. Self-harm and drowning/submersion represent the highest mortality rate (0.72 deaths per injury), followed by suffocation (0.37 deaths per injury). Pedestrian incidents (0.17 deaths per injury), firearms (0.16 deaths per injury), fire/flame (0.15 deaths per injury) and motor vehicle collisions (0.14 deaths per injury) were the only other mechanism higher than the average mortality rate.

4.2.2 Injury Severity

Overall, ICISS was calculated for 632,544 hospitalizations, or approximately 95% of the cohort. An ICISS was not available if the ICD-10 codes related to the hospital admission were not present in our ICD-10 to SSR database[44]. When examining each mechanism separately, ICISS was calculated for over 80% of each mechanism of injury except for suffocation, where ICISS was calculated only for 65.6% of the cohort. The ICISS ranged from 0 (least severe injuries) to 0.891 (most severe injuries) with a median of 0.017 and an IQR of 0.045. As the distribution of ICISS within each mechanism was highly right skewed, the median ICISS for each mechanism was used to calculate the corresponding IPPS. Figure 4.8 represents the median ICISS per mechanism of injury. The overall median ICISS was 0.017 with an IQR 0.04. Drowning/Submersion had the highest median ICISS (0.148). The widest IQR was seen in pedestrian incidents (IQR 0.122).

4.2.3 Resource Utilization

An estimate of cost was available for all but five hospitalizations, representing over 99.9% of the dataset. The cost calculation was not possible for the five hospitalizations in question as the associated RIW in the DAD was 0. As a hospitalization is highly unlikely to cost $0, these five hospitalizations were excluded from our cost calculations. The median cost per hospitalization was $6,100 and an IQR of $9,275. As the distribution of costs were highly left skewed, the median cost per hospitalization was used to calculate the corresponding IPPS. Figure 4.9 shows the median cost per hospitalization by mechanism of injury. Fires had the highest median cost ($9,511, with an IQR of $14,433). The widest IQR was seen in suffocation ($19,057).

4.2.4 PYLL

As the PYLL data is derived from the same Vital Statistics data used to calculate the mortality estimates, it is also available for all mortality counts with a total PYLL of 1,070,610 years. The overall median PYLL per injury is 0. Figure 4.10 represents the median PYLL per mechanism of injury. Legal interventions, assault and firearms had the highest PYLL (38 years).

4.2.5 Injury Prevention Priority Scores

Presented in Table 4.1 are the summary statistics used for the calculation of IPPS by mechanism of injury. Each mechanism has a mortality rate, median ICISS, median cost per hospitalization and median PYLL. From these distributions, the respective means and standard deviations for each domain is computed and presented in the last two rows of the table. These are used to calculate the corresponding Z scores, which are presented in Table 4.2. The IPPS for mortality, severity, resource utilization and PYLL are summarized in Table 4.3. Falls demonstrates the highest IPPS consistently for each domain. For mortality, the top three IPPS were falls (IPPS 75), self-harm (IPPS 67) and drowning/submersion (IPPS 66). For severity, the top three IPPS were falls (IPPS 77), drowning/submersion (IPPS 70), and suffocation (IPPS 61). For resource utilization, the top three IPPS were falls (IPPS 81), fire (IPPS 61) and suffocation (IPPS 60). For PYLL, the top three IPPS were falls (IPPS 72), assault (IPPS 62) and firearms (IPPS 59). Although motor vehicle collisions are not in the top three mechanisms in any domain, it was consistently in the top 5 priorities.

4.3. Sensitivity Analyses

Table 4.4 displays the calculated IPPS with our exposure variable modified to group motor vehicle collisions, pedestrian, motorcycle and pedal cyclist mechanisms into one single "traffic" mechanism of injury. The top three mechanisms of injury remain identical in the mortality, severity and resource utilization domains. In the societal domain, compared to the original mechanism categorization, traffic injuries surpassed firearms and became the third highest ranking mechanism (IPPS 60), after falls (IPPS 69) and assault (IPPS 61). The IPPS rankings for PYLL with the transformed mortality cohort, where we considered each age group/mechanism combination to have the mid value point of the cell range, were identical to the original cohort and are therefore represented in table 4.3.

Chapter Five: Subgroup Analyses

Chapter five presents the results for the second objective, detailing the changes in IPPS rankings at the provincial level and within each age group.

5.1 Provincial Analysis

Table 5.1 displays the IPPS for injury severity across provinces. Most provinces display similar IPPS scores for severity with identical mechanism rankings, except in Prince Edward Island which displays falls (IPPS 75), firearms (IPPS 73) and drowning (IPPS 55) as the top three mechanisms for prioritization in the severity domain. Table 5.2 displays the IPPS for resource utilization across provinces. Contrary to the severity domain, there is marked heterogeneity in the IPPS for resource utilization. Although falls is consistently the highest IPPS, the second and third ranking of IPPS varies significantly across provinces. Of note, because provincial level mortality data was not available, these analyses were restricted to hospitalized patients.

5.2 Age Group Analysis

5.2.1 Young Cohort

A total of 86,981 injuries were identified in individuals aged 0 to 19 years old. The overall mortality rate was 0.04 deaths per injury, the median ICISS per injury was 0.007, median cost per hospitalization was $3,207 and median PYLL per injury was 63 years. Table 5.3 presents the summary statistics for the calculation of IPPS in the young cohort and Table 5.4 presents the IPPS for all four domains for the young cohort, aged 0-19 years old. We notice that falls remained the highest ranked IPPS across all four domains. The top three rankings mirror the national rankings for mortality and severity. In the resource utilization domain, the top three mechanisms of injury were falls (IPPS 70), fires (IPPS 65) and self-harm tied with motor vehicle collisions (IPPS 60). The top three rankings for the societal domain were falls (IPPS 73), cut/pierce (IPPS 60) and motor vehicle collisions (IPPS 58).

5.2.2 Middle-Aged Cohort

A total of 266,681 injuries were identified in individuals aged 20 to 59 years old. The overall mortality rate per injury was 0.10, the median ICISS per injury was 0.009, the median cost per hospitalization was $4506 and the median PYLL per injury was 26 years. Table 5.5 presents the summary statistics for the calculation of the IPPS in the middle-aged cohort and Table 5.6 presents the IPPS for all domains for the middle-aged cohort. The top three rankings mirror the overall cohort for the mortality and resource utilization domains. In the severity domain, the top three mechanisms of injury were falls (IPPS 73), drowning (IPPS 71) and motor vehicle collisions (IPPS 60). In the PYLL domain the top three mechanisms of injury are motor vehicle collisions (IPPS 72), assault (IPPS 66) and falls (IPPS 63).

5.2.3 Senior Cohort

A total of 340,873 injuries were identified in individuals aged over 60 years old. The overall mortality rate per injury was 0.10, the median ICISS per injury was 0.028, the median cost per hospitalization was $9,816 and the median PYLL per injury was 0 years.

Table 5.7 presents the summary statistics for the calculation of the IPPS in the senior cohort and Table 5.8 presents the IPPS for all domains for the senior cohort, aged 60 years or older. The top three rankings mirror the overall cohort in the mortality, severity and resource utilization domains. Of note, as the median PYLL per mechanism was 0 years for all mechanisms, no IPPS was calculated for the societal domain in the senior cohort.

Chapter Six: Trauma System Influence on Mechanism of Injury Prevention Priority Score Ranking

Chapter six presents the IPPS rankings for provinces with and without inclusive trauma systems, both overall and in hospitalized patients.

6.1 Study Cohort

As seen in the flow chart in Figure 6.1, the mortality cohort separates into 32,045 deaths in provinces with an inclusive trauma system and 33,000 deaths in provinces without. Similarly, the hospitalization cohort separates into 266,943 hospitalizations in provinces with an inclusive trauma system and 394,688 hospitalizations in provinces without. When combining these respective cohorts, excluding 11,867 in-hospital deaths in provinces with an inclusive trauma system and 20,274 in-hospital deaths in provinces without our study population is stratified with 287,121 unique traumatic injuries in provinces with an inclusive trauma system and 407,414 in provinces without.

6.1.1 Demographics

As seen in Figure 6.2 the distribution of mechanisms of injury were similar in both cohorts. In provinces with an inclusive trauma system, the most common mechanism of injury was falls (57.2%), followed by motor vehicle collisions (10.3%) followed by other (7.9%). In provinces without an inclusive trauma system, the most common mechanism of injury was falls (61.1%), followed by other (9.0%), followed by motor vehicle collisions (8.4%). The age distribution of traumatically injured individuals is presented in figure 6.3. As shown, the cohort without an inclusive trauma system has a disproportionately higher number of older individuals who are hospitalized or died from traumatic injury. Figure 6.4 displays the sex distribution by mechanism of injury and by presence or absence of inclusive trauma system. As shown, the sex distribution is similar regardless of the presence or absence of an inclusive trauma system whereby most mechanisms of injury have more males injured than females, except for falls where females predominate.

6.2 Outcomes

The injury frequency, adjusted injury frequency, mortality, adjusted mortality, median ICISS, median cost per hospitalization and median PYLL are presented in Tables 6.1 and 6.2, respectively, for provinces with an inclusive trauma system and those without.

6.2.1 Injury Prevention Priority Scores

Presented in Table 6.3 are the mechanisms of injury prevention priority scores across the mortality, severity, resource utilization and PYLL domains in Canada 2009-2014, segregated by the presence or absence of an inclusive trauma system, adjusted for age and sex. The presence or absence of an inclusive trauma system does not affect the top three priority mechanisms of injury in all domains. In the mortality domain, in both provinces with and without an inclusive trauma system, the top three priority mechanisms of injury were falls (IPPS 73 and 75 respectively) followed by self-harm (IPPS 69 and 68 respectively) followed by drowning (IPPS 65 and 66 respectively). In the severity domain, in both provinces with and without an inclusive trauma system, the top three priority mechanisms of injury were falls (IPPS 76 and 77 respectively) followed drowning (IPPS 70 and 70 respectively) followed by suffocation (IPPS 61 and 61 respectively). In the resource utilization domain, in provinces with and without an inclusive trauma system, the top three mechanisms of injury are falls (IPPS 79 and 82 respectively) followed by fire (IPPS 64 and 59 respectively) followed by suffocation (IPPS 60 and 58 respectively). Finally, in the PYLL domain, in provinces with and without an inclusive trauma system, the top three mechanisms of injury are falls (IPPS 69 and 71 respectively), assault (IPPS 64 and 64 respectively) and motor vehicle collisions (IPPS 63 and 61 respectively).

6.2.2 In-Hospital Injury Prevention Priority Scores

Presented in Table 6.4 are the mechanisms of injury prevention priority scores for in hospital mortality in Canada 2009-2014, segregated by the presence or absence of an inclusive trauma system, adjusted for age and sex. The presence of a trauma system did not influence the ranking order of the top three mechanisms of injury, which were falls, suffocation and drowning.

Chapter Seven: Discussion

This study looked to understand the relative burden of different mechanisms of injury and classify them according to the highest priority for prevention across four domains: mortality, severity, resource utilization and PYLL It also sought to understand the relative burden of mechanisms of injury at the provincial level and within specified age groups.

7.1 Burden of injury

Our results echo the work published by Parachute Canada[20], which identified falls, self-harm and transport incidents as the largest contributors to mortality and falls, with other unintentional injuries and transport incidents as the largest contributors to the hospitalizations injury burden in 2011. Although similar mechanisms are identified as the largest contributors to mortality (falls and self-harm), our work differs from theirs in several ways- first in our exclusion of poisoning, and second in our period of study. Furthermore, the use of IPPS as a novel identifier of mechanisms of injury for prioritization is unique to the current study.

