EVALUATING RISK FACTORS FOR MAJOR HEAD INJURIES IN NOVA SCOTIA: A POPULATION-BASED STUDY

by

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Submitted in partial fulfillment of the requirements
for the degree of Master of Science

at

Dalhousie University
Halifax, Nova Scotia
March 2011

DALHOUSIE UNIVERSITY

DEPARTMENT OF COMMUNITY HEALTH AND EPIDEMIOLOGY

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Dated: March 18, 2011

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DALHOUSIE UNIVERSITY

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DEPARTMENT OR SCHOOL: Department of Community Health and Epidemiology

DEGREE: M.Sc. CONVOCATION: May YEAR: 2011

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DEDICATION PAGE

This work is decidated to my father Dipak Chandra Datta who sustained a fatal head injury on January 15^{th}, 1998. You remain always in my heart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Background: Examining factors unique to major head injury (HI) etiogenesis can help reduce the burden of injury by identifying factors amenable to prevention. **Objectives:** To describe the epidemiology of HI in Nova Scotia. Risk and protective factors unique to HI were also examined specific to falls and Motor Vehicle Collision (MVC) injuries. **Methods:** Descriptive analyses and regression models were used to examine the socio-demographic profile of HI and associated risk factors using data from the Nova Scotia Trauma Registry. **Results:** Regression analyses for MVC-related injury found age, injury place, vehicle type and lack of safety restraint to be independently associated with an increased risk of HI. For falls-related injuries, age, time of trauma, injury mechanism and place were significant factors for a HI event. **Conclusion:** While HI share many similar characteristics to other major injuries, prevention programs must be aware of both common and unique risk factors for head injuries.

LIST OF ABBREVIATIONS USED

AIS	Abbreviated Injury Scale
ATV	All-terrain vehicle
BAC	Blood alcohol concentration
CDC	Centers for Disease Control and Prevention
CDS	Comprehensive Data Set
CSR	Child Safety Restraints
CI	Confidence Interval
CIHI	Canadian Institute for Health Information
DDS	Death Data Set
DHA	District Health Authorities
EDH	Epidural hematomas
GCS	Glasgow Coma Scale
HAIS	Head Abbreviated Injury Score
HI	Head Injury
HM	Haddon's Matrix
ICD	International Classification of Disease
ISS	Injury Severity Score
MDS	Minimal Data Set
MVC	Motor vehicle collision
NTR	National Trauma Registry
NSTR	Nova Scotia Trauma Program Registry
OR	Odds Ratio
PYLL	Potential Years of Life Lost
RR	Relative Risk
SES	Socio-economic status
SDH	Subdural hematomas
TBI	Traumatic Brain Injury

ACKNOWLEDGEMENTS

I would like to acknowledge the support, guidance and incredible patience of my supervisors, Dr. Mark Asbridge and Dr. David Clarke, and committee member Dr. John Tallon. A special thank you to Beth Sealy, Nova Scotia Trauma Registry Coordinator, for being instrumental in providing on-going support and guidance throughout this research project.

I would also like to thank my family for being a constant source of support. Finally, my deepest gratitude to my fiancé, Jackson Wong, who never ceased to believe in me and helped carry me through the difficult times.

CHAPTER 1: INTRODUCTION

1.0 Introduction

Injury is one of the most under-recognized public health problems currently faced by Western society (1). In North America, injury remains the leading cause of death for those under the age of forty and the fourth leading cause of death for all ages (2-4). It is estimated that the economic burden of unintentional and intentional injuries combined costs Canadians $19.8 billion yearly. In addition, injury contributes to high levels of morbidity and mortality, placing considerable demands on healthcare services (5,6). Economic estimates have shown that unintentional injuries alone cost Canada more than $8.7 billion per year with falls contributing to the highest direct and indirect costs and motor vehicle collisions having the second highest cost to society and the health care system (7).

Understanding risk and protective factors specific to head-related injuries is an important area of research as these injuries are often more severe compared with other trauma groups and are a significant cause of morbidity and mortality especially in children, youth and the elderly (8-10). From a public health perspective, determining what factors increase or decrease the risk of head injuries when compared to other major trauma groups is useful in developing public health programs aimed to prevent the problem and lessen the likelihood of disability. Moreover, understanding the specific factors associated with head injuries sustained during major causes of injury (falls and motor vehicle collisions) is an important research area to address due to the large number of individuals who incur head injuries every year.

1.1 Study Rationale

Epidemiological studies of head injury exist in Canada (11-17) and abroad (18-25). Canadian studies of head injury have focused primarily on characterizing large but selected groups of patients admitted to hospital (17), a rehabilitation setting (15), and an acute care facility (13). Few studies have utilized population-based approaches to describe major head injuries and only three have done so in Canada (11,12,14). Although the epidemiology of surgically treated acute subdural and epidural hematomas has been previously examined in Nova Scotia (11), no study has comprehensively described the full spectrum of all major head injuries sustained in the province.

Much of the head injury research have focused on two broad areas: 1) studies focusing on the post-injury phase, which are aimed at identifying head injury outcomes (mortality, severity, prognosis, and rehabilitation) and associated factors such as relevant clinical and demographic variables and 2) studies aimed at understanding the pre-injury or injury phase. Fewer studies have looked to examine the risk and protective factors associated with the pre-injury and injury stage, that is, factors occurring before or during the head injury event. Informed by Haddon's Matrix (HM), the focus of this study is to examine the risk and protective factors for head injuries that occur during the pre-injury and injury stages while adjusting for important injury covariates. Examining factors unique to head injury etiogenesis can potentially help reduce the burden of injury by identifying environmental and human factors amenable to prevention.

1.2 Research Questions

There are three main research objectives of this study. A population-based trauma registry that captures all trauma events in the province of Nova Scotia between the periods of April 1st, 2000 to March 31st, 2007, was used to address the following research questions:

1. *What is the epidemiology of major head injuries sustained in Nova Scotia specific to the leading causes of head injury (i.e.: falls, MVCs)?*

2. *Are there pre-injury and injury related risk and protective factors unique to head injuries? Specifically, are characteristics associated with head injuries different from those associated with non-head injuries?*

3. *Are the similarities or differences between head injuries and non-head injuries consistent across different injury mechanism – particularly for falls and MVCs?*

CHAPTER 2: BACKGROUND INFORMATION

2.0 Introduction

The following section defines a number of terms relevant to this research study including definitions pertaining to injury, head injury, major trauma, falls and MVCs. Furthermore, the appropriateness of existing classification systems for identifying and categorizing head injury severity for this research study is explored. The importance of this research project to public health practice is discussed with emphasis on the use of Haddon's Matrix as a theoretical framework for understanding risk factors for injury.

2.1 Injury and Major Trauma Defined

The World Health Organization (WHO) defines injury as:

> "…the physical damage that results when a human body is acutely exposed to physical agents such as mechanical energy, heat, electricity, chemicals, and ionizing radiation interacting with the body in amounts that exceed the threshold of human tolerance. In some cases (e.g.: drowning, strangulation or freezing), injuries result from an insufficiency of a vital element such as oxygen or heat." (26)

The external causes of injuries are often classified as unintentional or intentional. Traffic related injuries, poisonings, falls and burns are categorized as unintentional while injuries related to assaults, self-inflicted violence and war are categorized as intentional injuries (27). Both unintentional and intentional injuries are amenable to preventative interventions and were therefore the focus of this research study.

The Injury Severity Score (ISS) is a scoring system that summarizes the extent of injury at different anatomical sites in a trauma patient (28). Based on the Abbreviated

Injury Scales (AIS), the ISS is a single number that is calculated by summing the squares of the grades of injury in each of the 3 most severely injured areas, to a maximum score of 75. The ISS has been widely used in research to evaluate and compare the injury severity of patient populations as well as its role in predicting patient outcomes post-injury (29-33). The Canadian Institute of Health Information (CIHI), National Trauma Registry (NTR) defines major trauma as "injury resulting from the transfer of energy (e.g.: kinetic, thermal) with an ISS greater than 12 and an appropriate International Classification of Disease (ICD) external cause of injury (E-Code)" (34). All 23 trauma centres in Canada that provide data to the NTR have adopted this working definition of "major trauma" in order to provide consistent data collection and reporting (35). The Nova Scotia Trauma Program's Registry (NSTR) captures blunt traumas with an ISS ≥ 12 as well as penetrating injuries with an ISS ≥ 9 (36).

Traumatic injuries can also be categorized as blunt trauma and penetrating trauma. Blunt trauma is the result of force (or energy transmission) from an object making contact with the body (37). Motor vehicle collisions and falls are examples of these types of major injuries. Conversely, penetrating traumas cause injury from objects that pierce and penetrate the surface of the body causing damage to soft tissues, internal organs and body cavities (37). Injuries from gunshot wounds and stabbings are examples of penetrating traumas.

This thesis defines trauma based on the criteria used by the CIHI, National Trauma Registry (NTR) which states that a trauma is an "injury resulting from the transfer of energy e.g. kinetic, thermal with an ISS score greater than 12 and an appropriate ICD External Cause of Injury Code." The NSTR defines blunt trauma based on the above definition and an ISS $\geq$ 12. A variation is given for penetrating trauma as defined by an associated ISS score of 9 or greater. Under these definitions, injuries resulting from drownings, hangings, suffocations and asphyxias are currently excluded unless they have an anatomic lesion meeting the ISS criteria. Inclusion and exclusion criterion for the NSTPR major injury dataset are detailed in Appendix 6.

The study sample for the first research objective included traumas sustained in Nova Scotia regardless of a patient's clinical outcome post-injury. This included traumas resulting in immediate death on scene or deaths on arrival at the emergency department as well as traumas requiring hospitalization. Blunt and penetrating traumas were included in the analysis but reported separately when appropriate. The study's exclusion criteria included traumas sustained outside the province of Nova Scotia as well as traumas related to burns, drownings, or of unknown mechanism of injury.

The study sample to address the second and third research objectives were the same as above, however penetrating traumas were excluded from analyses. The mechanisms and type of injury sustained during these types of traumas have unique risk factor profiles and are therefore systematically different from blunt traumas. Similar exclusions have been reported in previous studies (38-40).

2.2 Head Injury Defined

Several terms are used in the literature to describe head injuries including: brain injury, head trauma and traumatic brain injury (TBI). The parameters by which these terms are defined vary greatly and can often lead to the characterization of very different types of head injuries. For example, many studies have investigated risk factors particular to TBI—a specific and clinically defined group of head injured patients. For some studies, the case definition of a head injured patient allows for the inclusion of non-neurological head injuries such as fractures of the skull or face and damage to soft tissues of the head or face (19,24,41,42). In still other studies, immediate death occurring at the scene or death on arrival at the emergency department are excluded from analysis (43). Another problem evident in the research is that different criteria are used to make group comparisons such as the utilization of patients with violent versus nonviolent injury, those with intentional versus unintentional injury and those with penetrating versus blunt injury. It should be noted that many sub-classifications of the term *head injury* exist including a grading of mild, moderate and severe based on level of consciousness, post-traumatic amnesia and change in cognitive abilities (44). Given the diversity in terms used, it is important to be cognizant of the heterogeneity of studies related to head injury and the difficulties that arise in making direct comparisons (45).

In response to the varied case definitions used in the literature, the Centres for Disease Control (CDC) published guidelines in 1995 for the classification of central nervous system injury. However, the definition is specific to traumatic brain injury. According to the CDC, TBI is defined as:

> "an occurrence of injury to the head (arising from blunt or penetrating trauma or from acceleration-deceleration forces) that is associated with symptoms or signs attributable to the injury: decreased level of consciousness, amnesia, other neurological or neuropsychological abnormalities, skull fracture, diagnosed intracranial lesions or death. (46)"

For the purposes of this research study, head injuries were defined as all serious head injuries with an associated AIS of ≥ 3 for the head (neck excluded). Under this definition, non-neurological injuries such as a broken nose, fractured jaw, or lacerated cheek were not considered as a severe head injury event. Head injuries were identified using the International Classification of Diseases Codes (ICD-9 and ICD-10) (see Appendix 7). Use of the ICD codes and the AIS classification system has been widely used in epidemiological studies of head injury (29-33).

2.3 Classification of Head Injuries

Although there exist many classification schemes to describe head injuries, there is no universally accepted system. The literature includes classifications by level of severity, level of consciousness, mental status following head injury, or location of body injury (47). All existing classification systems have their limitations (47). This section briefly considers three measurement scales important for this research study: the Glasgow Coma Scale (GCS), the AIS and the ISS. Appropriate uses of these classification systems specific to this research study are explored.

2.3.1 The Glasgow Coma Scale (GCS)

The GCS is a standard clinical assessment tool used to evaluate and describe the degree of altered consciousness in head injured patients. Developed by Teasdale and Jennet in 1974, this tool has since been validated in many studies (32,48-52). The scale provides an objective measurement tool to numerically code the severity of head injury based on three separate components: eye opening, verbal response, and motor response (53). The total of the three scores can range from 3 to 15 with a score of less than 8 indicative of a coma (54). A patient who is unresponsive to painful stimuli, does not open eyes and has complete muscular flaccidity scores 3 on the scale. Conversely, a patient who is oriented, opens their eyes spontaneously and follows commands is given a score of 15 (53).

The GCS is a prognostic indicator of injury and is commonly used during the initial assessment of severity (44). It is often difficult to ascertain from studies whether the GCS was administered at the scene of the injury, during emergency transport or on arrival at the hospital (44). This time of assessment information is essential for proper comparison of research findings. Furthermore, the scoring of GCS is based on the patient's ability to respond and to communicate; hence there are certain instances that may render the GCS invalid. This includes difficulties applying the GCS to young children, intubated patients, and those with language difficulties or impairments. In addition, patients with significant facial swelling from blunt trauma, as well as patients under the influence of alcohol or other substances may further invalidate (or restrict) GCS measurements (44). It is therefore anticipated that reliance on this measurement tool may unnecessarily include or exclude patients intubated at the scene and traumas involving alcohol and other drugs.

2.3.2 The Abbreviated Injury Scale (AIS)

The AIS is primarily an anatomical scoring system that uses a simple numerical method for ranking and comparing injuries by severity in seven body regions – head and neck, face, chest and thorax, abdomen, extremities, external/burns (55). The AIS uses an ordinal scale of increasing severity from 0 (normal) to 6 (lethal). An AIS score of 1 reflects a minor injury, 5 a severe injury and 6 an unsurvivable injury (55) (See Appendix

1). The AIS will be used in this study to identify relevant head injured cases by selecting patients with an AIS of ≥ 3 for the head (neck excluded).

2.3.3 Injury Severity Score (ISS)

Originally developed in 1974 by Baker and colleagues to evaluate motor vehicle victims with multiple injuries, the ISS is a composite measure of the AIS and is the most widely used anatomical trauma scoring systems (28,56). The ISS is calculated by summing the squares of the highest AIS grade in each of the three most severely injured anatomic areas with a score ranging from 0 to 75 (28) (See Appendix 2). An injury with an AIS of 6 (unsurvivable injury) is automatically given an ISS score of 75. A large body of literature has demonstrated the use of this index as an important retrospective tool for epidemiologic studies as it correlates well with mortality, morbidity and other measures of severity (29-33).

The AIS and ISS scales are ideal measures for this study as they serve as a reference point for the comparison of trauma patients. The AIS scale allows for the identification of relevant cases as this measure permits the anatomical selection of head injured patients from the NSTR. Hence, this study selected head injured patients with an AIS ≥ 3 as this arithmetically defines severe head injuries. The ISS is a measure that includes additional information about the extent of injury to other anatomical sites and therefore is an ideal tool to ensure cases and controls are similar with respect to the degree of injury severity.