7.1.1 Falls

Although the rankings of IPPS change according to which domain is adopted, falls was consistently the highest ranked mechanism of injury, suggesting that if prevented, it would provide the most benefit to the largest population. This was largely driven by the high frequency of falls in our dataset, at 59.42%. The corresponding Z score for falls frequency was 3.789, well above other Z scores for frequency. This high proportion is similar to the Global Burden of Injuries study by Haagsma et al, where falls occurred at a frequency of 14.6% of outpatient injuries and 36.5% of inpatient injuries[3]. Similarly, in Canada, the 2015 Parachute report on the Cost of Injury showed that Falls were associated with 55.4% of hospitalizations and 25.7% of deaths from traumatic injury[21]. In 2014, 28.7% of Americans over the age of 65 reported falling at least once, with 37.5% of falls requiring medical treatment[129].

Falls, especially in the elderly population, can have devastating consequences. Falls resulting in at least one anatomical injury in the elderly were associated with a 2.2% mortality risk in a large cohort American Study[130]. Furthermore, falls in the elderly were more likely to be associated with bone fractures and death compared to younger controls[131]. In a cohort study of individuals aged over 71, a history of at least one fall in the last three months was associated with a decline in basic and instrumental activities of daily living and an increased risk of nursing home admission[132,133]. In children, falls is the most frequent cause of injury in the United States[134-137]. Falls in children, although rarely fatal[138,139], are associated with significant in-hospital costs and resource utilization[136]. Falls are also associated with an increase in healthcare utilization compared to controls with no fall history[140]. This would explain why falls represent such a large proportion of resource utilization. Considering the higher frequency of falls in the elderly in our sample and the associated median PYLL of 0, it is surprising to see it as the top IPPS of PYLL. However, given the high frequency of falls in our sample, even in the young and middle-age cohorts, the high ranking IPPS is undoubtedly largely driven by frequency.

7.1.2 Self-harm

Self-harm represented the second highest IPPS for mortality. Suicide is responsible for 30,000 deaths annually in the United states and up to 1 million worldwide [3,141,142] and 3,948 in Canada in 2010[21]. Compared to other reports, our study observed a high mortality from self-harm (72%), with most deaths occurring out of hospital (515 in hospital vs 141,330 out of hospital)[21]. 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 [143,144]. Death by self-harm tends to be underreported, likely secondary to the underlying social stigma, and, therefore, our IPPS for Self-harm may be underestimated[145,146]. It is possible that some of the self-harm fatalities are misclassified as non-intentional injuries (such as firearms), thus artificially increasing their respective IPPS and decreasing the self-harm IPPS. The relatively low ranking of self-harm in the severity domain may be explained by the fact that most injuries by self-harm resulted in death outside of hospital, and thus would not be captured in our severity or resource utilization metric. Furthermore, non-fatal suicide attempts are likely to be less severe and therefore less likely to be admitted to hospital, and thus would again not be captured in our dataset. Self-harm was reported as the leading cause of PYLL in the United States[147] and Canada[148]. The relatively lower ranking for PYLL in our study may reflect the exclusion of poisoning or misclassification, similar to the differences seen in mortality measures for suicide.

7.1.3 Drowning

Drowning figured prominently in the IPPS rankings, in third position for mortality and second position for severity domains. With an estimated annual occurrence of 400,000 fatal drownings [149], they represent 6.6% of injuries worldwide[150], represent 3800 deaths annually in the United States, and tend to occur more prominently in younger individuals compared to other mechanisms of injury[151,152]. In 2011, 369 fatal drownings were reported in Canada[21]. 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. It is surprising that drowning does not have a higher ranking on the PYLL domain given its tendency to affect younger populations; however, it does feature above average with an IPPS of 51. In our study, 16.7% of drownings occurred in individuals aged under 20, thus one might suspect that drowning figure more prominently on the IPPS for PYLL. The lower ranking in the societal domain, however, is undoubtedly explained by its low frequency (0.3%) and corresponding Z score for frequency of -0.418.

7.1.4 Suffocation

Suffocation also featured prominently in our results, with the fourth highest IPPS for mortality, third for severity and third for resource utilization. “Foreign body aspiration and foreign body in airway”, a proxy designation for suffocation, represents 2.07% of injuries worldwide in the Global Burden of Disease[150]. The distribution of age of suffocation is bimodal, with peaks in the age groups under 10 years and over 60[153]. In older adults, suffocation is associated with neurological disorders including cerebral infarcts and underlying pulmonary disorders such as neoplasms[154,155]. This may be contributing to the high IPPS in the severity and resource utilization domains. It should be noted that the ICISS for suffocation, however, was not available for a large proportion of the sample (1935 out of 5632, 34.6%) and thus the median ICISS may be less accurate compared to other mechanisms. The analysis was repeated with the missing ICISS and did not alter the rankings in the severity domain.

7.1.5 Assault

Assault was the second highest ranked IPPS for PYLL. Interpersonal violence consists of 8.06% of injuries worldwide as per the Global Burden of Disease study[150]. Our decreased frequency may be from our categorization of mechanism of injury. Unless intent is specifically coded in the admission, individuals may be misclassified into other categories with "undetermined intent" (for example, cut/pierce or firearms). The absence of intent with firearm injuries makes policy design toward limiting firearm injuries difficult, as intentional and unintentional injuries would be subject to very different prevention strategies. The distinction between intentional and unintentional injuries is important for injury prevention policy as they would likely require different prevention initiatives, depending on the intent. Assault tends to affect younger individuals (median age 29), which explains its high ranking in the PYLL domain and relatively low presence in overall mortality domain.

7.1.6 Mechanisms Prominent Across Several Domains

Some mechanisms of injury featured prominently across all domains, such as falls or to a lesser degree motor vehicle collisions, which, although never in the top three ranking, was consistently ranked fourth or fifth. If these mechanisms were prevented, the burden of injury would be decreased across all domains. This is contrasted to mechanisms of injury that feature very prominently in only one domain. For example, self-harm, if prevented, would only significantly impact the mortality domain. This underlines the mouldable interpretations of our data, whereby different mechanisms of injury may become targets for prevention, depending on which domain is under consideration, or if one wishes to address all domains. In such an "all domains" approach, focusing injury prevention on falls and motor vehicle collisions would extract the highest yield as they figure prominently in all domains.

7.2 Provincial variation

As seen in Tables 5.1 and 5.2, the IPPS for severity and resource utilization were similar across provinces. One should be careful prior to translating the displayed results into injury prevention policy as the provincial data is restricted to only a proportion of the Canadian population. Specifically, it only includes hospitalized patients, excludes Quebec and provides an incomplete picture of the burden of traumatic injury at the provincial level. However, our results underline the flexibility of the IPPS. If this were performed on the entire Canadian population, more accurate results could assist policy makers. If some mechanisms are similarly ranked across several provinces, this could invite policy makers to target these at the national level, whereas provinces who strongly differ from the national trends may select not to adopt such initiatives or adapting them to the local need. For example, in our data, the relative consistency of falls, drowning/submersion and suffocation as the top three IPPS for severity may reassure decision makers that national initiatives at reducing these mechanisms would decrease the burden of traumatic injuries across all priority metrics. In contrast, Prince Edward Island displayed a higher IPPS for firearms in the severity and resource utilization domains and the Yukon/Territories display a higher IPPS for legal interventions in the resource utilization domain compared to other provinces. Both of these regions display smaller populations relative to other provinces, and these small numbers may explain the higher variation compared to the national cohort. Alternatively, there may be region specific differences that produce these differing results. Both of these regions could use their provincial level data to accept, reject or adapt national injury prevention policies and initiatives. It should be restated that these observed differences were witnessed on a subset of the cohort (hospitalized injuries, excluding Quebec) and therefore may not be reflective of the variations in all injuries.

Canada is composed of populations with many ethnicities and populations may differ beyond simple geographic changes. Although not possible to distinguish from our data, it would be interesting to assess whether individuals who are First Nations or other ethnicities display different priorities for injury prevention.

7.3 Age-Related Variation

The IPPS were identical across all age groups in the mortality domain and were very similar across the severity domain, with the exception of motor vehicle collisions exceeding suffocation in the middle-aged cohort. In the resource utilization domain, the marked difference in rankings in the young cohort, with cut/pierce/struck by and motor vehicle collisions featuring prominently may suggest a disproportionate cost of these injuries in the young compared to their older counterparts. Falls represented 36% of the injuries in the young cohort, similar to the 34% reported in the United States in 2016 by the National Trauma Bank[156]. The prominence of falls even in the pediatric cohort may appear surprising, however, it is likely explained by the inclusion of sports injuries into the falls mechanism. Finally, the prominence of motor vehicle collisions and assault in the middle-aged cohort in the societal domain is likely a function of frequency, as this age group is more likely to engage in these activities. Similar to the provincial level data, this specific age-group breakdown allows injury prevention policy and initiatives to be appropriately selected, depending on the target population.

7.4 Inclusive Trauma Systems

The presence of an inclusive trauma system did not affect the priority rankings in all four examined domains, including mortality, severity, resource utilization and cost, suggesting that trauma systems do not disproportionately affect one mechanism of injury over another. Furthermore, our results were unchanged when restricted to in-hospital mortality.

Trauma systems have consistently demonstrated a reduction in mortality both in pre and post study designs [88,89,92-94] and comparative studies[96] in the United States. In Canada, trauma systems are associated with a reduced mortality[105,157] and provinces with inclusive trauma systems have an adjusted odds ratio for mortality of 0.93[104]. However, none of these studies examined the differential effect of trauma systems on various mechanisms of injury.

Our study did display higher IPPS for falls in all domains in provinces without an inclusive trauma system compared to the provinces with an inclusive trauma system. This suggests that perhaps trauma systems do have an effect on falls, though it is not significant enough to change the IPPS ranking compared to other mechanisms of injury.

Ontario and New Brunswick were in the process of developing trauma systems during the study period[85], however were not considered to have a fully inclusive trauma system as per the definition by the Trauma Association of Canada[86]. It is possible that the existing trauma system infrastructure, although not fully "inclusive," was sufficient to be equivalent to inclusive trauma systems.

Although there is evidence that trauma systems take approximately 10 years to mature prior to changing mortality outcomes[105,158], this would unlikely affect our results as the provinces in the inclusive trauma system cohort established the trauma systems more than a decade before the study period[119]. Since trauma systems are consistently improving, it is possible that over the study period improvements in trauma care could affect our results, however we do not expect this would have differentially affected the relative priority of mechanisms of injury.

Regional differences in traumatic injury have been described[21,26,80-82] and it can be difficult to distinguish if these are related to the individuals living in the population, from the differences in access to care or from geographical differences. By adjusting our mortality and injury frequency data by age and sex, we adjusted for differences related to host factors. It is possible that geographic, cultural and socioeconomic differences between provinces with and without inclusive trauma systems may have affected our results, however both our cohorts have significant heterogeneity in geography. For example, our inclusive trauma system cohort includes both small (Nova Scotia) and large (Alberta) geographical areas and provinces. As our analysis can only examine the relative contribution of each mechanism of injury, it is impossible to tell from our data if trauma systems reduce the overall burden of injury and in what ways, if any, trauma systems are protective.

7.5 Strengths and Limitations

7.5.1 Strengths

Our study contains many strengths. To our knowledge, it is the first study to examine the relative burden of mechanisms of injury while accounting for both for injury frequency and a secondary metric of interest in Canada. Also, our comprehensive dataset and large population allows a near-complete picture of the Canadian traumatically injured population. Finally, our subgroup analyses allow for adaption of our results at either the provincial or age-group level, providing objective, specific and unique information to policy-makers, researchers and stakeholders in trauma care.

7.5.2 Limitations

7.5.2.1 Administrative Data

As in any study using data that is collected for non-research purposes, several issues around accuracy and bias arise. Re-abstraction studies have demonstrated a 92.8% accuracy of coding for diagnoses in the DAD and an 84.8% accuracy for the most responsible diagnosis[159]. For injuries, the DAD displayed a false positive rate of only 5.5% and a false negative rate of 7.1%[160]. Any error in coding of the most responsible diagnosis could misclassify the mechanism of injury. A 1989 study explored the validity of ICD-9 injury coding and found an overall agreement of over 90% for the first 3 digits of the ICD code and decreased agreement (29-83%) when including the 4th digit[161]. ICD-10 coding is different to ICD-9, however the equivalent of 4th digit in ICD-10 coding would be unlikely to affect our classification, as most classifications are performed on the 3-digit basis. The only exception would be Y35 and Y36, which would be classified according to the 4th digit, as seen in Appendix 1. This minor mechanism (legal interventions) would be unlikely to affect our results substantially. Furthermore, any error in coding for the secondary diagnoses may affect our ICISS calculation.

For mortality data, a diagnosis is required as part of a death certificate. Death certificates, although the main source document used to assess mortality in injury research, may contain categorization errors[162,163] and have higher rates of unspecified injuries[164], which would be coded under the “other” mechanism. This would contribute to our high frequency of “other” mechanism of injury, but would only affect our IPPS if there were a higher proportion of unspecified injuries in one mechanism over another, which is unlikely.

7.5.2.2 Missing Patients

7.5.2.2.1 Quebec

Quebec does not subscribe to the DAD and therefore the hospitalizations for Quebec were not recorded. On the other hand, deaths for Quebec were obtained however from Vital statistics. As such, we are missing the data on non-fatal injuries in Quebec. Our results, therefore, may not apply to the province of Quebec.

7.4.2.2.2 Non-Admitted Patients

An important gap in our cohort are patients that are injured without being admitted to hospital. This would not affect the mortality or PYLL metrics. It would also be conceivable that injuries that do not require admission to hospital are less severe than injuries that do, and that the exclusion of these patients is unlikely to affect our IPPS calculation for severity. Although injuries requiring admission to hospital likely cost more per case compared to injuries not requiring admission, it is theoretically possible that a mechanism of injury not requiring hospitalization occurs at an overwhelming frequency and therefore the associated IPPS for resource utilization would be underestimated in our study.

7.4.2.3 Mechanism of Injury

Although our categorization of mechanisms of injury was based on the validated CDC proposed framework for presenting injury data[118], several adaptations were made. This was partly for logical reasons (for example Transport incidents were divided amongst motor vehicle collisions, motorcycle, pedal cycle and pedestrian incidents) and partly required to ensure confidentiality of the data obtained from Vital Statistics. An example of the latter was combining both injuries from fire and injuries from contact with hot surfaces. Combining mechanisms together would artificially increase the frequency of both while dividing mechanisms would decrease the frequency of each. However, our results did not vary significantly upon combining all traffic injuries, therefore we believe that our categorization was appropriate. As previously mentioned, there is also the possibility of misclassification of mechanisms of injury, specifically around intent. For example, if a gunshot is coded as ICD-10 code X93 "assault with a handgun discharge" the hospitalization would be coded as "assault", however, if it is coded as ICD-10 code Y22 "handgun discharge, undetermined intent" the hospitalization would be coded as "firearm." Some mechanisms, such as self-harm, may be more prone to be misclassified due to the social stigma associated with suicide[165].

7.4.2.4 Errors in Outcome Measurements

Each outcome measurement is associated with a different standard deviation, as seen in Table 9 and 10. For example, fire/flame has the largest standard deviation for both injury severity and resource utilization. The median values of each of severity and resource utilization may therefore be less accurate for fire/flame than for other mechanisms. This is particularly relevant for the calculation of Resource Utilization IPPS, where Fire/Flame has the second highest IPPS.

7.4.2.4.1 Frequency

The frequency of injury was estimated by adding the hospitalizations and the deaths from injury and removing duplicates (in hospital deaths). Whenever adding information from two databases, the errors from each database are at risk of compounding into larger errors. Although diagnosis coding is standardized, should an individual death be coded differently across both databases, the frequency of a specific mechanism may be artificially increased at the expense of another mechanism. Furthermore, if individuals are re-admitted to hospital but incorrectly captured as a repeat admission, the hospitalization would be coded as a repeat event rate for that mechanism of injury.

7.4.2.4.2 Injury Severity

ICISS is a validated method for estimating injury severity; however, it should be noted that it is scaled to mortality rather than morbidity. This is quite common in metrics of injury morbidity. ICISS represents the chances of survival from injury based on empirical data. Although this is assumed as a natural metric of severity, and correlates well with the established Injury Severity Score[45], it may underestimate morbidity when fatality rarely occurs. For example, the diagnosis of lower back pain would rarely be associated with mortality, yet may cause significant morbidity. Furthermore, although the database used included individuals of all ages[44], these SSRs may not be applicable to the age-related subgroups, especially in the pediatric cohort. Finally, some mechanisms of injury, such as suffocation, had a higher proportion of missing ICISS values which may have influenced the validity of the severity domain. The analysis was repeated with inputting the median value of ICISS within the mechanism for the missing ICISS, and this did not alter the results. We therefore believe it is unlikely that this small proportion of missing ICISS influenced our results.

7.4.2.4.3 Resource Utilization

Several sources of error may affect the calculation of resource utilization. The first is the use of the provincial CSHS, which is less precise than regional or hospital level CSHS. We did not have access to the hospital where each individual presented, therefore limiting our ability to use hospital level CSHS. Furthermore, as our interpretations are at the national and provincial levels, using the provincial CSHS allows us to better reflect the national/provincial costs and ensure that they are not affected by location-specific variation. Although repeat hospitalizations were accounted for, we did not incorporate the cost of transfers. Finally, as the CHSHS from 2012-2013 and 2013-2014 were still pending at time of writing, using the values from 2011-2012 for the latter years may be inaccurate. While using the CSHS from the Yukon for the Territories may also be inaccurate, the combined frequency of hospitalizations for Yukon and the Territories is 5.5% of our sample and unlikely to significantly affect our results.

7.4.2.4.4 PYLL

In order to protect individual confidentiality, the results from Vital Statistics are only available as aggregate data in 10-year increments. Vital Statistics employs a system controlled random rounding, whereby each cell is rounded in base 5, with the overall values will remaining rounded to the closest base 5[166]. Because of the small cell sizes for the mortality data, this could have affect our PYLL result. However, our sensitivity analysis displayed the same results as the original cohort, suggesting the rounding did not have a significant contribution. An important additional limitation of our PYLL metric, Potential Years of Life Lost, is that it does not account for non-fatal injury. Another metric such as DALYs could have adapted for this, unfortunately was not available for our study. Therefore, the non-fatal injuries would be under-represented in our PYLL metric vs fatal injuries.

7.4.3 Changes in Hospitalizations over Time

It is theoretically possible that there are trends in hospitalizations over time that may affect our data. For example, if the threshold for hospital admission were to increase over time, we would gradually miss an increasing number of injuries that would be included if they occurred earlier in the study period. This would especially change our results if the thresholds for admission changed non-uniformly for different mechanisms of injury. In Canada the number of hospitalizations for external causes increased from 211,768 in 2004 to 231,596 in 2011[21,26]. Given the increase in hospital admissions and our stable injury rate over time, this is unlikely to have affected our results.

7.4.4 Outdated Data

The data obtained was the most recent years available from the databases, however there are several years between the events reported (2009-2014) and the analysis/reporting. As injury prevention is an ongoing effort, acting on such dated information may be incorrect. However, as data processing and collection systems improve over time, it is conceivable that these data points would be available in near-real time, thus allow injury prevention efforts to be up to date.

7.5 Conclusions

Our study underlined the importance of considering different domains when approaching injury prevention and acquiring data from multiple sources to construct a complete picture of traumatic injury in Canada. Despite significant variations across all domains, falls dominate the burden of traumatic injury overall and by provinces and age groups. This suggests that initiatives at reducing falls and their consequences would produce the most benefit to the largest population in Canada. The relative burden of mechanisms of injury is unequal depending on which domain one wishes to prevent: mortality, severity, resource utilization, or societal cost. Furthermore, there are regional and age-related variations in rankings of priorities for mechanisms of injuries that should also be accounted for when designing injury prevention initiatives. The presence of an inclusive trauma system did not affect the relative burden of the various mechanisms of injury.

To our knowledge, this is the first study that identifies objective rankings for which mechanisms of injury could be prioritized while balancing both frequency of injury and a secondary metric of injury burden. The IPPS methodology allows for objective and empiric identification of the mechanisms of injury associated with the highest burden and allows for flexible interpretations, depending on the ultimate goal of the interpreter. It provides policy makers, researchers and other actors in injury prevention with an objective, empiric and quantitative road map of which injuries and mechanisms within which subgroup to target to provide the most benefit to the largest proportion of Canadians at risk.

Once identified, efforts can be put toward decreasing the frequency and consequences of such mechanisms. These efforts could target all aspects of Haddon's matrix, including pre-event, event and post-event phases. Similarly, interventions could target the host, vehicle/vector and environment. For example, one could decrease the burden of falls with interventions aimed at prevention such as increased safety equipment around order person's homes (pre-event and environment), interventions aimed at mitigating the consequences of a fall such as increasing bone density to prevent fractures (event and host) and finally, interventions such as increased rehabilitation services (post-event).

We believe this study will be a stepping stone toward further injury prevention initiatives and will help reduce the overall burden of injury in the Canadian population.

8.1: Figures

Figure 4.1: Flow Chart of Population Cohort: Traumatically Injured Population in Canada 2009-2014