2.4 Falls Defined

For the purposes of this research project, falls are defined as: “a sudden, unintentional change in position which causes an individual to land at a lower level, on an object, the floor or the ground, other than as a consequence of sudden onset of paralysis, epileptic seizure or overwhelming external force” which is the definition developed by Tinetti and colleagues (57). The NSTR distinguishes falls according to the following categories: a) fall on the same level; b) fall less than 1 meter (3.3 ft); c) fall 1 to 6 meters (3.3 – 19.7 feet); and d) falls greater than 6 meters (19.7).

2.5 Motor Vehicle Collisions Defined

For the purpose of the proposed research, a motor vehicle collision (MVC) is defined as any off-road or on-road vehicle involving injury. The NSTR categorizes MVC injuries based on type of vehicle involved at the time of the collision. Types of vehicles to be included in this study include the following: Passenger vehicles, Motorcycles, Bus, Heavy trucks (>Half ton), Light trucks (vans, pickup trucks, Sport Utility Vehicle), Transport trucks, Logging Trucks, All-Terrain Vehicles (ATVs), recreational vehicles, snowmobiles, and tractors. The definition also includes major traumas sustained by pedestrians involved in a collision with a motor vehicle.

2.6 Injury and Public Health

The traditional view of injuries as "accidents" or random events has resulted in the historical neglect of this important area of public health. Health care systems have often been structured to allocate a significant amount of resources towards the treatment of injuries rather than towards their prevention. It is only recently that injuries have been conceptualized as predictable and as such amenable to study within populations for the purposes of injury prevention (58).

The evaluation of many public health interventions has enabled a greater understanding of the unique role of prevention efforts in reducing the burden of injury. For example, it has been demonstrated that pediatricians who administer injury prevention counseling to families with children younger than 4 years can result in a 13 to 1 benefit cost-ratio (59). Similarly, one study determined that for every dollar spent on bicycle helmets in children aged 4 to 15, there is a savings of $2 for direct medical costs, $6 in future earnings and $17 in quality of life (60). Finally, the use of seatbelts and air bags has been estimated to result in a combined 80% reduction in motor vehicle injuries (61). Prevention can therefore play a key role in reducing morbidity and mortality related to head injury events.

2.6.1 The Burden of Injury

Fatal and nonfatal injuries are often graphically depicted in the form of an "injury pyramid", an adaptation of the work conducted in the 1930s by Heinrich (62). As one moves down the pyramid, an increase in the number of injuries resulting in fatalities, hospital admissions, and emergency department visits is observed. Injuries not requiring formal medical treatment are the most numerous and form the foundation of the injury pyramid. Lack of information about ambulatory, emergency department visits and injuries not requiring formal medical care have lead to erroneous estimates of the total burden of injury (4). It is therefore important to acknowledge that the full burden of injuries is missed when mortalities and severe injuries alone are studied (63).

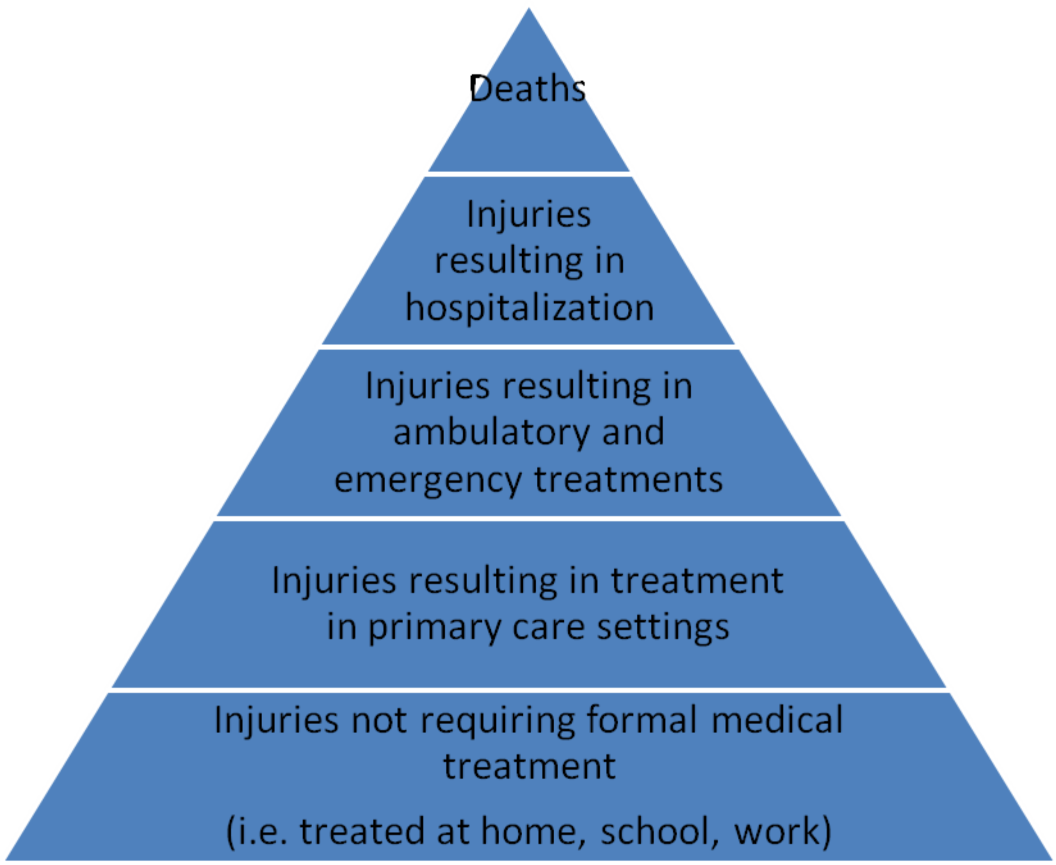


Figure 1: The Injury Pyramid

2.6.2 Injury Control Theory

Until recently, injuries were commonly referred to as “accidents” - events perceived to be related to human error or misaction (64,65). Early advocates struggling to bring injury control into the public health domain identified the common use of the word as a major barrier. The word accident has recently been discouraged in the health literature as it implies that all persons have equal probability of sustaining injury that is unexpected or unforeseen (66,67). The word also implies a high degree of randomness and lack of predictability. The application of scientific study for the prevention of injuries has helped to dispel the myth of “randomness” of injuries by identifying risk or protective factors that elevate or reduce the likelihood of sustaining an injury event (65). In fact, the importance of identifying risk and protective factors is critical to understanding the most appropriate interventions that can be instrumental in reducing the incidence or severity of injuries (68).

2.6.3 Haddon’s Matrix (HM)

The notion of studying injury in the same fashion as infectious diseases was first described by John Gordon, a mid-19th century epidemiologist. His work investigated patterns of injury according to such factors as age, place, and time which assisted in promoting the understanding of injury events as non-random occurrences (69). Haddon later expanded on this work by developing a conceptual model, the Haddon matrix, for describing the origins of injury and associated factors (70).

Haddon’s matrix (HM) is arguably one of the most important models used in injury control (58). Under this framework, variables relevant to injury aetiology and prevention are measured as they relate to both the epidemiological triad (host, agent and environment) and the time of the event (pre-injury, injury and post-injury) (71). Factors related to injury are then visualized using a table in which each cell represents components related to both the epidemiological triad and the temporality of the injury event (see table below). The three temporal dimensions (pre-event, event, post-event) each provide different windows of opportunity to intervene and to prevent primary and secondary injury (68). Use of this model helped shift injury prevention efforts that focused on changing individual behaviour towards efforts aimed to address the agent (for example, the motor vehicle) and the environment (for example, highway design).

Although HM was conceptualized as an approach in the prevention of motor vehicle injury, it has become a model for the prevention of many types of injuries. Using pedestrian injury as an example, factors identified in the matrix could include human characteristics (the use of devices that can distract pedestrians), agent characteristics (vehicle speed), environment (absence of sidewalks) and sociological factors (posted speed limits). Opportunities to prevent morbidity and mortality can be present at one or more of the three different time intervals: before, during and following an injurious event. Appendix 3 details relevant pre-injury and injury related risk factors specific to falls and MVC-related injury. The strength of the model is the ability to include the time element of an injury that effectively conceptualizes the event as both predictable and preventable (58). The matrix has also helped to define the role of trauma care teams and emergency medical services, largely in the prevention of secondary effects of injury during medical care (64,65).

Epidemiological Dimension					
		Human Factors	**Agent of Vehicle**	**Physical Environment**	**Socio-cultural environment**
Event Dimension	**Pre-event**	Alcohol Use Drug Use Use of distracting devices (cell phones, ipods, video games)	Speeding vehicle	Intersection with poor lighting Availability of sidewalks	Low rate of enforcement of yield laws
	Event	Comorbidies (e.g. diabetes, osteoporosis)	Direction of impact Size of vehicle	Road surface characteristics	Speed limits
	Post-event	Comorbidies (e.g. diabetes, osteoporosis)		Distance to trauma and facility	Regionalized trauma centre

Figure 2: Haddon’s Matrix Applied to Pedestrian Injuries

2.6.4 The Three Es of Injury Prevention

A second paradigm in the field of injury control is the concept that the most powerful interventions integrate three Es of injury prevention: Education, Enforcement and Engineering. It is recognized that the most effective strategies use a comprehensive approach including a combination of educational strategies (at the individual or community level), enforcement laws to reinforce the desired behavior change, and the use of engineering technical interventions (64). Examples of successful injury control programs that have utilized a combination of education, enforcement and engineering strategies include mandatory motorcycle helmet use laws and interventions pertaining to safety restraints.

2.6.5 Shifting Paradigms of Injury Control

There is overwhelming epidemiological evidence that injury control efforts such as motorcycle helmet regulations can drastically decrease a motorcyclist's risk of death or severe injury (72). Yet, concerns about infringement of individual liberties and criticisms that such policies rest on paternalistic values have set the stage for repeals of compulsory helmet laws for adults in many jurisdictions (72). In 2007, only 20 states in the United States required all riders to wear helmets (73). This contrasts dramatically with legislation 30 years ago when 47 states had passed mandatory helmet laws that applied to all riders (74). Not surprisingly, the consequences of these repeals have resulted in observed increases of fatalities among non-helmet wearing motorcyclist (72,75). The experience of helmet law repeals in the United States illustrates the profound impact of attitudes pertaining to individual rights and the crippling impact these perceptions can have on healthy public policies.

CHAPTER 3: LITERATURE REVIEW

A literature review was conducted for the purpose of describing the epidemiology of head injuries in Canadian populations and serving as a contextual framework for the leading causes of head injuries. Furthermore, empirical evidence pertaining to major predictors of head injuries were explored in order to serve as a guide for the inclusion of relevant study variables. This section presents the major findings from the literature review with emphasis on the existing gaps in the research.

3.1 Epidemiology of head injuries in Canada

Traumatic injuries are the leading cause of death for Canadians under the age of 45, contributing to more potential years of lost life (PYLL) than any other disease process including cardiovascular disease and cancer (36). Published incidence rates of blunt head injuries from U.S. samples range from 180 to 444 per 100 000 population (22,76). In Canada, approximately 17,000 patients are admitted to hospital with a head injury every year (77).

The societal costs of disability following injury can be substantial with both direct and indirect costs estimated at over $14 billion nationally (63). Head injuries are a major component of trauma and are one of the most common causes of neurologic mortality and morbidity in adults younger than 50 years of age (78). To establish the burden of injury, it is essential to understand the risk factors by which traumatic head injuries are sustained and the populations most at risk for injury.

3.1.1 Profile of Head Injury Hospitalizations

Data from the CIHI indicate that 9% of all trauma admissions were related to head injuries during the year 2003-2004. This represents a total of 46 admissions every day in Canada for major head injuries (77). Of these admissions, 91% were diagnosed with a traumatic brain injury, a clinically more severe form of head injury (77).

Head injuries pose a significant threat to the health and well-being of Canadians throughout the life cycle. National estimates indicate that head injuries are highest among children and youth (aged 0-19) with a hospitalization rate of 30%. Head injury rates are almost as high for the elderly (aged 60 and older), with a 29% hospitalization rate (77). Furthermore, deaths related to head injury accounted for 8% of all head injury admissions during the period of 2003 to 2004 with the majority occurring in the elderly (59%). This is twice as high as the death rate reported for all traumatic injury hospitalizations during this same time period (77). The burden of head injury is a significant concern especially among the elderly if one considers that this age group represents only 12% of the Canadian population overall yet represents 29% of traumatic head injury admissions and 59% of head injury deaths.

Trends from 1994 to 2004 in Canada elucidate some noteworthy changes in historical patterns of head injury over time. Since 1994, an overall 35% decrease in the rate of head injury admissions has been observed, reflecting a specific decrease of 17% for head injury admissions related to assaults and a 43% decrease for head injuries related to motor vehicle collisions (77). Although head injury hospitalizations are on the decline, the same cannot be said for the number of serious head injuries requiring admission to specialized trauma facilities. National estimates indicate that in 2000-2001 there were

3,880 cases with an ISS of > 12 (defined as serious head injury) that required admission to a lead trauma facility. In 2003-2004, serious injuries were reported to be 5,660 thus representing a 46% increase from 2000 (77).

3.1.2 Etiology of Severe Head Injury

National Trauma Registry data indicates that falls and motor vehicle collisions are the overall leading causes of traumatic injury in Canada (77). These findings are consistent with provincial data captured in the NSTPR (34). During the period of 2004-2005, provincial estimates for falls and MVC injury in Nova Scotia were reported to be 29% and 48% respectively. Causes of injury, however, differ significantly by age group. National estimates report causes of traumatic brain injury in children and youth to be related to falls (40%) followed very closely by motor vehicle collisions (39%) and injuries sustained in sports and recreational activities (28%) (77). Among adults aged 20 to 39, motor vehicle collisions accounted for 51% of head injury admissions followed by assaults and homicides (20%). Among Canadians aged 40 to 59, the leading cause of traumatic head injury was reported to be related to MVCs (40%) followed by falls (39%). Finally, 76% of all injuries in older Canadians were due to falls followed by MVC injury (17%). These findings underscore the need to identify the unique risk factors for head injury as well as the need for age-targeted injury prevention programs aimed to reduce head injury rates.

3.2 Falls

Falls are a major cause of unintentional injury resulting in a significant amount of emergency room visits and hospitalizations every year for all age groups (77). In 2003-2004 falls were the leading overall cause of injuries followed by injuries resulting from MVCs. During this same period, falls accounted for 45% of traumatic head injury hospitalizations in Canada (77). Age groups particularly vulnerable to falls are children, youth and older adults. Falls related to team based sports and recreational activities are one of the major causes of TBI among pediatric populations, particularly among youth aged 12 to 19 years (79,80). Among Canadian seniors, hospitalizations due to falls in 2003-2004 accounted for 82% of injury related hospitalizations (77). Understanding the risk factors for the prevention of falls is of considerable public health importance especially among older adults. The anticipated population growth among the elderly combined with the fact that people are living longer suggests that hospitalization rates related to falls may continue to increase among this age group (77).

3.3 Motor Vehicle Collisions (MVCs)

MVCs continue to be a public health concern despite decreasing MVC-related mortality and injury rates observed during the past few decades (81-83). Injury prevention measures that protect the head from impact such as seat belts, air bags, motorcycle helmets and child safety seats are likely the reasons for the decreases in overall injury and head injury death rates specifically (84). Despite these trends, previous studies have shown mortalities from MVCs continue to outrank every other cause of death among those 1 to 34 years of age (85-87). Analyzing motor vehicle related risk factors that influence head injury incidence, severity and outcome is therefore of considerable importance.

3.4 Correlates of Head Injuries

The section below examines important individual-level correlates for head injuries including sex and age, socioeconomic status, ethnicity, urban and rural settings, intentionality, alcohol use, previous head injury, safety device use and collision-related characteristics.

3.4.1 Sex and Age

In general, men are approximately twice as likely as women to incur a head injury (12,42). These differences, it has been argued, are due to the higher propensity for risk taking observed in men (i.e. high contact sports, thrill-seeking activities, reckless driving), thus making them more behaviorally susceptible to injury (88). Gender-related differences in head injuries may also reflect differences in exposure levels. For example, there may be higher injuries related to motor vehicle injury for males due to the higher frequency of driving observed in this group when compared to females. In contrast, injuries related to falls appear to occur more often with females. However, gender differences may be related, in part, to the higher number of females found in older age groups (44).

In a U.S. population-based study, age was found to have a significant independent effect on the survival of admitted and discharged patients (89). Other studies have demonstrated that age is one of the most significant risk factors for mortality following a head injury (90). Demographic groups observed to be particularly vulnerable to head injuries are young adults (15 to 25 years of age) and the elderly (aged 65 years and older) (91). High rates of head injuries in adolescence have been found to be associated with the use of alcohol and other drugs during the time of injury (92). In addition, studies report that young adults are more frequently involved in injuries at high speeds and experience higher risk taking behaviours (particularly males) which result in greater severity of injuries (88). Higher head injury fatality rates have also been observed in the elderly and have also been linked to greater overall injury severity. In one study, patients over 65 years of age had higher mortality rates than younger patients with the same injury severity score (ISS) suggesting a higher vulnerability of older brains to severe injury (93-95).

3.4.2 Age and Gender in MVC-Related Head Injury

As with injuries in general, studies report that males experience higher fatality rates and more severe MVC-related injuries even after adjusting for age and collision-related variables (96).

The profile of motor vehicle collisions also varies considerably by age group. In Canada, children and youth represent the highest proportion of MVC-related head trauma accounting for 33% of hospital admissions (77). Individuals aged 20 to 39 followed closely with 31% admissions attributed to MVC-related head trauma, representing the leading cause of head injury for this age group. Canadians aged 40 to 59 as well as those aged 60 and over have been reported to have lower rates of MVC-related head injury with hospitalization rates being 22% and 14% respectively (77). However, studies show that when injury does occur in the older age groups they are more likely to be serious or fatal MVC injuries (97).

3.5 Socioeconomic Status (SES) and Ethnicity

The existence of a social gradient in health has been well documented in the literature; wealthy, more highly educated individuals experience better health than their poorer, less educated counterparts (98). This relationship is observed in both adults and children sustaining injuries (42,99-103). More specifically, injury rates have been consistently found to be inversely related to socioeconomic level (26,42,104).

Although fewer studies have investigated the relationship between SES among head trauma patients, the results appear to be consistent with injuries in general. Hanks and colleagues reported socioeconomic factors play a significant role in violent head injuries sustained in a large U.S. sample (105). Similarly, Whitman and colleagues compared head injury rates in two socio-economically different communities in Chicago: an inner-city neighbourhood and a relatively affluent suburb (42). Findings showed that regardless of gender, individuals in the inner-city neighbourhood were at higher risk for head trauma than residents of affluent suburbs. A similar social gradient was also observed in relation to causes of injury. Interpersonal attacks accounted for the largest proportion of head injuries in the inner-city neighbourhood while head injuries among residents in the affluent suburb were most often related to MVCs, followed by falls and injuries as a result of recreational activities. Similarly, differences in causes of injury were also observed in the study by Kraus and colleagues who reported brain injury rates from firearms and assaults to be the highest in the lowest family income group (104). Environment and SES have also been found to affect the incidence of head injuries in pediatric populations. Cooper and colleagues found an overall rate of traumatic brain injury to be 400 pediatric cases per 100,000 in the inner-city (106). This rate was more than twice the national average at the time of the study suggesting an increased risk of injury among youth in economically depressed areas. In a study investigating fatal childhood head injuries in England, authors reported the mortality rate to be more than 14 times higher in the most socially deprived areas compared to least socially deprived areas (102).

Racial differences observed in many populations have also been reported; however, these differences may be attributed in part to the close association of race and income level. For example, Kraus found that after income was taken into account, consideration of race/ethnicity did not change the rates of injury considerably. Conversely, Whitman and colleagues found that African-Americans were at a higher risk for head injury compared to Caucasians even after controlling for income level (42). Interestingly, the risk for head injury among African-Americans residing in an inner-city neighbourhood was observed to be the same as African-Americans residing in an affluent community. This suggests that there may be differences in head trauma experiences between different racial groups, independent of place of residence.

3.6 Urban and Rural Settings

Only two known published studies have specifically investigated urban and rural differences for head trauma. Woodward and colleagues found that compared with urban populations, rural residents in South Australia had higher rates of head injuries as captured by hospital discharge records during the period of 1980 to 1981. In this study, hospitalized traumatic brain injury rates for "country" residents were 33% higher compared to "city" residents (107). Similarly, a study in Colorado, U.S. grouped injuries into a classification scheme that reflected an urban/rural continuum that accounted for the remoteness of some places of residence. Study findings showed that head injury rates increased as rurality increased (41). Specifically, residents in the most remote counties were reported to have the highest overall head injury rate as well as the highest mortality rates, almost twice as high as that observed among urban residents. However, timely access to care or effectiveness of trauma services received could not be assessed in this study and may therefore account for some of the differences observed between urban and rural places of residence.

3.6.1 Urban and Rural Settings for MVC-Related Injury

Very few studies have investigated urban and rural differences in head injuries sustained during MVCs. Available studies indicate that in general, people living in urban areas are at greater risk of being involved in road collisions; however, death rates and injury severity from MVCs are highest among those living in rural areas (108). Data from the U.S. has demonstrated MVC death rates to be 60% higher in rural areas compared to non-rural areas (109). An inverse correlation between MVC death rates and population density was also found in a study of U.S. counties, with death rates higher in areas of lower population density (110). Similar trends for injuries in general have also been demonstrated in the Canadian setting. One study utilizing population-based neurotrauma data in Ontario found high rates of head injuries in Northern Ontario, a high rural area (14). This research suggests that head trauma may be an important concern in rural and remote parts of that province. However, lack of data specific to understanding the role of geography on MVC-related head injury supports the need to further examine this relationship.

3.7 Alcohol

The association between risk for injury and positive blood alcohol concentration (BAC) is well established for many external causes of injury (111). Alcohol intoxication increases the risk for injury by impairing motor skills, reaction time, and judgment (112,113). Studies estimate that 30% to 50% of all patients hospitalized with trauma are intoxicated at the time of injury (114).

High rates of alcohol use have also been reported in studies pertaining to head injury. An early study comparing patients with minor head injury (defined by GCS scores of 8 or less) and patients with severe injury (defined by GCS scores of 13-15) found BAC level on admission to be 43% and 85% respectively (115). Similar findings were also reported in Kraus and colleagues who reported 56% of adults diagnosed with a brain injury to have positive BAC levels and 49% of those tested to have BAC levels above the legal limit (116). It is recognized however, that differential rates in BAC levels among mild, moderate and severely head injured patients as reported in the literature may be due to possible testing bias. Kraus and colleagues found BAC testing of injured patients who presented to the emergency department to vary based on the degree of injury severity, type of injury and in relation to sociodemographic variables. In their study, blood testing was found to be less frequent in males, young adults, those with mild brain injuries and among those injured from falls (116). Data from the NSTR indicate that during the years 2000 to 2007, approximately 68% of individuals were not screened for alcohol levels during their treatment following injury and therefore do not have recorded BAC levels as captured in the NSTR. Hence, a testing bias may also exist in this present study as reported in other studies.

Although alcohol is strongly implicated as a causal factor for head injury, the role of alcohol following a head injury event is less clear (117). Some studies suggest that alcohol worsens head injury outcomes (33,118-120), other studies have reported no effect (121) and still other studies suggest that alcohol may be neuroprotective (122,123). Waller and colleagues found that patients who tested positive for alcohol had an ISS that was 86% higher than their alcohol-negative counterparts (124). The finding that alcohol worsens head injury outcome has also been supported by a number of laboratory studies using animal models (125-131). Conversely, two U.S. studies reported that alcohol was associated with improved trauma outcomes (122,123). Both investigators found that among patients with equal injury severity, those with BAC levels on admission that were greater than 0 were associated with reduced trauma-related mortality and shorter length of hospitalization compared to patients with BAC levels of 0 (122,123). This suggests that alcohol may have pharmacological effects during the post-injury period that may lead to reduced mortality and improved health outcomes. However, it is also plausible that the presence of alcohol may mask the true severity of injured patients by making them initially appear more severely injured than they actually are.

3.7.1 Alcohol, Head Injury and MVCs

It has been estimated that one in eight of those admitted in a Canadian hospital for motor vehicle injury had alcohol consumption beyond the legal limit (63). National estimates have also reported that MVCs accounted for over 65% of severe injury admissions in the 15 to 24 age category (85). Among the five provinces where data were most recently available, severe injury admissions from MVCs were found to be the highest in the province of Nova Scotia (56%). Furthermore, among those tested for BAC, Nova Scotia also had the highest percentage of cases (18%) with BAC levels greater than the legal limit (63).

Numerous studies have shown driving under the influence of alcohol is an important risk factor for motor vehicle collisions (132-135). Miller and colleagues estimated from published studies that BAC levels above 100 mg/mL can result in 13 to 18 times the risk of involvement in a collision and by as much as 50 to 90 times the risk for a fatal crash (136). An increased risk for MVCs has also been demonstrated in BAC levels below this value (137). Furthermore, alcohol use has been associated with higher motor vehicle speeds and lower seatbelt use (138,139). Studies have also reported that alcohol is associated with more severe injuries thus contributing to higher mortality rates. A study that assessed for injury severity using vehicle deformation as a surrogate, found that alcohol significantly increased the likelihood of injury severity (120).

Studies specifically investigating the role of alcohol use for head injuries have found similar results. One study aimed to determine if alcohol potentiated the severity of TBI in the MVC victim after controlling for relevant collision characteristics (140). A total of 58 patients presenting to the two emergency departments were evaluated on a number variables including the Marshall score (a classification used to scale severity of head injury using head CT or autopsy reports), BAC levels, seat belt usage and traffic deformity (TAD) scores. Logistic regression was used in order to assess for the independent effect of alcohol on Marshall score while controlling for other relevant variables (seatbelt use, age, TAD, the interaction of belts and TAD, and alcohol use). Investigators found patients with positive BAC were 2.1 times more likely to have a more severe head injury as measured by the Marshall scores compared to individuals negative for alcohol. Although small sample size was one of the limitations to the study, it was one of the first clinical studies that accounted for collision-related characteristics in the analysis. The work of Stoduto and colleagues supports these findings and is the only Canadian study investigating the role of alcohol among seriously injured MVC victims (141). The study included a sample of 854 non-fatally injured MVC traumas presenting to a regional trauma unit in Ontario. Demographic, injury and crash characteristics were obtained from hospital charts and police reports and BAC blood samples were drawn for each patient. Investigators found that BAC-positive drivers were significantly more likely to be male, involved in a single-vehicle collision, not wearing a seat belt, ejected from the vehicle and traveling at higher speeds than their BAC-negative counterparts.

3.7.2 Alcohol, Head Injury and Falls

Alcohol has been found to play a significant role in falls especially among those who sustain a falls-related head injury (142-146). In a study by Brux and colleagues, autopsy records over a 10 year period in Frankfurt, Ireland were used to investigate the role of alcohol for injuries resulting from falls down flights of stairs (144). Findings showed a total of 54% of cases to be under the influence of alcohol. Similar results were observed in another study that investigated the pattern and severity of injury among patients who had fallen from a standing height (143). In this study, a total of 53.5% patients were found to be under the influence of alcohol and of these, 48% had sustained a head injury. Findings revealed that intoxicated patients did not use their arm to break the fall as indicated by lower incidences of limb injury in this group therefore leading to a greater force being transmitted to the head when it struck the ground. A meta-analysis of studies assessing alcohol involvement among non-traffic fatalities published during 1975 to 1995 found slightly lower estimates of falls related to alcohol use. Aggregating results from several studies, the review found a total of 32% of fatal falls to be related to alcohol intoxication (147). The authors however, state that this estimate may be conservative as BAC levels are more often tested at autopsy compared to the hospital setting. Given that alcohol continues to be metabolized even in severely injured persons, this is of particular concern among elderly patients who die days or weeks following a fatal falls-related injury (111). In these cases, the effects of alcohol on injury events can be masked due to the prolonged period between time of injury and time of BAC testing. Since adjustments for covariates were not conducted in any of the studies discussed above, multivariate statistical analyses are still needed to assess the independent role of alcohol on falls-related head injury.

3.8 Intentionality

Intent aims to identify whether an injury occurred as a result of an inadvertent act or whether the injury was deliberate. This has led to the classification of injuries as either “intentional” or “unintentional”. Traffic related injuries, poisoning, falls and burns are most often categorized as unintentional, while injuries related to assaults, self-inflicted violence and war are categorized as intentional injuries (27).

Assessing the circumstances of an injury event with specific understanding of injury intent is important for the identification and profile of individuals most at risk for different types of injuries. Although there is a large body of literature describing individuals who have sustained unintentional injuries, less is known about the profile of individuals who have sustained intentional injury. An important sub-group to intentional injury are individuals involved in violence-related trauma.

In a U.S. study of 1229 individuals, factors unique to patients sustaining violent TBI were investigated (105). A total of nine possible covariates were investigated among individuals receiving acute hospitalization and inpatient rehabilitation including: year of injury, age, employment status, marital status, education, race, gender, BAC on admission to the emergency department and history of a previous TBI. Logistic regression analysis showed that seven of the nine variables reliably predicted violent injury. Surprisingly, alcohol intoxication and educational levels were not found to be a significant predictor when violent injured cases were compared to non-violent controls. Rather, the key risk factors for violent TBI were: being a mid-thirties African-American male, unmarried and unemployed with a prior TBI. However, the lack of predictive relationship between alcohol use and violent TBI may be due to missing toxicology results in 18% of participants. Furthermore, the study sample may have been biased to those residing in chronically underserved urban settings. Wagner and colleagues (148) found similar results in a study that aimed to delineate demographic and event-related factors associated with intentional TBI. Using a sample of 2,637 participants who had sustained a TBI, the researchers analyzed demographic and incident-related factors such as age, race, gender, income, mechanism of injury, and drug and alcohol use at the time of the injury. Study findings revealed that gender, minority status, age, substance abuse and residence in a zip code with low average income were predictive of intentional TBI. Furthermore, multiple logistic regression modeling showed that after controlling for demographic variables, minority race and drug and alcohol consumption were independently predictive of intentional injury. The work by Harrison-Felix and colleagues (149) further supports this finding. In their study, patients with a violent TBI were compared with patients with a non-violent TBI on a number of pre-injury demographic variables. Study findings revealed that individuals with violence-related injuries were more likely to be male, nonwhite, single, living alone, unemployed and less educated at the time of the injury. Bogner and colleagues conducted a similar study and found the same risk factors among patients sustaining a violence-relation TBI as that reported by Harrisson-Felix and colleagues. Bogner’s study also found that patients who reported a history of substance abuse were at higher risk for violence-related TBI (150).

It is clear that demographic and socioeconomic factors play a key role in the risk for a violent head injury event. However, no known study has aimed to evaluate unintentional injury and the populations most at risk for these injuries within a Canadian setting.