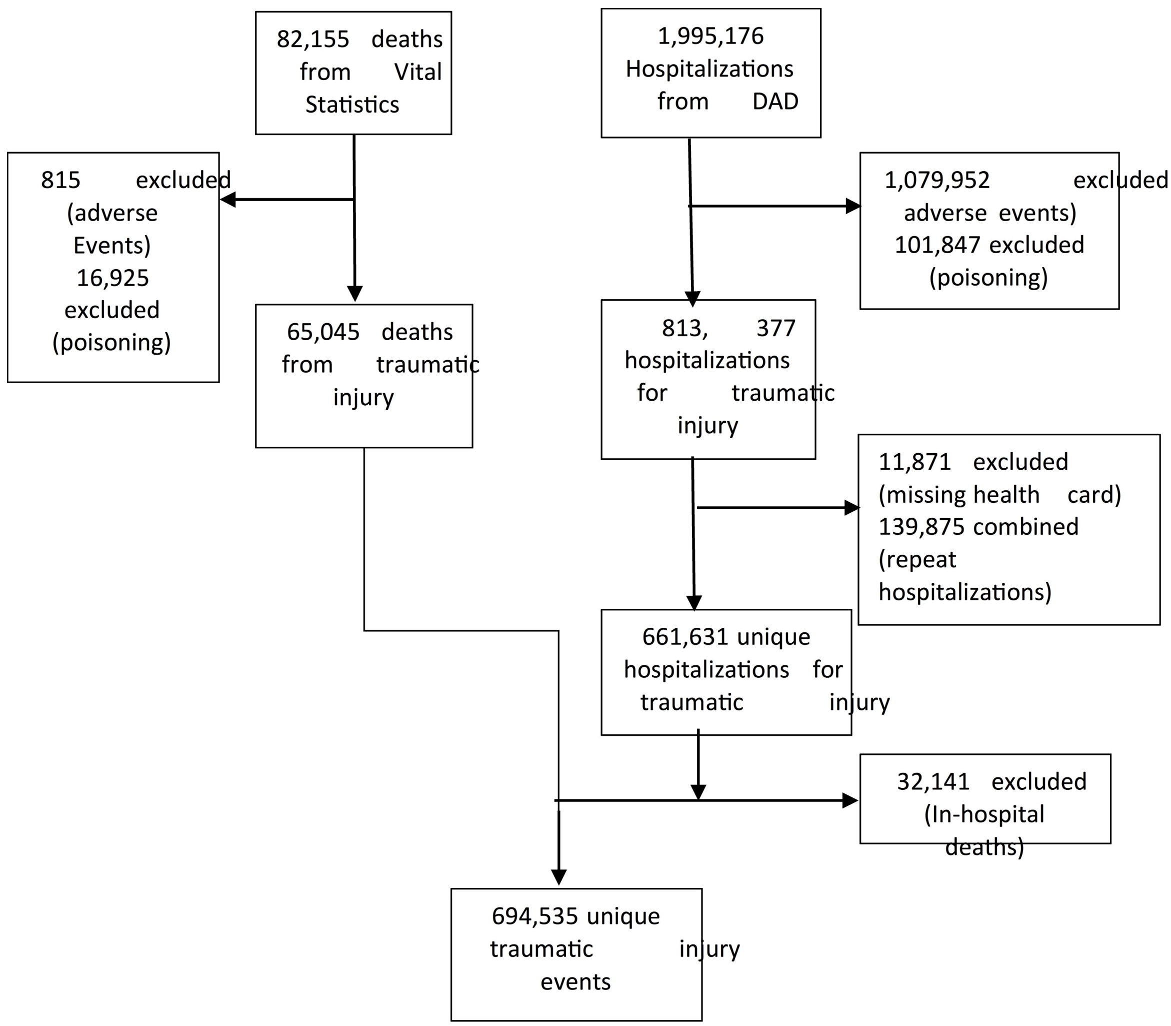


Figure 4.2: Distribution of Mechanisms of Injury in Canada 2009-2014

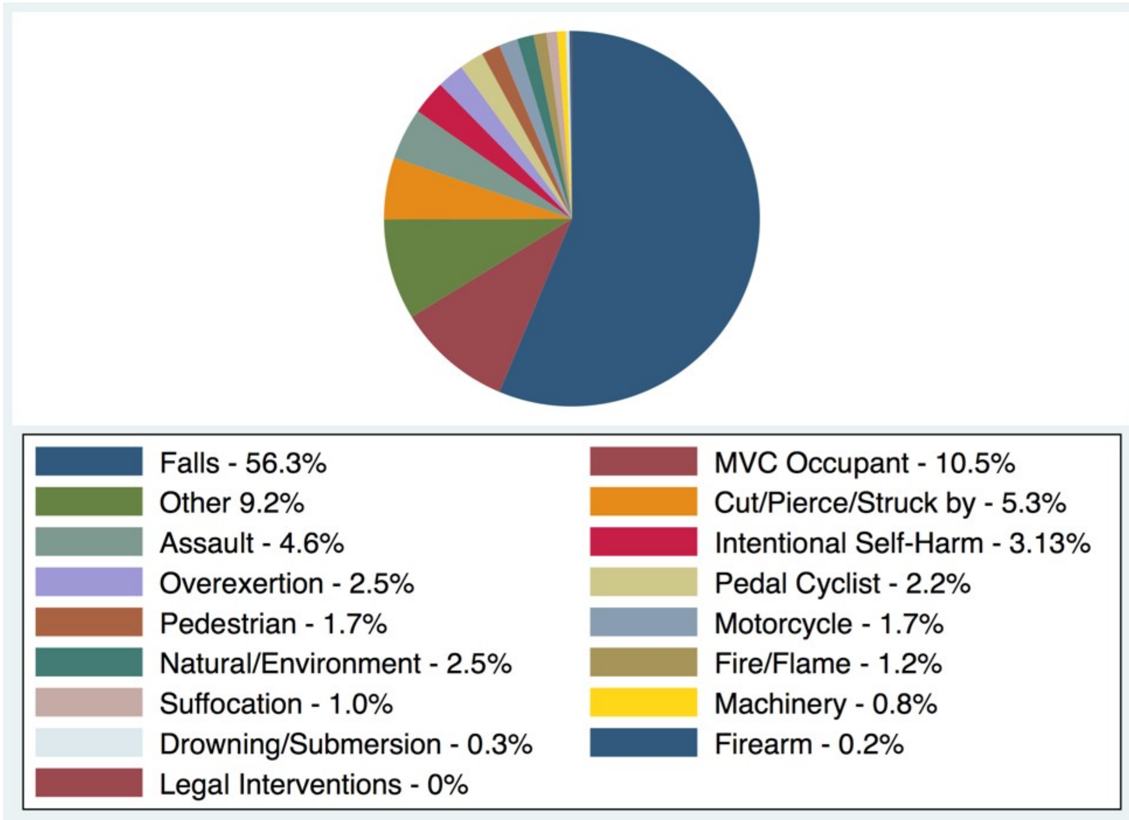
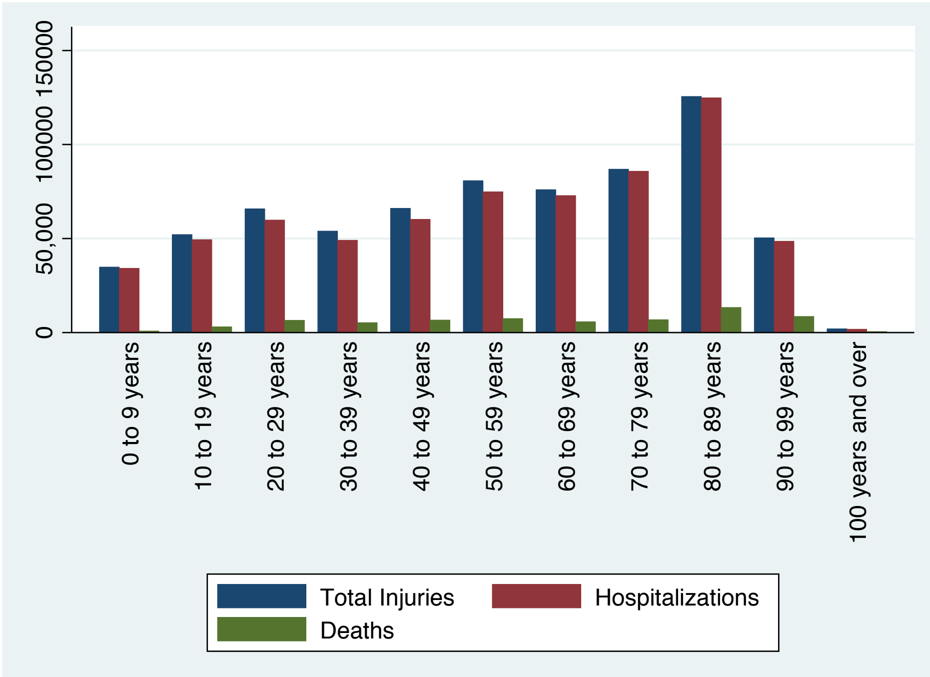


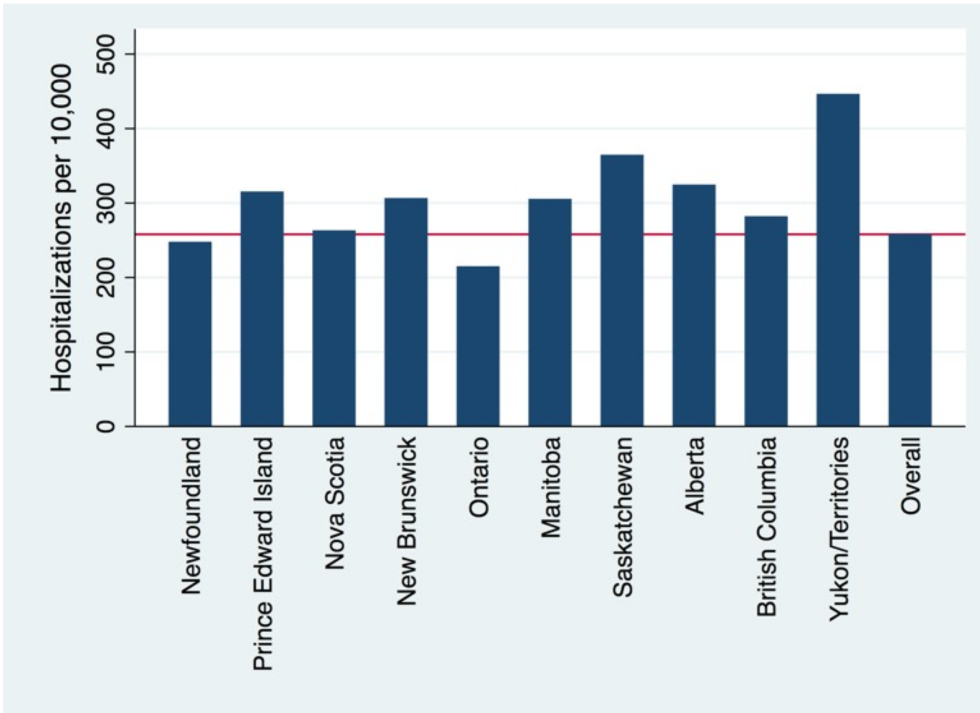
Figure 4.3: Age Distribution of Traumatic Injury in Canada 2009-2014



Total injuries= Hospitalizations + Deaths.

Figure 4.4: Sex Distribution by Mechanism of Injury for Traumatically Injured Population in Canada 2009-2014

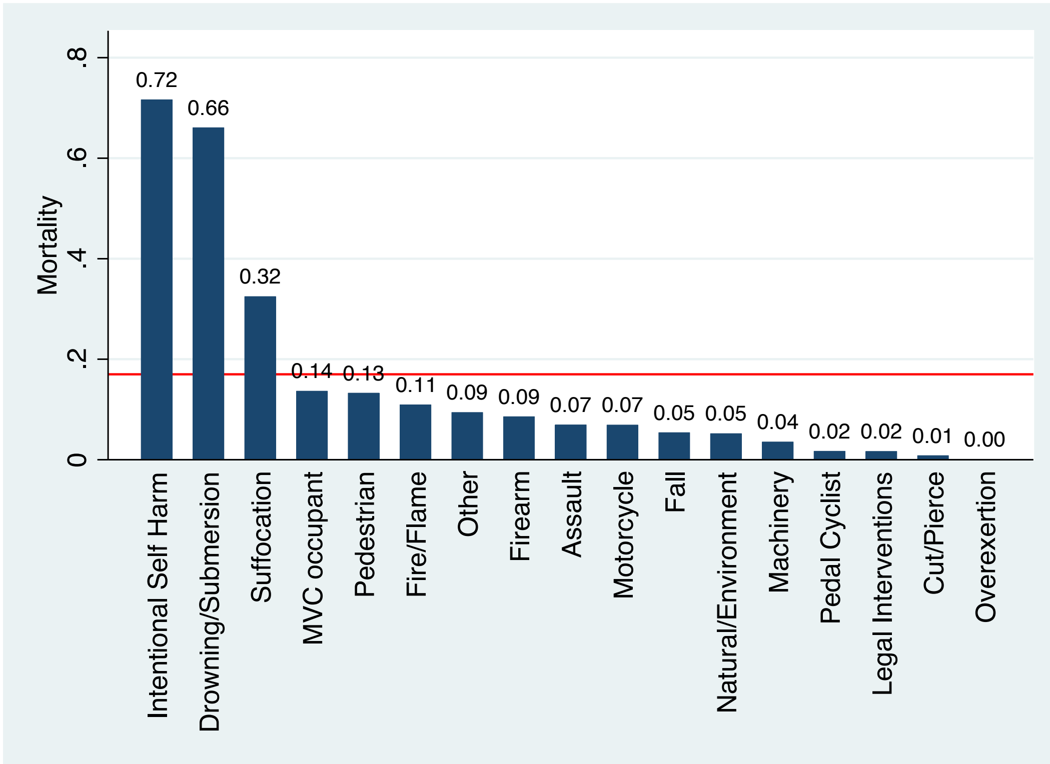
Figure 4.5: Provincial Variation in Rates of Traumatic Injury in Canada 2009-2014



The overall hospitalization rate in Canada (258 hospitalizations per 10,000 people) is presented by the red line.