3.9 Previous Head Injury

Some authors report previous head injury to be a risk factor for subsequent head injury events. However, no strong evidence currently supports this view. Annegers and colleagues were the first to report this association in Olmsted County, Minnesota, U.S. estimating the relative risk (RR) of a second TBI among those with an earlier TBI to be approximately 2.8 to 3.0 times that of the general non-injured population (24). Similar findings were also recently observed in a pediatric population in Montreal, Canada (151). In this study, children with a history of previous head injury were twice as likely to be predisposed to sustaining an injury similar to the original injury; however, age, gender and previous injury confounded the relationship. Anecdotal evidence has also suggested that athletes are prone to future concussive injuries after sustaining a sport-related head concussion (152,153). However, the likelihood of repeat injury may simply reflect repeat exposure to external or environmental factors (e.g. continued playing time, dangerous game strategies) rather than any inherent biological risk for subsequent injury (153).

3.10 Collision-Related Characteristics

Some studies have investigated the role of the initial angle of impact in MVCs and their relationship to occupant injury (138,154). Such research has demonstrated that fatal and nonfatal TBI may be more frequent and more severe after lateral collisions (155-162). One large population-based study found lateral impact to be an important independent risk factor for the development of TBI following MVC. Using a sample of 1,115 occupants, the severity of traumatic brain injury among occupants of lateral impact was compared with occupants of non-lateral impact. After controlling for crash-related characteristics, the relative risk (RR) of sustaining a TBI after lateral impact was found to be 2.60 (95% CI 1.1 to 6.0) (154). Using AIS and the GCS, the study also showed TBI severity to be greater following lateral collisions. These findings are supported by another study investigating differences between the types of brain injuries sustained in distinct collisions configurations. Using medical charts and police accident reports for 168 TBI patients, study findings revealed that lateral collisions and collisions involving contact with a fixed object were associated with the most severe brain injuries. Authors estimated that efforts to protect the head from injury during lateral impact could reduce MVC-related TBIs by as much as 61% and critical or fatal TBIs by 24% (154). Furthermore, the study found seatbelt use to not only reduce the probability of injury but also served to mediate the severity of brain injuries sustained. Other studies however, suggest that seat belt use may not be as effective in reducing injury risk in lateral collisions when compared to other collision types (155,163). One investigation found the protection of head injuries offered by seatbelt use was negligible for injuries sustained during lateral collisions (155). Elevated risk for severe injury in these types of collisions have been attributed to the proximity of occupants to interior and exterior structures of the vehicle, and less opportunity for energy dissipation compared to other types of collisions (164).

The necessity to investigate the role of collision-related characteristics on occupant injury has been emphasized in the literature for some time (165). It is clear from the literature that head injuries are the most damaging injuries sustained in MVCs and the most difficult to mitigate by vehicle design (159).

3.11 Safety Device Use

Restraint systems and protective devices such as airbags, seatbelts and child safety restraints (CSR) have been instrumental in protecting occupants against MVC-related injury (84). Airbags are automobile safety components designed to reduce injury by serving as a protective cushion between the occupant and the car interior, thus effectively slowing the transfer of energy that occurs during a frontal impact (61,67). With the exception of side airbags that are included in some types of motor vehicles, airbags are not engineered to protect occupants from side-impact, rear or rollover events (67). During these types of collisions, it is the seatbelt that offers the most protection against injury. Previous reports have estimated that airbags can reduce the risk of death by 24% to 28% for drivers and by 18% for front-seat passengers (39,40,61,166). This is much less than the 50% or greater reduction in death reported with the proper use of seat belts for frontal and other types of collisions (40,167-170). Recent reports suggest that the combined use of seat belts and airbags can reduce injuries by as much as 80% (61).

Comparable findings have also been reported with the correct use of CSR with reductions estimated to be 71% for fatal injury and 67% for serious injury (171).

Although many studies have evaluated the effectiveness of airbags and seatbelts in reducing injury and mortality, there is less published data that specifically examines the effect of restraint use for the reduction of head injuries. One study found that the use of CSR substantially reduced the likelihood of sustaining a head injury in infants properly restrained compared to infants who were improperly restrained (15.2% versus 92.8%) (172). Although results were most dramatic in the infant group, this protective effect was also seen in toddlers and young children. Results however, were not subjected to adjustments of relevant covariates such as the control of demographic characteristics, driver behaviour and collision-related factors, a major limitation to the study. Stewart and colleagues conducted one of the first Canadian studies that measured the effectiveness of airbags in reducing collision-related head injuries (38). Utilizing a case-control design, factors contributing to both airbag deployment and head injuries were examined. Findings showed that head injuries resulted in a higher ISS, and higher ejection and mortality rates. Not surprisingly, there were fewer head injuries with the deployment of an airbag and lower severity of head injuries. Although ISS, age, and ejection were found to be significantly associated with the odds of sustaining a head injury, airbag deployment was not statistically significant in the final logistic regression model (OR 0.827; 95% CI 0.560-1.220). This finding may be attributed to the study's inclusion of "near-frontal" cases rather than a more restrictive definition of purely frontal collisions in which airbags have been found to be most effective (167,173). Comparable results were also observed in another study investigating the effectiveness of restraint systems in reducing head injuries. In this study, the use of seatbelt or combination of seatbelt and airbags resulted in lower rates of serious head injury. However, the use of airbags alone was found to provide little additional prevention of head injuries when compared to unrestrained individuals involved in a similar collision (174).

Although studies report a net positive benefit in using airbags and seat belts for the prevention of injury, some studies have reported problems with their use. A U.S. study utilizing a large dataset from the National Automobile Sampling System assessed airbag deployment in frontal collisions for both high-impact and low-impact collisions. Study findings showed that airbags were effective in decreasing the probability of severe and fatal injuries during high-speed frontal collisions. However, airbag deployment in low severity (low-speed) collisions increased the probability of sustaining a “minor” injury (AIS < 3) especially among female drivers (175). Thus, airbags were found to have caused more serious injury when deployed at low-speed than would have occurred otherwise. Improper use of seatbelts has also been associated with a variety of injuries including: liver lacerations, small bowel tears, ocular and facial injuries, spine and neck injuries, lung perforation, aortic and vascular injuries, sternal fractures, chest injuries, kidney injuries and placental and fetal injury (67). Furthermore, improper restraint use in children has been documented to result in specific types of injuries known as “seat belt syndrome” (injuries to the intestinal viscera and to the lumbar spine associated with being restrained with lap seatbelt.) (176,177)

The protective effect of motorcycle helmets in reducing head injuries and death is well established in the literature. Population studies suggest that legislative efforts to increase helmet use are associated with decreased injury and mortality rates (178-180). A recent meta-analysis of the effectiveness of wearing a motorcycle helmet found that despite methodological differences in studies, there was remarkable consistency in results specific to death and head injury outcomes (181). Higher quality studies found in this review showed that helmets reduced the risk of head injury by 42% to 69%. However, empirical data is still needed to assess whether differences in helmet type confer more or less advantage in reducing head injuries.

Sports and recreational activities, particularly those involving body contact, projectiles and/or high speeds are associated with an increased risk of head injuries (182). Studies reporting the incidence and prevalence of head injuries sustained in sports and recreational activities are numerous and include high contact sports such as football, hockey and rugby. Head injuries have also been reported in baseball, boxing, equestrian and snow sports. The use of mandatory helmets has been argued to be critical for the prevention of head injuries sustained in sports. Helmets are designed to decrease the risk of injury by reducing the head impact force and head's acceleration to below relevant tolerance levels (182). Opponents of mandatory helmet use have argued that helmets may increase the risk of injury by reducing the field of vision and impairing hearing. Some authors report that helmets may also increase the risk of cervical spine injuries by creating a guillotine effect due to the higher mass added to the head especially when worn by children (183,184). However, sufficient statistical power regarding the relationship between neck injuries and helmet use is still lacking from published evidence.

A number of investigations have provided evidence that correct helmet use can prevent injuries sustained in a variety of sports. A systematic review performed by

Thompson and colleagues showed that compared to ‘no helmets’, the effectiveness of bicycle helmets had a significant advantage in reducing head and facial injuries. Studies included in the review found that helmets provided a 63% to 88% reduction in the risk of head, brain and severe brain injury for all ages of bicyclists (185). Similar reductions in injury from helmet use have been reported by a study commissioned by the CDC which noted a risk difference of 85% for brain injury and 88% for TBI among helmet-wearing cyclists (186). Helmets have also shown to reduce the risk of head injury in a recent case-control study involving skiers and snowboarders (187). After adjusting for covariates, the study demonstrated that helmet use was associated with a 60% reduction in risk for head injury when head injured skiers were compared to uninjured controls (OR 0.40; 95% CI 0.30-0.55). The effect was slightly reduced when skiers with other injuries were used as controls (OR 0.45; 95% CI 0.34-0.59). Reductions in injuries from helmet use have also been demonstrated among participants of ice hockey. Using historical data, Biasca and colleagues reported the combination of rigorous standards for ice hockey helmets and increased wearing rates to the reduction of fatal and serious head injury. However, increases in mild brain injury were also reported (188). Some studies suggest that mandatory face masks can provide a further reduction in both facial injuries and TBI (189,190). In university level ice hockey, the use of full face shield compared with half face shield was found to significantly reduce playing time lost due to concussion (79).

3.12 Summary

There are a number of key findings pertaining to the risk factors for head injuries resulting from falls and MVCs. First, gender and age emerge as important socio-demographic factors related to head injury events. Second, alcohol consumption is significantly associated with head injury events. And third, safety device use can play a key role in the reduction in rates of head injury morbidity and mortality. Another important aspect discussed in this literature review is the limited number of large-scale population-based studies in which data were subjected to adjustment of covariates. Use of population-based data can provide a broader, more accurate assessment of the occurrence, characteristics and groups most at high risk for head injuries and is a major critique of current published evidence.

CHAPTER 4: THE EPIDEMIOLOGY OF MAJOR HEAD INJURY IN NOVA SCOTIA - A POPULATION BASED STUDY

ABSTRACT

Objective: To describe the epidemiology of major head injuries among those aged 16 and over in Nova Scotia and to examine head injury patterns specific to motor vehicle collisions (MVCs) and falls.

Method: The Nova Scotia Trauma Registry (NSTR) was the main data source for this study. Data from April 1st, 2000 to March 31st, 2007, from blunt and penetrating head injured patients aged 16 years and older were included. Major head injuries were determined using an abbreviated injury score (AIS) of 3 or greater (isolated for head injuries only). Demographic variables (age, gender), injury and collision-related variables (day and time of injury, location of injury, position in vehicle, type of impact) and behavioural variables (restraint use, alcohol use, drug use) were evaluated.

Results: A total of 1798 patients experienced a major head injury during the study period. Men accounted for 74% of major head injuries, exceeding females for head trauma in all age groups. An overall annual incidence of major head trauma was found to be 33 per 100,000 population in Nova Scotia. Males experienced an annual incidence rate of major head injury that was approximately three times that of females (51 per 100,000 versus 17 per 100,000 respectively). The major external mechanisms of injury were MVCs (40%) and falls (38%). High rates of MVC-related head injury were found among males in all age groups particularly for those aged 16 to 24 years. Falls-related head injury was the most common mechanism of injury for both males and females among those aged 65 years and over. A trend toward increasing incidence rates of head trauma for males and females injured in falls and MVCs were observed over the study period. **Conclusion:** The high proportion of significant head injuries observed among those injured during MVCs and falls in Nova Scotia justifies on-going programs for prevention and control tailored to these specific areas. With an aging population and the greater risk of falls among seniors, falls prevention measures will continue to play an important role in the province.

Key words: Head injuries, epidemiology, population-based study

INTRODUCTION

Injury is one of the most under-recognized public health problems in North America (1). It is estimated that the economic burden of unintentional and intentional injuries combined costs Canadians in 2004 a total of $19.8 billion in direct and indirect costs (191). In addition, injury contributes to high levels of morbidity and mortality, placing considerable demands on healthcare services (5,6). Head injuries are a major component of trauma and are one of the most common causes of neurologic mortality and morbidity in adults younger than 50 years of age (78). It is argued that decreases in head injury mortality over the past two decades are the results of changes in public health policy and improved prevention programs (19). Despite these efforts, many studies continue to report a disproportionate number of males who sustain head injury, particularly among those aged 15 to 24 years and involved in a motor vehicle collision (MVC) (14,22). Falls on the other hand, account for larger percentages of head injuries among children and the elderly (22).

Epidemiological studies of head injury exist in Canada (11-17) and abroad (18-25) . Canadian studies of head injury have focused primarily on characterizing large but selected groups of patients admitted to hospital (17), a rehabilitation setting (15), and an acute care facility (13). Few studies have utilized population-based approaches to describe major head injuries and only three have done so in Canada (11,12,14). Zygun et al. identified head injured patients using an injury severity score of ≥ 12 and a subsequent application of specific criteria to identify severe traumatic brain injured patients residing in Calgary, Alberta. Conversely, Pickett et al. used a less restrictive inclusion criterion that included minor head injuries and concussions presenting for emergency medical care in Kingston, Ontario (14). Tallon et al. investigated surgically treated post-traumatic epidural hematomas (EDHs) and subdural hematomas (SDHs) among patients presenting to Nova Scotia's only neurosurgical centre, representing a population of severe head injuries not described by the other two Canadian studies (11). Previous epidemiological reports have recognized the lack of common definition used to identify head injury and the vast differences in study methodologies. This variability can often lead to the characterization of very different types of head injuries and makes direct comparisons of rates and risk factors among studies problematic (6,22).

Canada's National Trauma Registry (NTR) data has shown falls and MVC to be the overall leading external mechanisms of head injury in Canada (77). Understanding the risk factors that influence head injury incidence and severity, particularly for falls and MVC-related injury is therefore of considerable importance. However, few studies have described correlates of head injury specific to major external causes of injury (including MVCs and falls). The characterization of head injury in two Canadian population-based studies looked at overall rates and was restricted to such variables as age, gender, education, and clinical outcomes post-injury within a one-year (14) and three-year (12) period respectively. Other covariates for head injury that have been examined in published research include alcohol intoxication, drug use, restraint use, urban and rural differences, occupation and socioeconomic status (15,38,42,71,117,192,193). The NSTR is a unique population-based dataset that captures information specific to the circumstances of injury for the entire province of Nova Scotia including data specific to MVC and falls-related injury. Important variables captured in the NSTR include demographic variables (age, gender), injury and collision-related variables (location of injury, position in vehicle, type of impact) and behavioural variables (restraint use, alcohol use, drug use). The NSTR can therefore serve as an important tool to understanding the location and context of head injuries and the unique factors associated with head injuries sustained from falls and MVCs. As previous studies have been restricted to single clinical sites or small geographic regions, the NSTR also serves as an important population-based trauma database to describe head injuries within an entire provincial region.

Although the epidemiology of surgically treated acute SDHs and EDHs has been previously examined in Nova Scotia, no study has comprehensively described the full spectrum of all major head injuries sustained in the province. We undertook this study to examine head injuries sustained in the province using a population-based trauma registry. This study reports on all head injuries within a 7-year period in the province of Nova Scotia serious enough to cause death or hospitalization. The main objective of this research was to describe the epidemiology of head injuries among those aged 16 and over during the period of April 1st, 2000 to March 31st, 2007. We were also interested in examining the patterns of head injury specific to the major external causes of injury (MVCs and falls) in order to provide insight into which groups are most at risk for these types of injuries and thus potentially guide injury prevention initiatives.

METHODS

Study Region

As of 2006, Nova Scotia had a population of approximately 913,000 with 53% residing in rural areas and less than 4% of the total population representing visible minorities (194). Comprehensive, universally accessible, and portable medical insurance has been available to all residents since 1969 (195). The province has two tertiary trauma centres (one adult and one pediatric, located in its capital city Halifax) which play a lead role in providing care to seriously injured patients. In addition, the Province has eight district trauma centres in both rural and urban regions with sufficient resources to treat patients with single- and multi-system traumas prior to referral to a tertiary centre.

Data Source

Information was obtained from NSTR's Comprehensive Data Set (CDS) and the Registry's Death Data Set (DDS). The CDS captures information on all major trauma patients in the province of Nova Scotia. Data is collected from extensive manual chart reviews including information pertaining to the nature of the injury and trauma event, patient demographics, the type and severity of injuries sustained, the processes of care, procedures and treatments provided following injury, and the discharge outcome. Data specific to the Registry's DDS was obtained from files reviewed at the Chief Medical Examiner's Office where information is collected on all traumatic deaths provincially, excluding injuries where there is a lack of anatomical lesion (i.e. drowning). Collectively, the dataset for the specified study period represents patients sustaining "major trauma" who were admitted to the province's 10 district and/or tertiary trauma centers in addition to information from patients resulting in traumatic scene deaths (196).

Inclusion of major trauma cases into the NSTR is based on the Injury Severity Score (ISS) which considers the severity of injuries and body regions involved. The ISS is a composite measure of the AIS used to summarize the extent of injury in a trauma patient. The AIS is an anatomically based system that uses a 6-point ordinal scale in six body regions that ranges from AIS 1 (minor) to AIS 6 (unsurvivable) (28,55). The ISS is calculated by summing the squares of the highest AIS grade in each of the 3 most severely injured areas with a score ranging from 0 to 75 (28). The higher the ISS, the greater the severity of the injury. Traumas are defined by the National Trauma Registry (NTR) as: "injury resulting from the transfer of energy (e.g. kinetic, thermal)" with an Injury Severity Score (ISS) greater than 12 and an appropriate ICD External Cause of Injury Code. The NSTR defines blunt trauma based on the above definition. A variation is given for penetrating trauma as defined by an associated ISS ≥ 9. Under these definitions, injuries resulting from drownings, hangings, suffocations and asphyxias are currently excluded unless they have an anatomic lesion meeting the ISS criteria.

Several measures are performed on Trauma Registry data to ensure data quality, accuracy and completeness. Registry software provides automated internal edit checks that is assessed periodically and at the end of each data collection year to ensure that dates and times are consistent and that no invalid codes have been entered. Data is also visually examined by the provincial trauma registry coordinator and annual re-abstracting audits are completed for 10% of randomly selected cases. In addition, NSTR submits data annually to the NTR, which is managed by the Canadian Institute for Health Information (CIHI). Following the annual data submission, CIHI provides an error report that serves to identify coding errors not identified through other data quality procedures. The NSTR has been used to support other peer-reviewed research (11,197-199).

Selection of Participants

The study period was April 1, 2000 to March 31, 2007. Head injured patients were selected using an abbreviated injury score (AIS) of 3 or greater (isolated for head injuries only).

Under this definition, isolated head injuries as well as head injuries to other body regions were included in the study provided they met the trauma registry inclusion criteria. This definition was designed to capture injury events that resulted in significant injury to the head including basal and vault skull fractures, subarachnoid hemorrhage and subdural hematoma. Conversely, non-neurological injuries such as a broken nose, fractured jaw, lacerated cheek and/or bruises to the head were not considered a severe head injury event. Blunt head injuries (Injury Severity Score ≥ 12) and penetrating injuries (Injury Severity Score ≥ 9) that were sustained in Nova Scotia by patients aged 16 or older were included in the analysis. Patients with major burns or patients with an unknown cause of injury were excluded from the study sample. This study was approved by the Research Ethics Board of the Capital District Health Authority, Halifax, Nova Scotia, Canada.

Data Elements and Definitions

Demographic, injury, and collision-related variables were used to create a descriptive profile of major head injuries. Age, sex, and district health region were the main demographic data elements. Age was categorized into four groups: 16 to 24, 25-39, 40 to 64, and those aged 65 and over. Geographic location of injury was categorized into the 9 district health regions found in Nova Scotia.

Injury related variables included the day of the week (Monday-Sunday), intent of injury (unintentional, self-inflicted, homicide/assault), and location of injury (home, road, other). Time of injury was categorized as follows: 00:00 a.m. – 6:59 a.m. (early morning), 7:00 a.m. – 11:59 a.m. (morning), 12:00 p.m. – 18:59 p.m. (afternoon), 19:00 p.m. – 23:59 p.m. (evening/late evening). Mechanism of injury for blunt injuries were categorized as (MVC-Street, MVC-Off Road, Fall, Other Blunt) while penetrating injuries were reported separately. Season of the trauma was categorized into four groups: Fall (Sept - Nov), Winter (Dec-Feb), Spring (March-May), and Summer (June-Aug).

Blood Alcohol Concentration (BAC) was categorized into the following groups: 1) "No Detectable Blood Alcohol Level" (BAC=0 mmol/L), 2) "Positive Blood Alcohol Level, Below the Legal Limit" (< 0 mmol/L < 17 mmol/L, 3) "Positive Blood Alcohol, Above the Legal Limit" (BAC ≥ 17 mmol/L) and 4) "Blood Alcohol Level Not Tested". Drug use was categorized as "positive" if patients receiving toxicology testing were found to be positive for one or more drugs, "negative" if patients received toxicology testing but were not found to have any drugs in their system and those who were "not tested" for drug use.

Analyses specific to MVCs included data characterized by: vehicle type (passenger vehicle, light trucks, motorcycle, pedestrian, other, unknown), impact type (approaching head on, single motor vehicle rollover, sideswipe/t-bone, other, unknown), position in vehicle (driver, front seat, back seat, other), restraints used (one restraint used, more than one restraint used, no restraint used), and ejection status following the collision (full ejection, partial ejection, no ejection).

"Major Head Injury" was defined as patients with AIS of ≥ 3 for the head (neck excluded) which arithmetically defines major head injuries. To assess severity of injuries, the maximum abbreviated injury score of the head (Head AIS) was used with the following categorization: a score of 3 (serious), 4 (severe), 5 (critical) and 6 (unsurvivable). Motor vehicle collisions" was defined as any off road or on road vehicle involving injury. Pedestrians involved in a collision with a motor vehicle are included in this definition and are reported separately from on-road and off-road collisions. Falls were grouped into the following four categories, occurring from a fall at a height of: 1) the same level, 2) less than 1 meter, 3) between 1-6 meters and 4) greater than 6 meters.

Statistical Analysis

Descriptive statistics including proportions, means, medians, and standard deviations were determined for all head injuries, as previously defined. Incidence rates of head injuries were calculated using NSTR data (numerator) and census data (denominator). We conducted two subgroup analyses specific to head injuries sustained during MVCs and falls. Unpaired t-tests and Mann Whitney U tests were used for continuous data, and the chi-square statistic was used for categorical data. A p-value less than or equal to 0.05 was considered statistically significant. Values were not imputed for missing data. Descriptive summaries and data analyses were performed using SPSS statistical software (SPSS version 17.0, SPSS Inc., Chicago, IL).

RESULTS

A total of 1798 patients experienced a major head injury during the study period with 1330 (74%) head injury events sustained by males and 468 (26%) head injury events sustained by females. The majority of these head injuries were from a blunt force (90%). A large proportion of head injuries were observed in the two largest urban centres of Nova Scotia with 292 (16%) reported in the Cape Breton Health Authority (city: Sydney) and 660 (37%) reported in the Capital Health District Authority (city: Halifax). The distribution of head injuries showed a higher number of major head injuries during weekdays compared to weekends (64% versus 34%) (Table 1). However, the per diem distribution resulted in a higher proportion of head injuries on weekends compared to weekdays (13% versus 17%). The most common environmental injury location for a head injury was the road (42%) followed by head injuries occurring at home (33%). Unintentional injuries were the most common (78%) among the head injured cohort, followed by self-inflicted injuries (10%) and assaults (9%). Seventy-four percent of head injuries were due to falls and MVCs (Table 2). A relatively even distribution of head injuries by month for the entire dataset was observed (Figure 1). A total of 181 penetrating head injuries were observed during the study period. Of these cases, 169 (97%) head injuries were incurred by males. Further, 169 (93%) penetrating inuries were from gunshot wounds.

The overall annual incidence of major head injury was 33 per 100,000 population (Table 3). Males experienced an annual incidence rate of major head injury that was approximately three times that of females (51 per 100,000 versus 17 per 100,000 respectively). Head injury incidence rates were equal for patients sustaining injury from falls and those sustaining injury from street-related MVCs (Table 3).

Head Injury Severity

Injury severity scores (ISS) ranged from 9 to 75 with a mean of 29 (± 16). Using the abbreviated injury classification of severity, 302 (17%) of all head traumas were identified as serious, 802 (45%) were severe, 610 (34%) were critical and 84 (5%) were unsurvivable. Head injury severity varied by major external cause of injury with street-related MVCs accounting for the highest proportion of serious and maximum injury while the highest proportion of head traumas with severe and critical injury were found among those injured in a fall (Table 4).

Age and Sex Differences

The overall median (± SD) age of head injured patients was 49 (± 22) years with a significantly lower median age observed for males 46 (± 21) compared to females 62 (± 24). Overall, males accounted for 74 % of major head injuries and represented a higher proportion of injuries than females across all age groups. A significantly higher median age was found among patients sustaining falls-related injury compared to those involved in MVC-related injury (70 versus 35 respectively).

The majority of head injuries among females aged 16 to 24 years were from MVC-related injury (80%). However, MVC-related head injury was found to be three times more common among males in this age group accounting for a total of 175 (65%) of all head injuries in this age group (Table 5). High rates of MVC-related head injuries among males aged 25 to 64 years were also observed, however, the differences between males and females were less pronounced than those aged 16-24 years. Head injury from falls was the most common mechanism of injury for both males and females among those 65 years and over (68% for males, 78% for females).

Drug and Alcohol Consumption

A total of 642 subjects (36%) were clinically tested for blood alcohol concentration (BAC). Of those tested, 348 (66%) of head injured males and 75 (65%) of head injured females were found to have a BAC greater than zero. Of these patients, a total of 294 (56%) of head injured males and 59 (51%) of head injured females had a BAC level above the legal limit (≤ 17 mmol/L). Similar proportions of alcohol intoxication above the legal limit were found among head injuries resulting in injury from MVCs and falls (54% versus 58% respectively) (Table 7). No significant variations were observed between head injury severity and alcohol levels above the legal limit (p=0.341). Among the small number of head injured patients who were tested for drug use (n=370), positive toxicology results were found in 95 (31%) males and 21 (36%) females.

External Causes of Injury: MVC- and Falls-Related Injury

MVCs were the most common external mechanism of head injury accounting for 40% of all major head injuries while falls followed closely as the second leading cause of major head injury (38%). Twenty percent of falls-related head injuries were due to a fall from a height of 1 to 6 meters while approximately one-quarter of major head injuries occurred at the same level. Data on the type of falls sustained were missing for 41% of cases (Table 9).

Table 7 compares MVC and falls with important injury variables. Patients sustaining major head trauma from falls were significantly older than patients involved in MVC-related head injury. However, the severity of their injuries as measured by the injury severity score (ISS) was significantly lower than their MVC head-injured counterparts. Time of head trauma for both MVC and fall-related injury was found to occur most frequently during the late evening/early morning (12:00 p.m. to 18:59 p.m.) with significantly more injuries reported among the MVC-related group. No seasonal differences in head injuries between these two groups were observed. There were no significant differences in alcohol use (p=0.38) and drug use (p=0.65) between MVC-related and falls-related head trauma.

Motor-vehicle related head injuries are further characterized in Table 8. Collisions resulted in 665 major head injuries accounting for 37% of all major head injuries sustained during the study period. Among MVC-related head injuries, 58% involved occupants of passenger vehicles, and 14% involved occupants of trucks. Another 13% of head injuries involved pedestrians and 9% resulted in injury to motorcycle riders. Single motor vehicle rollovers (36%) and head-on collisions (24%) accounted for the majority of MVC street-related head injuries. Head injuries occurred most often among drivers (62%) and among those who did not use safety restraints including seatbelts, helmets or airbags (31%). Full or partial ejection from the vehicle occurred among 32% of head injured patients involved in a MVC-related injury.

Head Injury Trends

Sex-specific incidence rates of head trauma over time for MVCs and falls are shown in Figure 2. A trend towards increasing incidence rates of head trauma among those injured in falls and MVCs were observed over time. Over the study period, rates of MVC-related head injury were highest among males with increasing rates observed in this group over time. Rates of falls-related head injury were similar in 2001 to 2003 for both genders with an increasing trend in incidence rates observed in the following years, particularly for females. In 2006, fall related head injury incidence rates were observed to be 9 per 100,000 population for males and 15 per 100,000 for females compared to 5 and 6 respectively, in 2001.

DISCUSSION

This population-based study found an overall annual incidence of major head trauma to be 33 per 100,000 population in Nova Scotia. This incidence rate falls within the range described from other published studies of major head trauma. A UK study investigating serious head injuries found the incidence rate to be 52 per 100,000 while an incidence rate of 12 per 100,000 was found in Australia (200,201).

Our study found males to have an overall incidence rate of head injury that was approximately three times the incidence rate observed among females (51 per 100,000 versus 17 per 100,000). This is consistent with other epidemiological accounts that report rates of head injuries in males to be two to three times that observed among females (14,18,193). Gender differences are likely due to higher propensity for risk taking in males that make them more susceptible to injury particularly during adolescence (88). One Canadian population-based study from Kingston, Ontario found head injury incidence rates to be 160 per 100,000 for males and 70 per 100,000 for females (14). The higher rates observed in this study compared to our estimates are likely due to the inclusion of milder cases along with severe head injuries presenting to the Emergency

Department. Conversely, a significantly lower incidence rate was reported in another Canadian study of head injury in Calgary, Alberta (12). In this study, published head injury incidence rates were reported as 17 per 100,000 population for males and 6 per 100,000 population for females. These estimates more closely match our results and can be attributed in part to similar inclusion criteria of patients sustaining “severe” head injuries only.

Age and gender differences by external causes of head injury have been reported in the literature and are reflected in our data. High rates of MVC-related head injury were found among males in all age groups particularly for those aged 16 to 24 years. This is similar to Levin et al. who reported a high incidence of head injury among those aged 15-24 years (202). Conversely, falls-related head injury was the most common mechanism of injury for both males and females among those aged 65 years and over. Peak rates of falls observed among the elderly underscores the need for continued prevention strategies targeted to this vulnerable age group. An excess of head injuries during the summer months has been reported by others, although the rates have been found to vary by external cause (23). Higher rates of head injuries observed during these months have been argued to be due to better weather conditions that result in an increase in outdoor-related injuries. However, seasonal differences in head injuries were not found in the present study. Our study found penetrating head injury to occur in only 10% of the head injured cohort with the majority of these injuries attributed to gunshot injury. In contrast, one U.S. study found 44% of TBI-related deaths were attributable to firearms compared to 34% attributable to motor vehicles and 9% to falls (203). The low prevalence of penetrating injuries especially from firearms may be explained in part by the lower rate of violent crimes found in Nova Scotia when compared to major cities in the United States.