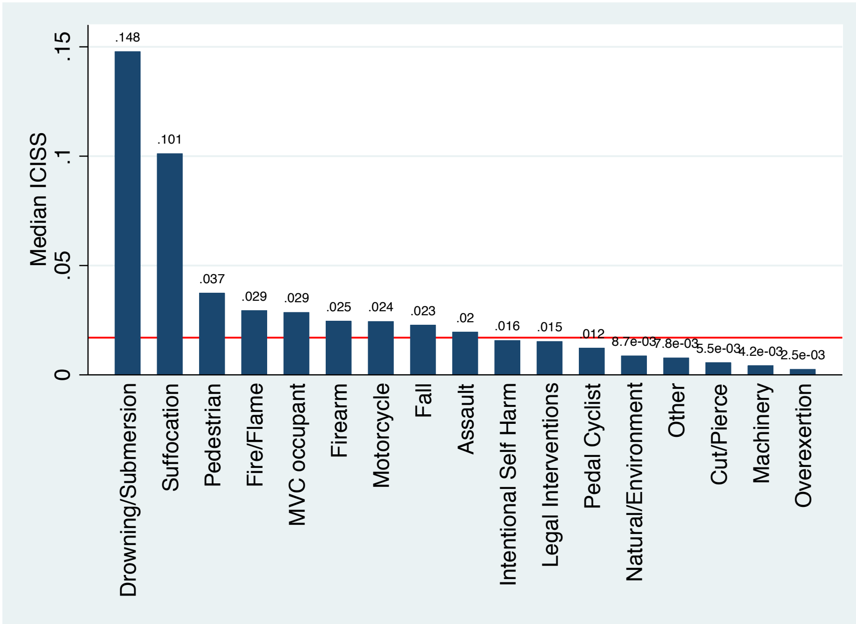
Figure 4.6: Temporal Distribution of Traumatic Injury in Canada 2009-2014

Figure 4.7: Mortality by Mechanism of Injury in Canada 2009-2014



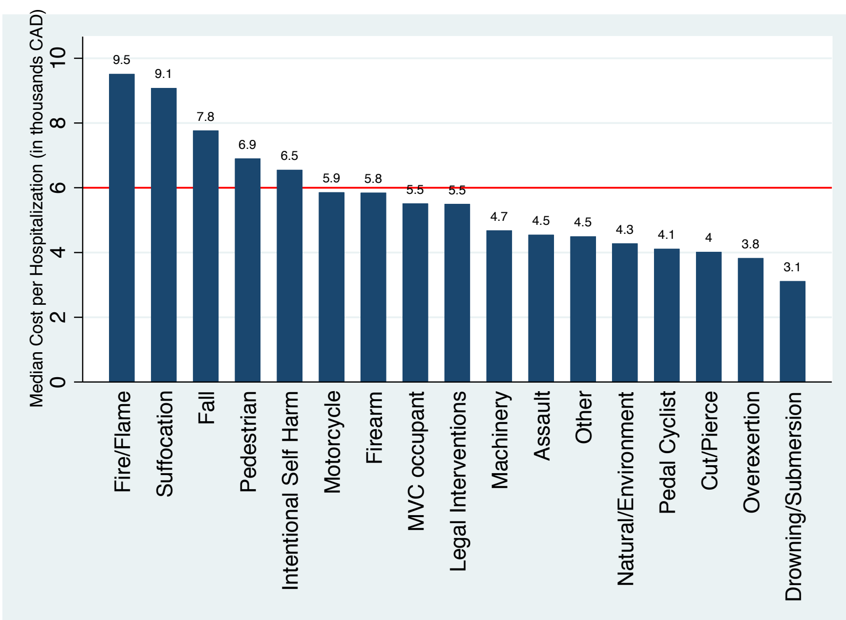
The overall mortality rate for injuries (0.09 deaths per injury) is indicated by the red line.

Figure 4.8: Injury Severity by Mechanism of Injury in Canada 2009-2014



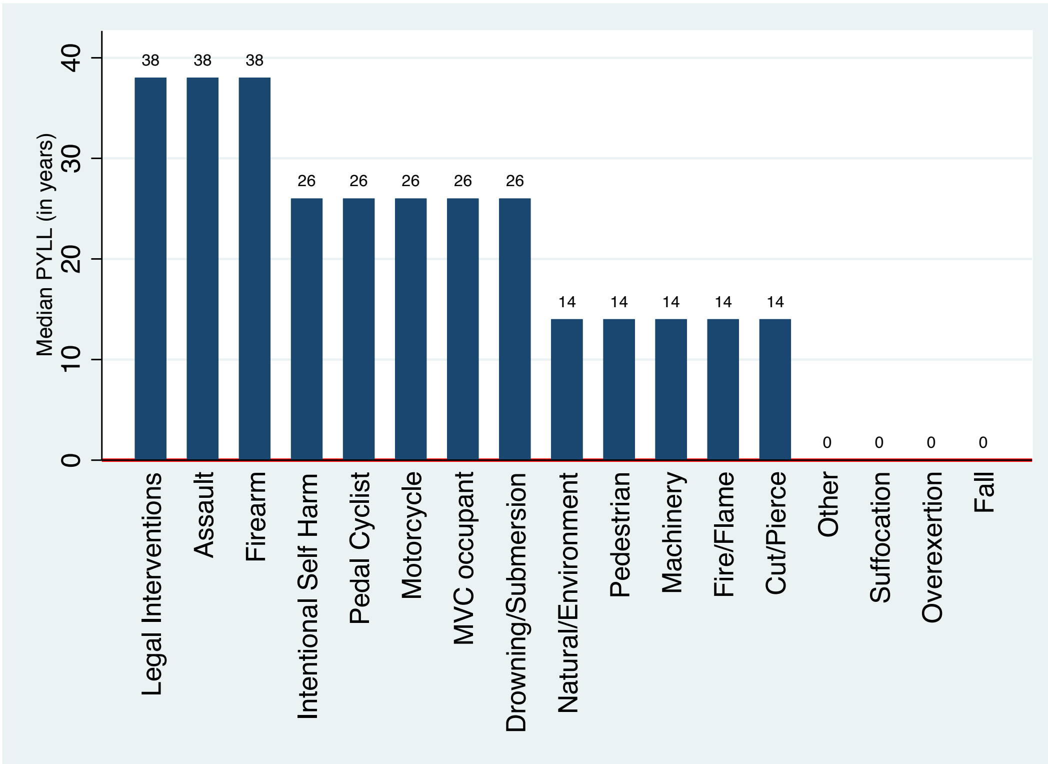
The red line represents the overall median ICISS (0.019) for all injuries.

Figure 4.9: Median Cost per Hospitalization by Mechanism of Injury in Canada 2009-2014



The red line represents the median cost per hospitalization ($6,000) for traumatic injury overall.

Figure 4.10: Median PYLL per Injury by Mechanism in Canada 2009-2014



The median PYLL per mechanism of injury in Canada 2009-2014. The overall median PYLL per injury is 0.

Figure 6.1: Flow Chart of Population Cohort: Traumatically injured Population in Canada 2009-2014 Separated by the Presence or Absence of an Inclusive Trauma system

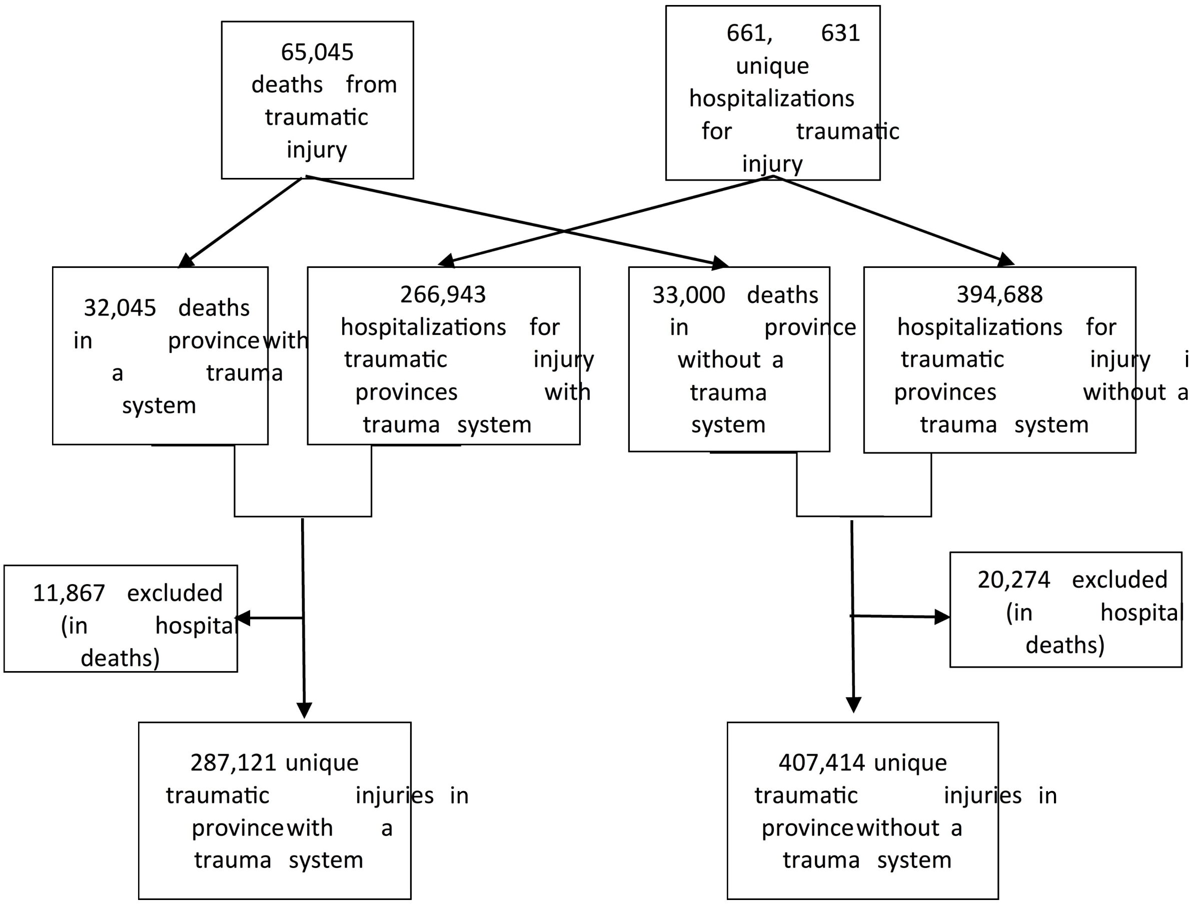


Figure 6.2: Distribution of Mechanisms of Injury by Presence or Absence of an Inclusive Trauma System in Canada 2009-2014