High rates of alcohol and drug use have been reported in epidemiological studies of head trauma, albeit from sparse and fragmented data. Recognizing the importance of drug and alcohol as modifiable risk factors for injury, this study aimed to understand the prevalence of intoxication among head trauma patients particularly by major external causes of injury. Our study found that of those tested for BAC, approximately 348/527 (66%) of head injured males and 75/115 (65%) of head injured females had blood alcohol concentrations (BAC) greater than zero, suggesting that alcohol has been a contributor to the head injury event. Further, 55% of all head injuries where blood alcohol levels were tested involved levels above the legal limit, with similar rates observed among head injuries sustained during MVCs and falls (54% versus 58%, respectively). However, a large proportion of head injured cases (64%) were not tested for BAC. It should be acknowledged that testing bias may also exist in this present study as reported by others (116,117). Alcohol is metabolized quickly and may result in misclassification of cases. A patient with a BAC greater than 0 at the time of injury may be classified as having a BAC of 0 at the time of testing due to having already eliminated alcohol in their blood via metabolism (117). In addition, important clinical factors may affect the decision to test for BAC and may lead to possible selection bias. One study found that BAC testing among head injured cases most frequently occurred among those aged 25 to 44 and among subjects involved in MVCs and assaults; lower rates of BAC testing were also observed among persons with less severe head injuries. The authors suggest that differential rates of BAC testing may be due its relative importance in determining the medical management of head-injured cases (116). In this study population, BAC testing may not be requested even if obvious signs of alcohol impairment are observed, if testing would not materially assist in determining patient disposition; that is, at the time of this data collection, alcohol testing was not mandatory but rather at the discretion of the treating clinician. Therefore, the influence of alcohol on head injury may be severely underestimated in this studied cohort.

This is the first province-wide assessment of major head injuries to be completed in Canada. Our present analysis was based on population data that served the trauma needs of both rural and urban areas. Similar to that reported by Pickett et al., the observed patterns of injury cannot be explained by differential access to health care as universally accessible medical insurance has been available to all residents of Nova Scotia since 1969 (195). There are limitations to this study that warrant further discussion. The NSTR captures only major traumas requiring hospitalization, trauma team activation, or major traumas resulting in death at the scene. The study therefore does not include patients sustaining minor or moderate injury seen on an outpatient basis or those treated in emergency departments that did not result in a hospital admission. Further, the pediatric population (aged 15 or younger) were not included in the analyses. Consequently, our findings underestimate the overall magnitude of head injuries in the province of Nova Scotia.

The high number of head injuries reported among those injured in MVCs and falls justifies on-going programs for prevention and control tailored to these specific areas. There are many population-based and community level prevention strategies aimed at reducing injuries in Nova Scotia for specified target groups. With an aging population and the greater risk of falls among older adults, falls prevention measures will continue to play an important role in Nova Scotia. The Nova Scotia Department of Health Promotion and Protection has recently developed a strategic framework for preventing falls-related injuries using evidence from injury prevention research. Under this framework, a comprehensive approach to prevent falls among seniors is outlined and includes such activities as exercise programs, medication review, assistive protective devices and environmental modifications and education (204). In addition, several public health policy initiatives in Canada have assisted in the reduction of MVC-related injury and head injury severity over the last few decades. Such policies include environmental efforts (traffic-calming measures, vehicle safety) and enforcement efforts (road-side checks, random breath testing, helmet-wearing legislation).

Population-based administration datasets, such as the NSTR, can serve as important tools to assess the effectiveness of current public health policies and prevention strategies targeted at those most at risk for head injuries. Continued surveillance using population-based registries can provide a broader and more accurate assessment of the occurrence, characteristics and groups most at risk for head injuries; in addition, they can help to establish and respond to head injury trends and guide injury prevention strategies.

Table 1: Demographic and Temporal Characteristics of Major Head Injured Patients (Nova Scotia Trauma Registry, 2000-2007)

Characteristics	**Major Head Injury Trauma N (%)**
Total N	1,798
Sex	
Male	1,330 (74.0)
Female	468 (26.0)
Total	**1,798 (100)**
Age Group	
16-24	332 (18.5)
25-39	318 (17.7)
40-64	590 (32.8)
65 +	558 (31.0)
Total	**1,798 (100)**
Location of Injury	
Home	593 (33.0)
Road	763 (42.4)
Other	350 (19.5)
Unknown	92 (5.1)
Total	**1,798 (100)**
Day of Trauma	
Weekend	614 (34.1)
Weekday	1162 (64.6)
Unknown	22 (1.2)
Total	**1,798 (100)**
Season of Trauma	
Fall	497 (27.6)
Winter	409 (22.7)
Spring	392 (21.8)
Summer	495 (27.5)
Unknown	6 (0.3)
Total	**1,798 (100)**
District Health Authority	
DHA 1 – South Shore Health	113 (6.3)
DHA 2 – South West Health	99 (5.5)
DHA 3 – Annapolis Valley Health	147 (8.2)
DHA 4 – Colchester East Hants Health Authority	129 (7.2)

Characteristics	**Major Head Injury Trauma N (%)**
DHA 5 – Cumberland Health Authority	68 (3.8)
DHA 6 – Pictou County Health Authority	97 (5.4)
DHA 7 – Guysborough Health Authority	99 (5.5)
DHA 8 – Cape Breton Health Authority	292 (16.2)
DHA 9 – Capital Health District Health Authority	660 (36.7)
Unknown	94 (5.2)
Total	**1,798 (100)**

Table 2: Injury Related Characteristics of Major Head Injured Patients (Nova Scotia Trauma Registry, 2000-2007)

Variable	Head Injury Cohort N (%)
Total N	1,798
Blunt	
MVC (Street)*	665 (37.0)
MVC (Other)	62 (3.4)
Fall	674 (37.5)
Other Blunt Mechanism	216 (12.0)
Penetrating	
Unspecified	181 (10.1)
Total	**1,798 (100)**
Unintentional	1,408 (78.3)
Self-Inflicted	176 (9.8)
Homicide/Assault	156 (8.7)
Unknown	58 (3.2)
Total	**1,798 (100)**
Alcohol Level	
BAC = 0	219 (12.2)
BAC (< 0 mmol/L to < 17 mmol/L)	70 (3.9)
BAC (≥ 17 mmol/L)	353 (19.6)
BAC Level Not Tested	1156 (64.3)
Total	**1,798 (100)**
Toxicology Level	
Tested Negative	254 (14.1)
Tested Positive	116 (6.5)
Not Tested	1,428 (79.4)
Total	**1,798 (100)**

*Includes motorcycle, pedestrian and vehicle collisions occurring on road or street

Figure 3: Distribution of Major Head Injuries by Month of the Year (Nova Scotia Trauma Registry, 2000-2007)

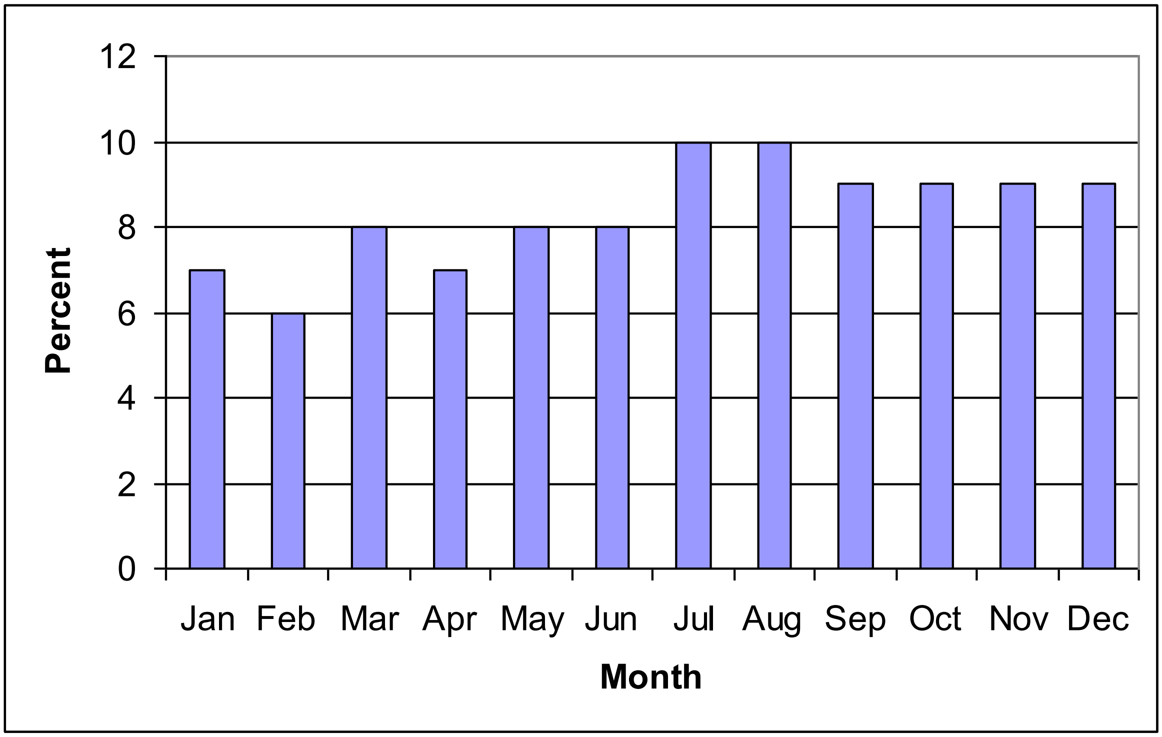


Table 3: Major HI Rates (per 100,000) by Year and Major External Cause of Injury (Nova Scotia Trauma Registry, 2001-2006*)

	2001		2002		2003		2004		2005		2006		Average for Study Period	
Injury Mechanism	**# of Head Injuries**	**Rate****	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**
Blunt														
MVC (Street)	88	12	94	12	71	9	94	12	93	12	114	15	92	12
MVC (Off-Road)	13	2	9	1	12	2	9	1	6	1	8	1	10	1
Fall	74	10	86	11	77	10	88	11	118	15	139	18	97	13
Other	29	4	20	3	33	4	42	5	32	4	38	5	32	4
Penetrating														
Unspecified	22	3	30	4	30	4	32	4	23	3	21	3	26	4
Total	**226**	**30**	**239**	**31**	**223**	**29**	**265**	**34**	**272**	**35**	**320**	**41**	**258**	**33**

*Data for 2000 and 2007 were excluded as they represent cases for partial year only.
**Incidence rates represent major head injuries (numerator) by Nova Scotia census population over 16 years (denominator).

Table 4: Distribution of Head Trauma Severity by Major External Cause of Injury (Nova Scotia Trauma Registry, 2000-2007)

Injury Mechanism	All Head Trauma N (%)	Serious (HAIS* = 3) N (%)	Severe (HAIS* = 4) N (%)	Critical (HAIS* = 5) N (%)	Maximum (HAIS* = 6) N (%)
Blunt					
MVC (Street)	665 (37)	181 (60)	236 (29)	186 (30)	62 (74)
MVC (Off-Road)	62 (3)	15 (5)	25 (3)	19 (3)	3 (4)
Fall	674 (37)	58 (19)	405 (50)	208 (34)	3 (4)
Other Blunt	216 (12)	44 (15)	120 (15)	46 (8)	6 (7)
Penetrating					
Unspecified	181 (10)	4 (1)	16 (2)	151 (25)	10 (12)
Total	**1798 (100)**	**302 (100)**	**802 (100)**	**610 (100)**	**84 (100)**

*HAIS = Head Abbreviated Injury Score

Table 5: Frequency and Prevalence of Major External Cause of HI by Age Group and Gender (Nova Scotia Trauma Registry, 2000-2007)

Age Group	**16-24 years N (%)**		**25-39 years N (%)**		**40-64 years N (%)**		**65 and over N (%)**		**Total (N/total) N (%)**	
Injury Mechanism	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Blunt										
MVC (Street)	175 (65.3)	51 (79.7)	103 (38.6)	38 (74.5)	139 (30.0)	54 (42.5)	61 (18.4)	44 (19.5)	478 (35.9)	187 (40.0)
MVC (Off-Road)	11 (4.1)	5 (7.8)	22 (8.2)	0 (0)	15 (3.2)	2 (1.6)	4 (1.2)	3 (1.3)	52 (3.9)	10 (2.1)
Fall	23 (8.6)	7 (10.9)	33 (12.4)	8 (15.7)	142 (30.7)	58 (45.7)	226 (68.1)	177 (78.8)	424 (31.9)	250 (53.4)
Other	39 (14.6)	1 (1.6)	69 (25.8)	4 (7.8)	78 (16.8)	10 (7.9)	14 (4.2)	1 (0.4)	200 (15.0)	16 (3.4)
Penetrating										
Unspecified	20 (7.5)	0 (0)	40 (15.0)	1 (2.0)	89 (19.2)	3 (2.4)	27 (8.1)	1 (0.4)	176 (13.2)	5 (1.1)
Total	**268 (100)**	**64 (100)**	**267 (100)**	**51 (100)**	**463 (100)**	**127 (100)**	**332 (100)**	**226 (100)**	**1330 (100)**	**468 (100)**

Table 6: Major Head Injury Rates (per 100,000) by Year and DHA in Nova Scotia
(Nova Scotia Trauma Registry, 2001-2006*)

	2001		2002		2003		2004		2005		2006		Average for Study Period	
DHA (District Health Authority)	**# of Head Injuries**	**Rate****	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**	**# of Head Injuries**	**Rate**
DHA 1	17	33	15	29	8	15	18	35	22	42	20	38	17	33
DHA 2	15	28	16	30	14	26	16	30	13	25	15	29	15	28
DHA 3	13	19	17	25	25	37	20	29	28	41	19	27	20	29
DHA 4	11	19	18	31	22	37	20	33	10	17	30	49	19	32
DHA 5	5	18	9	32	6	22	14	50	15	54	12	43	10	36
DHA 6	16	40	12	30	12	30	8	20	16	40	14	35	13	33
DHA 7	15	38	10	25	11	28	18	46	16	41	19	49	15	38
DHA 8	32	29	50	46	33	30	40	37	42	39	53	49	42	38
DHA 9	83	26	76	23	77	23	96	29	107	32	127	38	94	29
Total	**207**	**27**	**223**	**29**	**208**	**27**	**250**	**32**	**269**	**34**	**309**	**39**	**245**	**33**

*Data for 2000 and 2007 were excluded as they represent cases for partial year only.
**Incidence rates represent major head injuries (numerator) by Nova Scotia census population over 16 years (denominator).