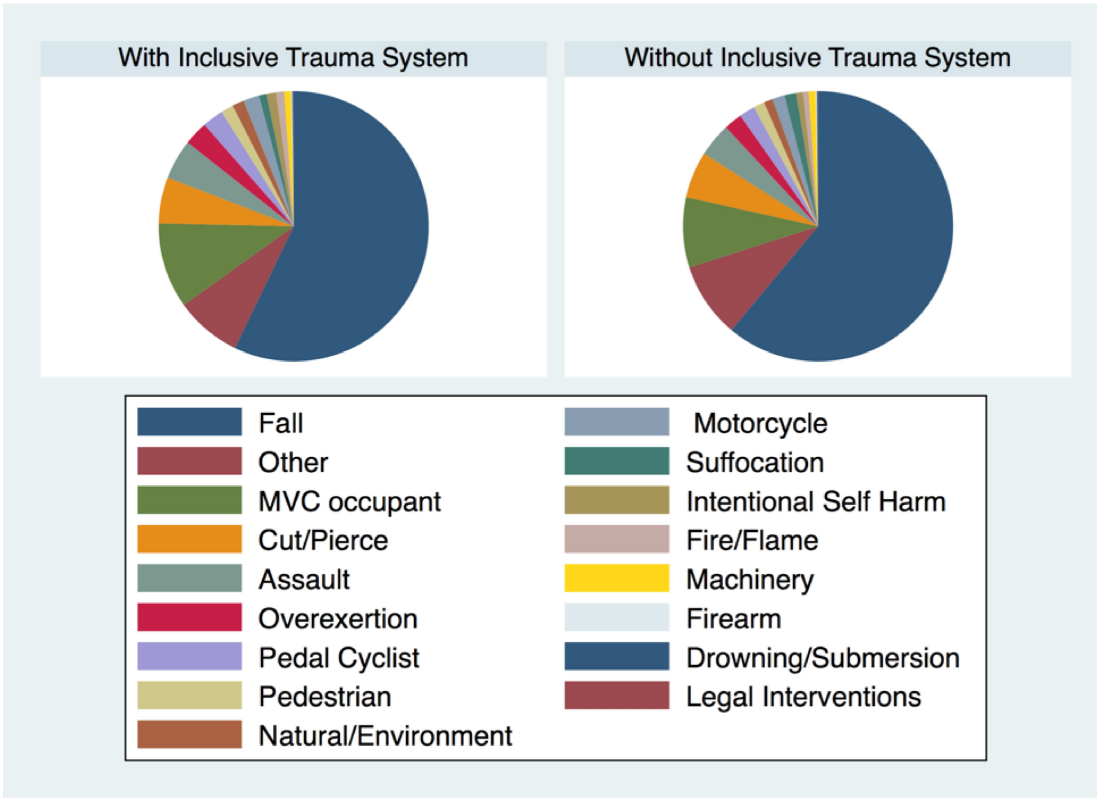


Figure 6.3: Age Distribution of Traumatic Injuries by Presence or Absence of an Inclusive Trauma System in Canada 2009-2014

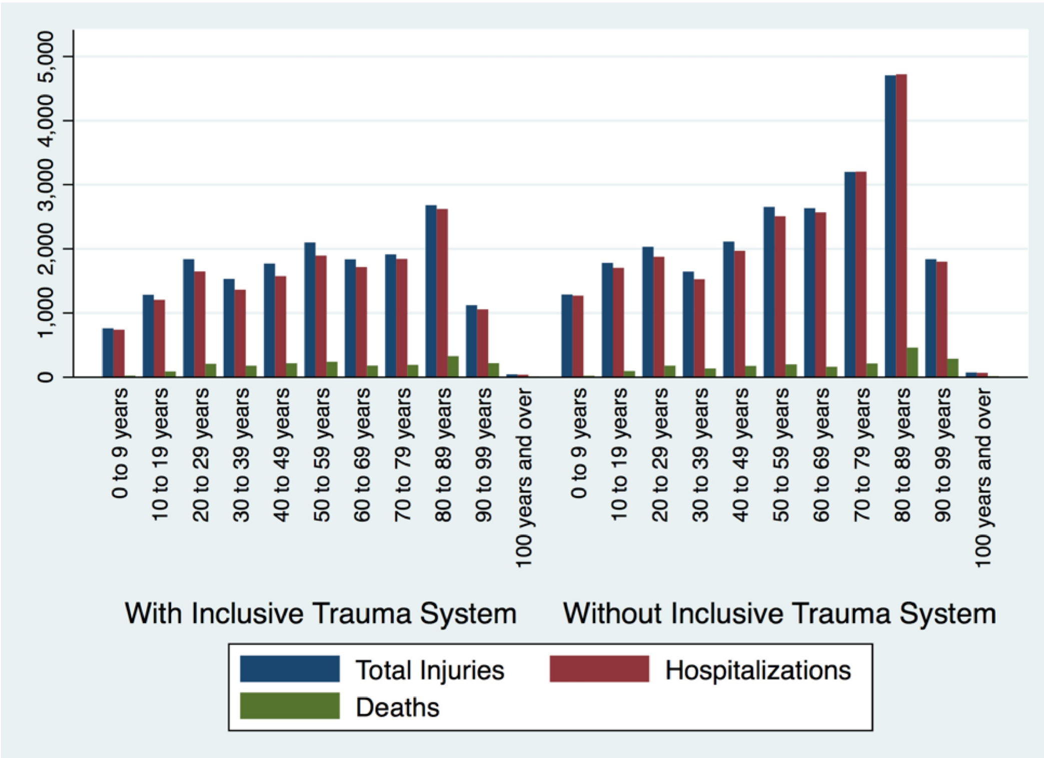
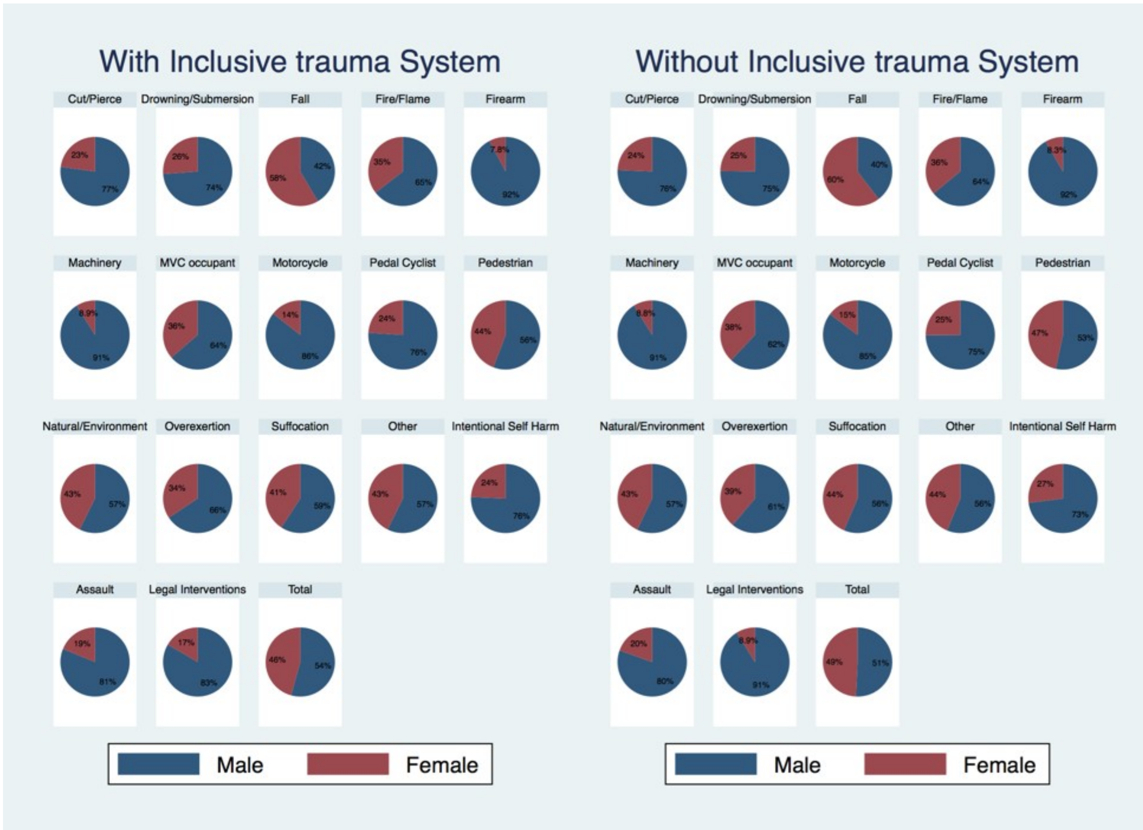


Figure 6.4 Sex Distribution by Presence or Absence of an Inclusive Trauma System and Mechanisms of Injury in Canada 2009-2014



8.2 Tables

Table 2.1: Summary Table of Trauma Metrics

Metric	Definition	Pro	Con
Mortality	Number of deaths related to injury. Can be expressed as crude number or % of population or deaths.	Unambiguous, easily and reliably measured, readily available.	Does not account for non-fatal outcomes. Does not account for disability. No temporal dimension.
PYLL (Potential Years of Life Lost)	Life expectancy – age of death	Unambiguous, easily and reliably measured, readily available.	Does not account for non-fatal outcomes. Does not account for disability.
ISS (Injury Severity Score)	Anatomically based scoring system for injury severity.	Validated and used internationally. Accounts for non-fatal outcomes of injury.	Labour intensive, subjective, no temporal dimension.
Glasgow Coma Scale (GCS)	Score of eye, motor and verbal response	Based on physiological criteria	Subjective, low interrater reliability, non-predictive of mortality
Revised Trauma Score (RTS)	Physiologically based scoring system for injury severity	Predictive of mortality	Controversial ability to predict non-fatal outcomes, not readily available and difficult to calculate, relies on GCS
TRauma and Injury Severity Score (TRISS)	Combined anatomical and physiological scoring system of injury severity	Empirically based, predictive of mortality	Subjective, difficult to measure, not readily available, no temporal dimension.
ICD-10 derived Injury Severity Score (ICISS)	Empirically derived survival probability based on ICD-10 coding	Empirically derived, superior to ISS and TRISS, easily calculated	Dependent on ICD-10 accuracy. No temporal dimension.
DALY (Disability Adjusted Life Years)	Sum of years of life lost secondary to injury and years of life lived with a disability, adjusted for the severity of disability.	Addresses non-fatal outcomes and disability and has temporal dimension.	Not readily available. Relies on social value judgements.
QALY (Quality adjust Life Years)	Number of years lived after injury adjusted for quality of life.	Addresses non-fatal outcomes and disability and has temporal dimension.	Not readily available. Relies on social value judgements.
Direct costs	Total number of healthcare associated charges from injury.	Objective and easy to calculate.	Does not account for all costs associated injury.
Indirect costs	Total cost associated with injury including productivity loss from disability.	Comprehensive.	Difficult to calculate and depends on estimations on future earnings.
IPPS (Injury Prevention Priority Score)	Relative score of mechanisms of injury according to relative frequency and metric of interest.	Objective and quantifiable.	Novel and complex.

Table 2.2: Haddon's Matrix for Prevention of Motor Vehicle Injuries

	Pre-event	Event	Post-Event
Host	Role of alcohol in crash initiation.	The large resistance of the properly packaged human body to crash forces.	Bleeding of damaged people.
Vehicle/Vector	Tire blowouts or other mechanical failures	The susceptibility of fenders and other exterior structures to damage.	Difficulty and cost of vehicle-damage repair.
Environment	Low coefficients of friction on road surfaces/ ineffective police control of speeding.	Trees, ditches, unyielding poles, bridges and other solid structures without interposed guard rails.	Inadequate provision of emergency telephones.