Table 7: Injury-Related Characteristics by Major External Cause of Injury (Nova Scotia Trauma Registry, 2000-2007)

Variable	MVC (Street)* N (%)	Falls N (%)	p-value
Total N	665	674	----
Age in Years, N (%)			
16-24	226 (34.0)	30 (4.5)	0.0001
25-39	141 (21.2)	41 (6.1)	
40-64	193 (29.0)	200 (29.7)	
65 and over	105 (15.8)	403 (59.8)	
Median Age (and SD)	35.0 (20)	70.0 (19)	0.0001
Gender, N (%)			
Male	478 (71.9)	424 (62.9)	0.0001
Female	187 (28.1)	250 (37.1)	
Total	**665 (100)**	**674 (100)**	
ISS mean (and SD)	37.8 (19.0)	21.7 (9.0)	0.0001
Day of Trauma			
Weekday	399 (60)	460 (68.2)	0.0001
Weekend	266 (40)	199 (29.5)	
Time of Trauma			
00:00 a.m. – 06:59 a.m.	139 (20.9)	57 (8.5)	0.0001
7:00 a.m. – 11:59 a.m.	89 (13.4)	98 (14.5)	
12:00 p.m. – 18:59 p.m.	204 (30.7)	117 (17.4)	
19:00 p.m. – 23:59 p.m.	140 (21.1)	70 (10.4)	
Unknown	93 (14.0)	332 (49.3)	
Total	**665 (100)**	**674 (100)**	
Season of Trauma			
Fall	196 (29.5)	164 (24.3)	0.058
Winter	142 (21.4)	175 (26.0)	
Spring	135 (20.3)	151 (22.4)	
Summer	192 (28.9)	181 (26.9)	
Alcohol Level			
No Blood Alcohol Concentration (BAC = 0)	114 (17.1)	46 (6.8)	0.0001
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	34 (5.1)	18 (2.7)	
Positive Blood Alcohol Level, Above Legal Limit (BAC ≥ 17 mmol/L)	172 (25.9)	89 (13.2)	
Blood Alcohol Level Not Tested	365 (51.9)	521 (77.3)	
Total	**665 (100)**	**674 (100)**	
Toxicology Level			
Tested Negative	140 (21.1)	45 (6.7)	0.0001
Tested Positive	59 (8.9)	22 (3.3)	
Not Tested	466 (70.1)	607 (90.1)	
Total	**665 (100)**	**674 (100)**	

*Includes motorcycle, pedestrian and vehicle collisions occurring on road or street

Table 8: Characteristics of Major Head Injuries Caused by MVC (Street)*
(Nova Scotia Trauma Registry, 2000-2007)

Variable	Head Injury Cohort N (%)
Total N	665
Restraint Use (Seatbelt, Helmet, Airbag)	
One Device Used	269 (40.5)
More than One Device Used	43 (6.5)
No Devices Used	207 (31.1)
Unknown	146 (22.0)
Total	**665 (100)**
Vehicle Type	
Passenger Vehicle	389 (58.5)
Light Trucks	90 (13.5)
Motorcycle	62 (9.3)
Pedestrian	88 (13.2)
Other	33 (5.0)
Unknown	3 (0.5)
Total	**665 (100)**
Ejected from Vehicle	
Full ejection	174 (26.2)
Partial ejection	37 (5.6)
No ejection	335 (50.4)
Unknown	119 (17.9)
Total	**665 (100)**
Impact Type	
Approaching, Head On	162 (24.4)
Single Motor Vehicle, Rollover	238 (35.8)
Sideswipe, T-bone	68 (10.2)
Other	82 (12.3)
Unknown	115 (17.3)
Total	**665 (100)**
Position in Vehicle	
Driver	411 (61.8)
Front Seat	76 (11.4)
Back Seat	52 (7.8)
Other/Inappropriate	93 (14.0)
Unknown	33 (5.0)
Total	**665 (100)**

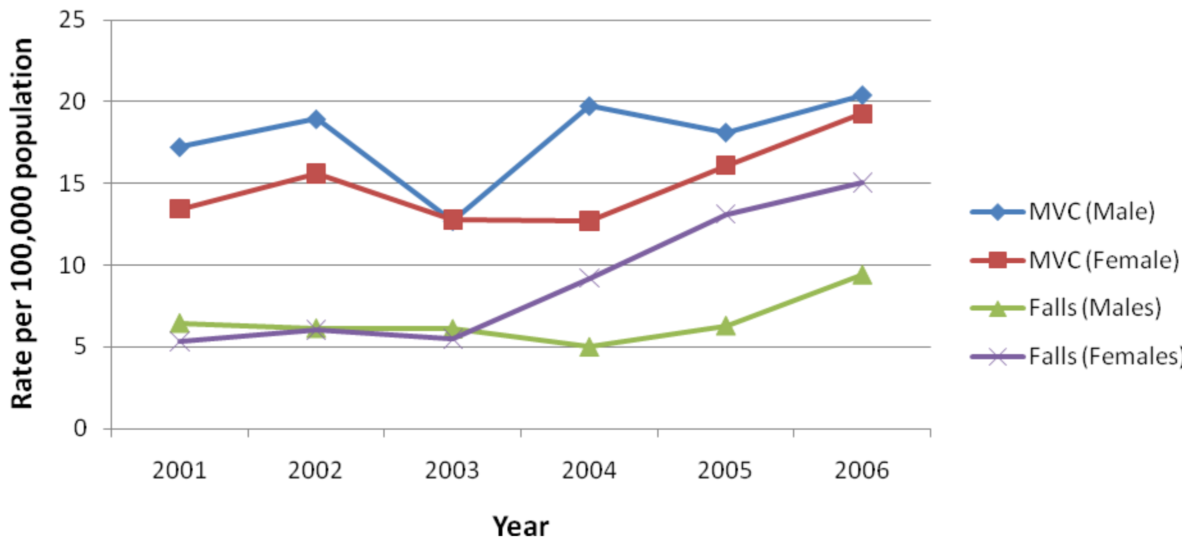
*Includes motorcycle, pedestrian and vehicle collisions occurring on road or street

Table 9: Distribution of Head Trauma Severity by Falls-Related Injury (Nova Scotia Trauma Registry, 2000-2007)

	All Head Trauma N (%)	Serious (HAIS* = 3) N (%)	Severe (HAIS* = 4) N (%)	Critical (HAIS* = 5) N (%)	Maximum (HAIS* = 6) N (%)
Fall on Same Level	164 (24)	14 (24)	102 (25)	48 (23)	0 (0)
Fall < 1 meter	57 (8)	3 (5)	32 (8)	22 (11)	0 (0)
Fall 1- 6 meters	137 (20)	25 (43)	75 (18)	36 (17)	1 (33)
Fall > 6 meters	41 (6)	10 (17)	16 (4)	13 (6)	2 (67)
Fall Not Further Specified	277 (41)	6 (10)	181 (45)	90 (43)	0 (0)
Total	**676 (100)**	**58 (100)**	**406 (100)**	**209 (100)**	**3 (100)**

*HAIS = Head Abbreviated Injury Score

Figure 4: Annual Incidence of Major HI (per 100,000) by Sex and External Cause (Nova Scotia Trauma Registry, 2000-2006)



CHAPTER 5: A POPULATION BASED INVESTIGATION OF RISK AND PROTECTIVE FACTORS FOR BLUNT HEAD INJURY IN NOVA SCOTIA

ABSTRACT

Objective: To examine whether there are unique risk and protective factors for major blunt head injuries with particular attention to the factors related to falls and motor vehicle collision (MVC) injury.

Method: Data from the Nova Scotia Trauma Registry (NSTR) was used from April 1st, 2000 to March 31st, 2007. Subjects 16 years or older who had sustained a major blunt injury in the province of Nova Scotia were included for analyses. Major head injuries were determined using an abbreviated injury score (AIS) of 3 or greater (isolated for head injuries only). Multiple logistic regression modeling was used to examine the effects of demographic, environmental and human factors on the likelihood of sustaining a head injury event.

Results: A total of 2937 patients experienced a major injury during the study period with 1617 (55%) of these involving major injury to the head. The adjusted regression model found gender, injury place, time and the location of injury to be independently associated with the risk of sustaining a head injury event. Head injuries were four times more likely to occur during a fall-event relative to a MVC-event. Separate analyses for MVC-related injury found higher odds of head injury for pedestrians compared to vehicle occupants. Significantly lower odds were observed among those in motorcycle injury compared to vehicle occupants. Ejection from a vehicle increased the odds for head injury while use of more than one safety devices reduced the odds for head injury. The adjusted model for the falls-related cohort found age, time of trauma and injury place to be related to a head injury event. Interestingly, falls that occurred from 3 categorized heights were less likely to result in a head injury relative to falls occurring at the same level.

Conclusion: The purpose of this study was to identify unique risk and protective factors for head injury that are amenable to public health prevention. Results showed that when compared to other major types of injuries, only a small number of factors were unique to the head injury event. This suggests that major head injuries share similar pre-event and event-related characteristics to other severe injuries. Public health interventions that address multiple risk factors can therefore play a major role in the prevention of all types of injuries including head-related injury.

Key words: Major head injuries, epidemiology, population-based study

INTRODUCTION

Traumatic injuries are the leading cause of death for Canadians under the age of 45, contributing to more potential years of lost life (PYLL) than any other disease process including cardiovascular disease and cancer (36). Head injured patients represent a unique and important injury group as they tend to be the most severely injured (78). In Canada, approximately 17,000 patients are admitted to hospital with a head injury every year, accounting for 9% of hospital-related injury admissions (77). Head injuries can have a profound impact on the lives of those affected. Patients who survive a head injury often suffer significant lifelong disability that can pervasively impair areas of physical, emotional and social functioning (77). The societal costs following a head injury can be substantial as treatment and provision of support services are often needed long-term or even permanently (205). Reducing the burden of head injuries is therefore of considerable public health importance.

The traditional view of injuries as "accidents" or random events has resulted in the historical neglect of this important area of public health. Identifying and positioning injuries as a major public health problem over the past few decades has resulted in greater awareness that, similar to most other diseases, injuries and their precipitating events can be predicted and prevented (70,206). Haddon's Matrix is a conceptual model that has been widely used in injury control research for the systematic and comprehensive examination of injuries. Under this model, variables relevant to injury aetiology and prevention are measured as they relate to both the epidemiological triad (host, agent and environment) and the time of the event (pre-injury, injury and post-injury) (70).

Much of the head injury research can be divided into two broad areas: 1) studies focusing on the post-injury phase, which are aimed at identifying head injury outcomes (mortality, severity, prognosis, and rehabilitation) and associated factors such as relevant clinical and demographic variables; and 2) studies aimed at understanding the pre-injury or injury phase. Fewer studies have examined the risk and protective factors associated with the pre-injury and injury stage; that is, factors occurring before or during the head injury event. Understanding factors pertaining to these two important stages of injury can be critical to efforts in reducing head injuries and their consequences. Studies have estimated that 30% to 90% of all deaths attributable to injuries could be prevented in the pre-injury stage (207-209). Informed by Haddon's Matrix, the focus of the current study is to examine the risk and protective factors for head injuries that occur during the pre-injury and injury stages while adjusting for important injury covariates.

Head injury-related morbidity and mortality is most commonly the result of motor vehicle collisions (MVCs) and falls (36,77) and particular groups or populations have an increased risk of these head injury events. For MVCs, the individuals at greatest risk are typically those aged 15 to 24 years, with males reported to be two to three times more likely than females to sustain a MVC-related head injury (14,18,22,193). Women are more likely to experience falls-related injuries, particularly as older adults (210). These trends are almost universal in the published literature and have been the rationale for prevention measures targeted to these high risk groups.

Beyond age and gender, other important factors have been associated with increasing or decreasing the occurrence of head injuries. Key risk factors associated with head injuries are alcohol intoxication and drug use (211), while the use of airbags, seatbelts, child safety restraints and helmets represent important protective factors (38,61,181). Risk patterns for injury by time of day have also been explored with particular attention to the role of time on MVC risk. Studies have shown that nighttime travel (especially after midnight) enhances the risk for injury compared to daytime travel for all driver groups, but is disproportionately higher among young drivers (212).

Two questions emerge from existing head injury research. First, are the pre-injury and injury related risk and protective factors unique to head injuries? In other words, are the characteristics associated with head injuries different from those associated with non-head injuries? Second, are the similarities or differences between head injuries and non-head injuries consistent across different injury mechanism – particularly for falls and MVCs?

This study aims to address these questions using provincial trauma registry data from the Nova Scotia Trauma Registry. The NSTR captures a number of pre-injury and injury-related variables and is therefore an excellent data source to examine factors for head injury. Variables examined in this study include: demographic (age, sex) environmental (time of injury, day of week, season, and location of injury) and human factors (blood alcohol concentration, drug use, safety restraints). The trauma registry also collects important collision related data (location from vehicle, ejection from vehicle, position in vehicle, and impact type) and falls-related data. The NSTR is described below in further detail.

METHODS

Data Source

The NSTR was the sole data source for this study. The NSTR collects and analyzes information on all major traumas sustained in the province of Nova Scotia and includes the comprehensive data set (CDS) and the death data set (DDS). Data contained in the CDS is collected from extensive manual chart reviews collected by a team of health care professionals (nurses, paramedics, health records personnel) several months following a patient's discharge. The CDS includes information pertaining to the nature of the injury and trauma event, patient demographics, the type and severity of injuries, the processes of care, procedures and treatments provided following injury, and the discharge outcome. The death data set (DDS) provides detailed data on deaths at the scene, en route, or on arrival at a primary trauma center where registry data is not otherwise collected. Collectively, these two datasets represent patients sustaining a major trauma event who were admitted to the province's 10 district trauma centers and/or tertiary trauma centres as well as traumas resulting in traumatic scene deaths province-wide (196).

Cases are selected for inclusion into the trauma registry primarily using the Injury Severity Score (ISS) but full Trauma Registry inclusion criteria are described in appendix B. The ISS is a composite measure of the Abbreviated Injury Score (AIS) used to summarize the extent of injury in a trauma patient. The AIS is an anatomically based system that uses a 6-point ordinal scale in six body regions that ranges from AIS 1 (minor) to AIS 6 (unsurvivable) (28,55). The ISS is calculated by summing the squares of the highest AIS grade in each of the three most severely injured separate body areas with a score ranging from 0 to 75; the higher the ISS, the greater the severity of the injury (28).

Several steps were taken to ensure data quality, accuracy and completeness. Registry software provides automated internal edit checks performed as every case is completed. Data is also visually examined by the provincial trauma registrar as data is transferred from the individual institutional databases and annual re-abstracting audits are completed for 10% of randomly selected cases. In addition, NSTR submits data annually to the National Trauma Registry, which is managed by the Canadian Institute for Health Information (CIHI). Following the annual data submission, CIHI provides an error report that serves to identify coding errors not identified through other data quality procedures. The NSTR has been used to support other peer-reviewed research (11,197-199).

Selection of Participants

The study period was April 1, 2000 to March 31, 2007. To be eligible for inclusion in this study, subjects must have sustained a major blunt injury in the province of Nova Scotia, be aged 16 years or older, and have recorded AIS and ISS scores. Patients excluded from analysis included major burns, penetrating trauma, as well as traumas sustained outside of Nova Scotia but receiving care at one of the provinces' district or tertiary trauma centers. This study was approved by the Research Ethics Board of the Capital District Health Authority in Halifax, Nova Scotia, Canada.

Data Elements and Definitions

Major Blunt Trauma Defined

The term "major blunt trauma" was based on the criteria used by the Canadian Institute of Health Information National Trauma Registry (NTR) which defines trauma as "injury resulting from the transfer of energy (e.g. kinetic, thermal) with an ISS greater than 12 and an appropriate ICD external cause of injury (E-code) (77). All 23 trauma centers in Canada that provide data to the NTR have adopted this working definition of "major trauma" in order to provide consistent data collection and reporting. As such, inclusion in the NSTR requires blunt trauma based on the above definition and an ISS $\geq$ 12 (36).

Falls Defined

Falls were defined using the definition used by the International Classification of Diseases (ICD 9) which states that a fall "is an unexpected event where a person falls to the ground from an upper level or the same level" (213).

Motor Vehicle Collisions Defined

A motor vehicle collision (MVC) was defined as any off-road or on-road vehicle involving injury to a person inside or external to the vehicle. Types of vehicle included in the study include the following: Passenger vehicles, Motorcycles, Bus, Heavy Trucks (> Half ton), Light trucks (vans pickup trucks, Sport Utility Vehicle), Transport trucks, Logging Trucks, All-Terrain Vehicles (ATVs), recreational vehicles, snowmobiles, and tractors. Under this definition, pedestrians and bicyclists involved in a collision with a motor vehicle were included in the analyses.