Table 4.1: Summary Statistics by Mechanism of Injury for Calculation of IPPS for Mortality, Severity, Resource Utilization and PYLL by in Canada, 2009-2014

Mechanism	Total Injuries	Mortality	ICISS (Median)	Cost (Median, in CAD$)	PYLL (Median)
Falls	391068	0.055	0.023	7,761	0
MVC occupant	68976	0.143	0.029	5,508	26
Other	60481	0.101	0.008	4,494	0
Cut/Pierce	36916	0.014	0.006	4,013	14
Assault	30802	0.082	0.020	4,544	38
Self-harm	20553	0.722	0.016	6,548	26
Overexertion	16157	0.001	0.003	3,825	0
Pedal Cyclist	14489	0.029	0.012	4,112	26
Pedestrian	11208	0.167	0.037	6,897	14
Motorcycle	11127	0.087	0.024	5,855	26
Natural/Environment	9887	0.078	0.009	4,276	14
Fire/Flame	7706	0.154	0.029	9,511	14
Suffocation	6400	0.370	0.101	9,075	0
Machinery	5138	0.060	0.004	4,675	14
Drowning/Submersion	2214	0.718	0.148	3,113	26
Firearm	1109	0.158	0.025	5,844	38
Legal Interventions	304	0.033	0.015	5,493	38
Mean	40855	0.1748	0.030	5,620	18.47
Standard Deviation	92418	0.2224	0.379	1,833	13.44

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

Table 4.2: Z scores by Mechanism of Injury for Calculation of IPPS for Mortality, Severity, Resource Utilization and PYLL in Canada 2009-2014

Mechanism	Z Frequency	Z Mortality	Z Severity	Z Resources	Z PYLL
Falls	3.789	-0.538	-0.187	1.168	-1.374
MVC occupant	0.304	-0.144	-0.035	-0.061	0.56
Other	0.212	-0.334	-0.583	-0.614	-1.374
Legal Interventions	-0.439	-0.638	-0.385	-0.069	1.453
Firearm	-0.43	-0.077	-0.141	0.122	1.453
Drowning/Submersion	-0.418	2.443	3.117	-1.368	0.56
Machinery	-0.386	-0.515	-0.679	-0.515	-0.333
Suffocation	-0.373	0.879	1.883	1.884	-1.374
Fire/Flame	-0.359	-0.095	-0.011	2.122	-0.333
Natural/Environment	-0.335	-0.434	-0.559	-0.733	-0.333
Motorcycle	-0.322	-0.394	-0.144	0.128	0.56
Pedestrian	-0.321	-0.036	0.198	0.697	-0.333
Pedal Cyclist	-0.285	-0.656	-0.465	-0.823	0.56
Overexertion	-0.267	-0.782	-0.722	-0.979	-1.374
Self-harm	-0.22	2.462	-0.374	0.506	0.56
Assault	-0.109	-0.418	-0.271	-0.587	1.453
Cut/Pierce	-0.043	-0.724	-0.642	-0.877	-0.333

A Z score is calculated by subtracting the mean of a statistic and dividing by the standard deviation. The Z scores for frequency and each domain are then summed, and a new Z-score of the sum is computed to produce the final IPPS.

Table 4.3: Mechanism of Injury Ranking by Injury Prevention Priority Score for Mortality, Severity, Resource Utilization and Cost in Canada 2009-2014

Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL
Falls	75	77	81	72
Self-harm	67	46	52	53
Drowning/Submersion	66	70	39	51
Suffocation	54	61	60	34
MVC occupant	51	52	52	58
Other	49	47	47	40
Pedestrian	47	49	52	44
Fire/Flame	46	47	61	44
Firearm	46	46	48	59
Assault	46	47	46	62
Motorcycle	44	47	49	52
Cut/Pierce	44	45	44	47
Natural/Environment	44	43	43	44
Machinery	43	42	44	44
Pedal Cyclist	43	44	43	52
Overexertion	42	43	42	35
Legal Interventions	42	44	47	59

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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.

Table 4.4: Mechanisms of Injury Prevention Priority Scores for Mortality, Severity, Resource Utilization and Societal cost in Canada 2009-2014 using "Traffic" as mechanism of injury

Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL
Fall	72	74	78	69
Self-harm	65	45	51	53
Drowning/Submersion	64	68	39	51
Suffocation	53	60	58	36
Traffic	52	53	53	60
Other	48	47	47	40
Fire/Flame	46	47	60	44
Firearm	45	45	48	58
Assault	45	47	45	61
Cut/Pierce	43	44	44	47
Natural/Environment	43	43	43	44
Machinery	42	42	44	44
Overexertion	41	42	42	36
Legal Interventions	41	44	47	58

Motor vehicle collisions, pedestrian, motorcycle and pedal cyclist incidents are combined into a single "traffic" mechanism. IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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 higher the priority for injury prevention.

Table 5.1: Mechanism of Injury Prevention Priority Score for Severity by Province for Hospitalized Patients in Canada 2009-2014

Mechanism	CA	NL	PEI	NS	NB	ON	MB	SK	AB	BC	YK/NT
Falls	77	77	75	77	77	77	77	76	76	77	74
Drowning/Submersion	70	70	55	70	71	70	71	70	70	71	70
Suffocation	61	61	50	60	60	61	61	61	61	61	61
MVC occupant	52	52	49	52	53	51	52	54	53	51	54
Pedestrian	49	48	45	48	50	50	48	47	50	49	46
Firearm	47	47	73	48	43	47	47	43	45	46	43
Motorcycle	47	46	45	48	48	47	45	45	46	47	45
Other	47	46	47	46	47	47	47	47	48	46	48
Assault	47	45	44	46	46	47	50	49	48	47	56
Self-harm	46	44	44	45	44	46	44	45	44	44	45
Cut/Pierce	45	44	47	45	45	45	45	46	45	45	45
Pedal Cyclist	44	44	44	44	44	44	44	44	44	46	44
Legal Interventions	44	51	46	43	44	44	44	44	44	44	48
Natural/Environment	43	43	45	44	44	43	44	44	43	43	43
Overexertion	43	42	45	43	43	43	42	43	43	43	41
Machinery	42	42	43	43	43	42	42	43	42	42	40
Fire/Flame	46	48	45	49	49	47	47	48	47	47	46

CA= Canada, NL= Newfoundland, PEI= Prince Edward Island, NS= Nova Scotia, ON= Ontario, MB= Manitoba, SK= Saskatchewan, AB= Alberta, BC= British Columbia, YK/NT= Yukon and Northern Territories. IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 50 are displayed in blue. The IPPS by definition has a mean of 50 and a standard deviation of 10. The higher the higher the priority for injury prevention.

Table 5.2: Mechanism of Injury Prevention Priority Score for Resource Utilization by Province for Hospitalized in Canada 2009-2014

Mechanism	CA	NL	PEI	NS	NB	ON	MB	SK	AB	BC	YK/NT
Falls	72	82	78	82	81	82	83	82	78	82	78
Assault	62	47	46	45	46	45	48	48	46	45	51
Firearm	59	53	72	52	44	49	56	47	46	46	56
Legal Interventions	59	41	39	50	49	47	51	40	46	50	63
MVC occupant	58	51	51	51	53	51	51	54	52	50	54
Self-harm	53	50	48	48	51	52	48	52	48	49	44
Motorcycle	52	47	46	47	50	49	48	49	47	49	44
Pedal Cyclist	52	43	44	41	42	44	43	42	42	44	42
Drowning/Submersion	51	38	43	42	37	38	37	39	41	42	41
Cut/Pierce	47	47	47	44	45	44	44	45	45	44	42
Fire/Flame	44	59	46	57	64	57	57	59	68	61	60
Machinery	44	46	45	46	45	44	43	47	44	43	40
Pedestrian	44	52	47	51	55	53	51	57	52	53	52
Natural/Environment	44	44	45	43	44	43	45	44	44	44	49
Other	40	48	48	47	47	48	48	48	48	47	44
Overexertion	35	45	45	42	43	43	42	44	42	42	43
Suffocation	34	58	47	63	54	60	56	55	61	60	49

CA= Canada, NL= Newfoundland, PEI= Prince Edward Island, NS= Nova Scotia, ON= Ontario, MB= Manitoba, SK= Saskatchewan, AB= Alberta, BC= British Columbia, YK/NT= Yukon and Northern Territories. IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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 higher the priority for injury prevention.

Table 5.3: Summary Statistics by Mechanism of Injury for Calculation of IPPS for Mortality, Severity, Resource Utilization and Societal Cost in Canada 2009-2014 for Individuals Aged 0 to 19 Years Old

Mechanism	Total Injuries	Mortality	ICISS (Median)	Cost per Hospitalization (Median in CAD$)	PYLL (Median)
Fall	31165	0.003	0.005	2755	63
Cut/Pierce	11293	0.004	0.006	3297	76
MVC occupant	10848	0.114	0.024	4293	63
Other	10380	0.007	0.005	2834	63
Assault	5106	0.069	0.018	4304	63
Pedal Cyclist	4444	0.016	0.007	3105	63
Self-harm	2324	0.452	0.010	5974	63
Pedestrian	2185	0.126	0.035	4647	63
Fire/Flame	2051	0.054	0.030	6740	76
Natural/Environment	1981	0.020	0.011	3011	63
Overexertion	1831	0.000	0.003	3731	0
Suffocation	1035	0.208	0.101	4806	76
Motorcycle	1024	0.049	0.016	4282	63
Drowning/Submersion	623	0.425	0.148	1755	76
Machinery	391	0.051	0.004	4179	63
Firearm	285	0.070	0.017	4755	63
Legal Interventions	15	0.000	0.011	4901	0
Mean	5117	0.098	0.026	4080	59
Standard Deviation	7703	0.140	0.039	1233	23

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

Table 5.4: Mechanisms of Injury Prevention Priority Scores for Mortality, Severity, Resource Utilization and Societal Cost for Canadians aged 0 to 19 Years Old 2009-2014

Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL
Fall	72	73	70	73
Self-harm	68	44	60	51
Drowning/Submersion	65	71	28	51
MVC occupant	58	57	60	58
Suffocation	52	61	50	52
Cut/Pierce	51	52	51	60
Other	50	51	47	56
Assault	49	49	52	53
Pedestrian	48	49	51	50
Fire/Flame	44	47	65	52
Pedal Cyclist	44	45	42	52
Firearm	43	43	49	48
Machinery	42	40	45	50
Motorcycle	42	43	47	36
Natural/Environment	42	43	38	36
Overexertion	41	41	43	36
Legal Interventions	39	41	53	35

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 50 are displayed in blue. The higher the IPPS by definition has a mean of 50 and a standard deviation of 10. The IPPS the greater priority for injury prevention.

Table 5.5: Summary Statistics by Mechanism of Injury for Calculation of IPPS for Mortality, Severity, Resource Utilization and Societal Cost in Canada 2009-2014 for Individuals Aged 20 to 59 Years Old

Mechanism	Total Injuries	Mortality	ICISS (Median)	Cost per Hospitalization (Median)	PYLL (Median)
Fall	93073	0.018	0.006	4506	14
MVC occupant	42704	0.141	0.028	5205	38
Other	23978	0.031	0.005	3974	26
Assault	23962	0.078	0.020	4527	38
Cut/Pierce	20135	0.014	0.005	4124	26
Self-harm	14747	0.735	0.018	6548	26
Overexertion	10258	0.000	0.002	3557	14
Motorcycle	8758	0.088	0.024	5827	26
Pedal Cyclist	7953	0.030	0.013	4204	26
Pedestrian	5475	0.152	0.033	6562	26
Natural/Environment	4814	0.083	0.008	4189	26
Fire/Flame	3628	0.145	0.035	10582	26
Machinery	3583	0.049	0.004	4499	26
Suffocation	1549	0.349	0.094	10041	26
Drowning/Submersion	1057	0.847	0.148	4750	26
Firearm	741	0.169	0.028	6596	38
Legal Interventions	266	0.038	0.016	5205	38
Mean	15687	0.174	0.028	5582	27
Standard Deviation	22917	0.248	0.038	2015	7

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

Table 5.6: Mechanisms of Injury Prevention Priority Scores for Mortality, Severity, Resource Utilization and Societal cost for Canadians aged 20-59 Years Old 2009-2014

Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL
Fall	72	73	74	63
Self-harm	68	47	54	48
Drowning/Submersion	67	71	41	43
MVC occupant	58	60	58	72
Suffocation	51	59	63	43
Assault	50	51	49	66
Other	48	48	46	51
Cut/Pierce	46	46	46	50
Pedestrian	46	47	50	45
Fire/Flame	45	47	66	44
Firearm	45	44	49	57
Motorcycle	45	47	48	46
Pedal Cyclist	43	44	41	45
Natural/Environment	43	41	40	44
Machinery	42	40	41	44
Overexertion	42	42	40	32
Legal Interventions	40	42	43	57

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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.

Table 5.7: Summary Statistics by Mechanism of Injury for Calculation of IPPS for Mortality, Severity, Resource Utilization and Societal Cost in Canada 2009-2014 for Individuals Age over 60 Years Old

Mechanism	Total injuries	Mortality	ICISS (Median)	Cost per Hospitalization (Median in CAD$)	PYLL (Median)
Fall	266830	0.074	0.035	10120	0
Other	26123	0.201	0.014	7826	0
MVC occupant	15424	0.166	0.035	7983	0
Cut/Pierce	5488	0.036	0.011	6193	0
Overexertion	4068	0.002	0.006	5597	0
Suffocation	3816	0.423	0.101	10495	0
Pedestrian	3548	0.216	0.046	9726	0
Self-harm	3482	0.850	0.027	9946	0
Natural/Environment	3092	0.108	0.010	6062	0
Pedal Cyclist	2092	0.053	0.035	7208	0
Fire/Flame	2027	0.271	0.025	11594	0
Assault	1734	0.176	0.021	7852	0
Motorcycle	1345	0.112	0.035	7494	0
Machinery	1164	0.099	0.005	5551	0
Drowning/Submersion	534	0.805	0.148	6259	0
Firearm	83	0.361	0.028	5496	0
Legal Interventions	23	0.000	0.007	11250	0
Mean	20051	0.233	0.035	8038	0
Standard Deviation	63931	0.253	0.037	2091	0

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

Table 5.8: Mechanisms of Injury Prevention Priority Scores for Mortality, Severity and Resource Utilization for Canadians aged 60 Years or Older 2009-2014

Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources
Fall	75	78	81
Self-harm	67	47	54
Drowning/Submersion	65	70	43
Suffocation	54	61	56
Firearm	52	47	40
Other	50	47	50
Fire/Flame	49	46	59
MVC occupant	47	50	49
Pedestrian	47	50	53
Assault	46	45	48
Machinery	44	42	41
Motorcycle	44	48	47
Natural/Environment	44	43	42
Cut/Pierce	42	44	43
Pedal Cyclist	42	48	46
Overexertion	41	43	41
Legal Interventions	40	43	58

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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 higher the priority for injury prevention.

Table 6.1: Injury Frequency, Age/Sex Adjusted Injury Frequency, Mortality, Age/Sex Adjusted Mortality, Median ICISS, Median cost per Hospitalization and Median PYLL by Mechanism of Injury in Canada 2009-2014 for Provinces with an Inclusive Trauma System

Mechanism	Injury Frequency	Adjusted Injury Frequency	Mortality (Percent)	Adjusted Mortality (Percent)	ICISS (Median)	Cost per Hospitalization (Median)	PYLL (Median)
Fall	151649	5864.8	0.052	0.029	0.019	7696	0
MVC occupant	32130	1945.9	0.166	0.162	0.027	5617	26
Other	24331	1160.6	0.161	0.065	0.007	4805	0
Cut/Pierce	14874	916.5	0.017	0.016	0.005	4322	14
Assault	13803	895.3	0.089	0.087	0.019	5084	38
Self-harm	11291	712.6	0.749	0.744	0.013	6823	26
Overexertion	7628	460.2	0.001	0.001	0.003	4141	0
Pedal Cyclist	6912	438.7	0.033	0.032	0.012	4272	26
Motorcycle	5643	372.9	0.109	0.108	0.024	6110	26
Pedestrian	4807	270.6	0.199	0.181	0.039	7322	14
Natural/Environment	4073	236.7	0.098	0.095	0.008	4674	14
Fire/Flame	3069	174.7	0.197	0.169	0.030	11795	14
Suffocation	2951	123.6	0.400	0.355	0.101	10507	0
Machinery	2320	144.9	0.075	0.070	0.004	4889	14
Drowning/Submersion	1009	59.3	0.738	0.749	0.148	4096	26
Firearm	462	29.7	0.195	0.192	0.022	5956	26
Legal Interventions	169	11.2	0.059	0.058	0.014	6548	38
Mean	16889	813	0.20	0.18	0.03	6156	17.76
Standard Deviation	35807	1396	0.23	0.23	0.04	2199	12.65

Adjusted injury frequency and adjusted mortality are adjusted for age and sex according to the 2011 Canadian census.

Table 6.2: Injury Frequency, Age/Sex Adjusted Injury Frequency, Mortality, Age/Sex Adjusted Mortality, Median ICISS, Median cost per Hospitalization and Median PYLL by Mechanism of Injury in Canada 2009-2014 for Provinces without an Inclusive Trauma System

Mechanism	Injury Frequency	Adjusted Injury Frequency	Mortality (Percent)	Adjusted Mortality (Percent)	ICISS (Median)	Cost per Hospitalization (Median)	PYLL (Median)
Fall	239419	8448.0	0.057	0.029	0.024	7801	0
MVC occupant	36846	2187.4	0.123	0.119	0.029	5345	26
Other	36150	1777.1	0.060	0.031	0.008	4285	0
Cut/Pierce	22042	1330.8	0.012	0.010	0.006	3781	14
Assault	16999	1096.4	0.076	0.074	0.021	4131	38
Self-harm	9262	582.5	0.690	0.684	0.020	6323	26
Overexertion	8529	489.9	0.001	0.000	0.003	3525	0
Pedal Cyclist	7577	469.6	0.025	0.024	0.012	3836	26
Pedestrian	6401	353.6	0.143	0.135	0.037	6701	14
Natural/Environment	5814	320.9	0.064	0.057	0.009	3987	0
Motorcycle	5484	360.0	0.065	0.064	0.024	5504	26
Fire/Flame	4637	262.8	0.125	0.113	0.029	8382	14
Suffocation	3449	137.8	0.345	0.297	0.101	8300	0
Machinery	2818	175.1	0.048	0.042	0.004	4560	14
Drowning/Submersion	1205	69.0	0.701	0.700	0.148	2486	26
Firearm	647	41.3	0.131	0.129	0.027	5801	38
Legal Interventions	135	8.7	0.000	0.000	0.016	4897	0
Mean	23966	1065	0.16	0.15	0.03	5273	15.41
Standard Deviation	56657	2004	0.22	0.22	0.04	1739	13.73

Each mechanism of injury has a corresponding frequency, adjusted frequency, mortality, adjusted mortality, ICISS, cost per hospitalization and PYLL. The mean and standard deviations of each statistic is summarized in the last two rows of the table. Adjusted injury frequency and adjusted mortality are adjusted for age and sex according to the 2011 Canadian census.

Table 6.3: Age and Sex Adjusted Mechanisms of Injury Prevention Priority Scores for Mortality, Severity, Resource Utilization and Societal cost by Presence or Absence of an Inclusive Trauma System Canada 2009-2014

	With Trauma System				Without trauma System			
Mechanism	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL	IPPS Mortality	IPPS Severity	IPPS Resources	IPPS PYLL
Fall	73	76	79	69	75	77	82	71
Self-harm	69	46	52	55	68	46	52	54
Drowning/Submersion	65	70	40	51	66	70	37	52
MVC occupant	56	56	54	63	53	54	54	61
Suffocation	52	61	60	34	52	61	58	37
Other	48	47	48	40	49	48	49	44
Pedestrian	47	49	51	44	47	49	53	46
Assault	47	48	47	64	47	48	46	64
Fire/Flame	46	47	64	43	46	47	59	46
Firearm	46	44	46	51	45	45	49	59
Cut/Pierce	45	46	45	48	46	46	45	50
Motorcycle	45	47	48	53	44	46	49	53
Natural/Environment	44	43	43	44	44	43	43	38
Pedal Cyclist	43	45	42	53	43	44	43	54
Machinery	42	41	43	43	43	41	45	46
Overexertion	42	43	42	36	42	42	42	38
Legal Interventions	41	42	47	59	40	43	45	37

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 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 the priority for injury prevention.

Table 6.4: Age and Sex adjusted Mechanisms of Injury Prevention Priority Scores for In Hospital Mortality by Presence or Absence of an Inclusive Trauma System in Canada 2009-2014

	With Trauma System	Without Trauma System
Mechanism	IPPS In hospital Mortality	IPPS In hospital Mortality
Fall	77	77
Suffocation	71	70
Drowning/Submersion	59	60
MVC occupant	52	51
Self-harm	51	53
Other	50	51
Firearm	48	45
Assault	47	47
Cut/Pierce	46	46
Pedestrian	46	47
Fire/Flame	45	45
Motorcycle	44	44
Pedal Cyclist	44	44
Natural/Environment	44	44
Overexertion	43	43
Machinery	42	42
Legal Interventions	42	41

IPPS over 80 are displayed in red, over 70 are displayed in orange, over 60 are displayed in yellow and over 50 are displayed in blue. The IPPS by definition has a mean of 50 and a standard deviation of 10. The higher the greater the priority for injury prevention.

Appendix 1: Mechanism of Injury Categorization

Mechanism	ICD code ranges
Cut/Pierce and Struck by or against	W25-W29 Y28 W45-W46 W35.4 W20-W22 W50-W52 Y29 Y35.3
Drowning/Submersion	W65-W75 Y21
falls	W00-W19 Y30-Y31
Fire/Flame and Hot Surface/Substance	X00-X09 Y26 X10-X19 Y27
Firearm	W32-W34 Y22-Y24 Y35.0
Machinery	W24 W30-W31
Motor Vehicle Collision, Occupant	V30-V79 V80-V89 Y85 Y32 V90-V99
Motorcycle	V20-V29
Pedal Cyclist	V10-V19
Pedestrian	V01-V09
Natural/Environment	W42-W43
	W53-W64 W92-W99 X20-X39 X51-X58
Overexertion	X50
Suffocation	W75-W84 Y20

Mechanism	ICD 10 Code range
Other	W23 W35-W41 W44 W49 W85-W91 X58-X59 Y86 Y33 Y89-Y99 Y25 Y87.2 Y34
Intentional Self Harm	X70-X84 Y87.0
Assault	X85-X99 Y00-Y09 Y87.1
Legal Interventions	Y35.7 Y36.3 Y36.1 Y36.2 Y35.6 Y35.4 Y35.1 Y36.9

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