Outcome variable

In this study, major head injury (HI) was defined as any patient with an Abbreviated Injury Score (AIS) of 3 or greater (isolated for head injuries only) and an ISS $\geq$ 12. AIS is an anatomical scoring system that uses a numerical method to rank and compare injuries by severity in seven body regions –head and neck, face, chest and thorax, abdomen, extremities, external/burns (55). Under this definition, isolated head injuries as well as head injuries combined with an injury to another body region were included in the study provided they met the trauma registry inclusion criteria. This operational definition was designed to capture injury events that resulted in significant injury to the head including basal and vault skull fractures, intracranial vessel injuries and/or internal organ injuries to the brain stem, cerebellum or cerebrum. Use of the AIS classification system has been widely used in epidemiological studies of head injury (29-33). The comparison group consisted of non major-head injured patients who had sustained a major blunt injury (ISS $\geq$ 12) without an AIS $\geq$ 3 for the head.

Covariates

Age, sex and District Health Region were the sole demographic data elements. The geographic location of injury was categorized into the 9 District Health Regions found in Nova Scotia.

Injury related variables included day of injury event (weekend, weekday), season of injury event (fall, winter, spring, summer), time of injury (00:00 a.m. – 6:59 a.m.; 7:00 a.m. – 11:59 a.m.; 12:00 p.m. – 18:59 p.m.; 19:00 p.m. – 23:59 p.m.) and injury place categorized as home, road, and other.

Human characteristics included data elements specific to blood alcohol concentration (BAC) and drug use. BAC was categorized as follows: 1) "No Blood Alcohol Level (BAC = 0), 2) "Positive Blood Alcohol Level, Below Legal Limit (<0mmol/L < 17 mmol/L), 3) "Positive Blood Alcohol, Above Legal Limit" (BAC $\geq$ 17 mmol/L) and 4) "Blood Alcohol Level Not Tested". Drug use was reported as "positive" if patients receiving toxicology testing were found to be positive for one or more drugs. Patients were reported as "negative" if they received toxicology testing and were not found to have any drugs in their system, while those who did not receive testing for drug use were reported as "not tested".

Analysis specific to falls included the NSTR categorization of mechanism of injury as “fall on the same level”; “fall less than 1 meter (3.3 feet)”; “fall 1-6 meters (3.3 – 19.7 feet)”; “falls greater than 6 meters (19.7 feet)” and “fall not further specified”.

MVC collision-related variables included vehicle type (passenger vehicle, light trucks, motorcycles, ATV, pedestrian, other) and ejection status following the collision (full ejection, partial ejection, no ejection). Safety restraints (the use of seatbelt, helmet and/or airbags) were classified as: “one restraint used”, “more than one restraint used” and “no restraint used”. Impact type was classified as: “approaching head on”; “single motor vehicle, rollover”; “sideswipe, T-bone” and “other”.

It should be noted that for some variables there were unknown responses. A separate category was created for unknown responses and included in all analyses, though not reported. No effort at imputation was utilized for any missing interval or ratio data.

Statistical Analysis

All statistical analyses were performed using SPSS statistical software (SPSS version 17.0, SPSS Inc., Chicago, IL). Descriptive analyses were performed, followed by unadjusted and adjusted logistic regression models. Chi-Squared tests for categorical variables and nonparametric Wilcoxon rank sum test for continuous variables were used in the unadjusted analyses to measure the strength of association and to assess the potential for confounding. As an exploratory analysis, we employed multiple logistic regression models to examine the effects of demographic, environmental and human factors on the likelihood of sustaining a head injury event. Three regression models were run to assess the risk factors for sustaining a head injury and whether these risk factors varied by injury mechanism. For each model, covariates were determined based on risk and protective factors identified in the literature and the variables available from the NSTR. The first model included all major blunt injuries in the province of Nova Scotia over the study period adjusted for demographic factors (age, gender), environmental factors (day, time, season, place of injury and injury mechanism) and human factors (alcohol use and drug use). The second model included blunt injuries sustained during a motor vehicle collision adjusting for the same variables included in the first model as well as the following collision-related variables: vehicle type, ejection from vehicle, impact type and restraint use. The third model was specific to blunt injuries sustained during a fall adjusting for the same variables described in model one. Relevant interaction terms were entered into the models where appropriate. All regression models used maximum likelihood (ML) estimators to estimate the model. ML estimators find the parameter values that make the observed data most likely and are unbiased estimators in large samples (214).

Results are expressed as adjusted odds ratios (OR) with corresponding 95% confidence intervals (CI). All tests of significance were two-sided and the significance level was set at $p<0.05$.

Additionally, a test for multicollinearity was performed on variables included in all models. An examination of collinearity diagnostics (tolerance and variance inflation factors) revealed no issues of multicollinearity.

RESULTS

Descriptive Results

A total of 2937 patients experienced a major injury during the study period with 1617 (55%) of these involving major injury to the head (AIS $\geq$ 3). A comparison of head injuries with non-head injuries is presented in Table 10. Arithmetic injury severity was greater in the pure HI cohort as indicated by the mean injury severity scores (29 vs. 21; p=0.0001). The age distribution of those individuals sustaining a major head injury was significantly different than those with a major non-head injury, with a greater proportion of head injuries occurring among those 65 and older, while most non-head injuries were among those 40-64 years. While significant differences were observed by location of injury, the highest proportion of injuries for both groups were found to occur in the largest urban centres of Nova Scotia with 609 (38%) of major head injuries and 392 (30%) major non-head injuries occurring in the Capital Health District Authority (Halifax) where 43% of the population of Nova Scotia resides. Differences by mechanism of injury were observed between the two comparison groups with 45% of head injuries and 64% of non-head injuries due to an MVC. Similarly, differences were also observed for alcohol levels and drug use, with higher testing rates and a higher proportion of individuals with recorded alcohol levels and drug use among those sustaining major head injuries. No significant differences were observed between the two comparison groups for gender, day of trauma, and season of trauma.

Comparison of MVC-related head injuries to MVC-related non-head injuries is presented in Table 11. Differences in vehicle type were observed between the two groups with passenger vehicles (55%) and light trucks (11%) contributing to the greatest proportion of major head injuries. Conversely, a large proportion of major non-head injuries involved passenger vehicles (54%) and motorcycles (13%). No significant difference in the proportion of individuals ejected from their vehicle were observed between the two groups with 33% of the major head injured cohort reported to be either fully or partially ejected from their vehicles, while 29% of major non-head injuries reporting full or partial ejection from their vehicles (data not shown).

Although differences in the use of safety restraints (seatbelt, helmet, airbags) were observed between the two groups, the proportion of those who used more than one safety device was highest for both groups (40% versus 47% respectively), followed by those who reported using one safety device (32% versus 25% respectively).

A comparison between falls-related head injuries with falls-related non-head injuries is presented in Table 12. Significant gender differences were observed between the two groups with females sustaining 37% of major head injuries while only 28% of non-head related injuries were observed among females. Although not clinically significant, statistical differences in age distribution were observed between the two groups with the mean age reported to be 66 years among major head injuries compared to 61 years among major non-head injuries. Differences in the distribution by mechanism of injury were also observed between the two groups. The greatest proportion of head injuries were reported among falls not further specified (41%) followed by falls occurring on the same level (24%). Conversely, the proportion of non-head injuries were highest among falls occurring at heights from 1-6 meters (40%) followed by falls not further specified (21%).

Regression Results – All Major Injuries

Logistic regression results comparing head injuries to non-head injuries are presented in Table 13. Results were limited as only a small number of factors were found to be independently associated with the risk of sustaining a head injury event. Adjusted results indicate that the odds of a head injury were higher for females versus males, and to occur on the street rather than in the home. Additionally, the odds of a head injury were higher between midnight and 6:59 a.m. relative to other times, and to occur in Cape Breton District Health Authority (OR 1.5, CI: 1.03 – 2.04) and the Capital District Health Authority (OR 1.5, CI: 1.0 -2.03), relative to other regions in Nova Scotia. Finally, the odds of a head injury were four times more likely to occur during a fall relative to MVCs (OR 3.9, CI: 2.8 – 5.4). Alcohol consumption and drug use were not associated with the likelihood of a head injury relative to a non-head injury.

Regression Results – Motor Vehicle Collisions

Adjusted regression models comparing MVC-related head injuries to MVC-related non-head injuries are shown in Table 14. The odds of sustaining a head injury were lower among those involved in an off-road event as compared to injuries occurring on the street (OR 0.5, CI: 0.31 – 0.84), and lower among motorcyclists relative to other vehicle types (OR: 0.6, CI: 0.39 – 0.98). Conversely, higher odds of sustaining a head injury were observed among pedestrians compared to other vehicle types (OR: 2.9, CI: 1.5 – 5.5), and for those fully ejected from their vehicle (OR: 1.4, CI: 1.03 – 1.96) and those partially ejected from their vehicle (OR: 1.8 CI: 1.05 – 3.20), when compared to those who were not ejected from their vehicle. Finally, the odds of sustaining a head injury were lower when more than one safety device was used (OR: 0.57, CI: 0.36 – 0.90) when compared to those where no safety device was used.

Regression Results – Falls

Table 15 presents the logistic regression model for the falls-related cohort. A key factor was age, where advancing age increased the odds of sustaining a head injury event. The odds of a head injury were lower between 19:00 p.m. and 23:59 p.m. relative to midnight and 6:59 a.m. In addition, the odds of sustaining a head injury were more likely to occur in the Cape Breton District Health Authority (OR 1.9, CI: 1.02 – 3.45) and the Capital District Health Authority (OR 1.9, CI: 1.10 -3.31) relative to other regions. Relative to falls occurring at the same level, head injuries were less likely to occur among falls from a height of less than one meter (OR: 0.29, CI: 0.17 – 0.51); falls occurring at a height of 1-6 meters (OR: 0.23, CI: 0.14 – 0.37); and falls occurring at a height greater than one meter (OR: 0.14, CI: 0.08 – 0.28).

The explained variance for all logistic regression models was less than 25% suggesting that other important explanatory variables have not been measured. Low alcohol and drug testing rates observed in the Emergency Department are likely to have affected the study findings. Other factors that may be important in understanding head injury risk may include individual socioeconomic status, indicators such as education and household income, psychosocial indicators such as risk taking propensity as well as measures of comorbidity (such as the Charlson Index that aims to account for chronic medical conditions such as systemic anticoagulation, diabetes, and congestive heart failure).

DISCUSSION

This study endeavored to identify risk and protective factors unique to head injuries relative to other major injuries using a large population-based dataset. Head injuries are an important injury group to examine as they often incur severe, disabling sequalae. Examination of factors unique to head injury etiogenesis can potentially help reduce the burden of injury by identifying important environmental and human factors amenable to prevention.

This study drew on HM as a conceptual model for identifying important pre-injury and injury-related factors relevant to the injury event. Trico et al. used HM to identify and characterize pre-event and event-related risk factors for traumatic brain injuries (TBIs) sustained within the workplace setting. Using data obtained from the Chief Coroner's Office of Ontario from 1996-2000, a broad range of contributing factors related to host, agent and physical environment were examined (71). The study found that workers aged 20-44 and 50-64 as well as those in construction, transportation, logging and agriculture industries were at greatest risk of sustaining a TBI. Injuries from falls and motor-vehicle collisions were also a major cause of mortality among the head injured cohort. However, the narrow scope of patients studied and the lack of control for confounders prevented a population-based assessment of the risk and protective factors involved in sustaining a head injury event. The NSTR used in this study served as a rich data source as it captures important variables related to the circumstances of injury including key factors specific to falls and motor vehicle collisions. Use of this population-based dataset also enabled the identification of independent risk and protective factors for head injury while controlling for important injury covariates.

The adjusted regression model of all major injuries found gender, injury place, mechanism of injury, time and the location of injury to be independently associated with the risk of sustaining a head injury event. The odds of sustaining a head injury were four times higher during a fall compared to MVC injuries. Examination of all injuries found the odds for head injuries to be greatest between midnight and early morning. Although this association remained in the falls adjusted model, the study did not find time of injury to be an independent factor for head injury risk among those injured in MVCs. Adjusted risk for head injuries was highest in the two largest urban centres of Nova Scotia, specifically in the Capital Health District Authority (containing the city of Halifax) and the Cape Breton Health Authority (containing the city of Sydney). Although reasons for these observed study findings are unclear, they do suggest unique patterns for head injury among those residing in urban settings particularly among the falls-related cohort. Factors that may increase head injury risk in urban areas may include important contextual factors such as a higher proportions of urban violence, the built environment (uneven pavements, wet or slippery surfaces, abrupt changes in elevation), human activity patterns (e.g. movement through busy street junctions and higher density of pedestrians), as well as changing weather conditions (rain, sleet, and snow).

MVC-Related Injury

Separate analyses were conducted for MVC-related injury to identify unique and common factors for head injury among this cohort. Not surprisingly, the odds for head injury were three times higher for pedestrians when compared to vehicle occupants. This is consistent with other studies that have demonstrated that compared to injured vehicle occupants, pedestrians are more likely to sustain multisystem injuries, have higher injury severity scores and incur a greater risk for mortality (215,216). Although evaluation of vehicle design on the type and severity of pedestrian injuries was not the focus of this current study, Roudsari and colleagues, found that after adjusting for pedestrian age and impact speed, light truck vehicles (LTVs) were associated with three times higher risk of severe injuries when compared to pedestrians struck by passenger vehicles (215). The authors suggest that the unique trajectory pattern of pedestrians struck by LTVs, and the increased likelihood of being run over by the vehicle as it decelerates, increases the risk for more severe forms of injury for pedestrians involved in these types of collisions (61,215).

Significantly lower odds for head injuries were observed among those involved in motorcycle injury. Our data shows that 96% of motorcyclist used helmets. This suggests that compliance in helmet wearing was high among this cohort and provided the necessary protection from serious injury to the head. These findings are congruent with a recent meta-analysis that found motorcycle helmets significantly reduced risk for head injuries by 69% when compared to those who did not use helmets (181). Compared to injuries where no safety device was used, major injuries involving use of more than one safety device (seatbelt, helmet or airbags) resulted in a 43% reduction in head injury risk.

Those ejected from their vehicle (suggesting that safety restraint use was not used) resulted in a 42% to 82% increased risk for head injury. These findings are consistent with the literature, and underscore the importance of safety device use in reducing risk for head injury.

Injury epidemiology has widely recognized males to be at higher risk for head injuries, explained in part by their higher propensity for risk taking (88). These findings contrast to those of Bring and colleagues which found males to be at lower risk of sustaining a head injury compared to female occupants following a motor vehicle collision (217). Reduced risk for head injury among males, it was argued, was due to having greater neck muscle strength and thus less head movement in a collision, in addition to males having greater height and weight leading to better body positioning in the vehicle during impact (217).

Although gender differences were observed in the logistic regression model comparing head injuries to non-head injuries, there were no gender differences observed by mechanism of injury specific to falls and MVCs.

Studies on risk patterns for injury by time of day with particular attention to the role of time on MVC risk have been previously examined. Potential reasons for the observed excess collision risk at nighttime have been proposed and include: reduced visibility (218), driver inexperience (219), fatigue (220,221) and higher incidence of alcohol impairment at night (212,222). After adjusting for relevant covariates, we did not find any evidence that time of injury was an independent factor for head injury in the MVC-injured cohort. This suggests that altered driving conditions imposed by the time of the day may not necessarily pose greater risk of head injury when compared to MVC-related traumas involving injury to other body regions.

Although not a risk factor for head injury in this present study, empirical evidence has found that impact force in a motor vehicle collision is an important determinant in the pattern and severity of injury (157,158,223). Of particular concern are studies that have found head injuries to be more frequent and more severe following lateral collisions (154,157,159,161). One study found occupants in vehicles involved in lateral impacts to be 160% more likely to incur a TBI compared to occupants of vehicle involved in non-lateral impact (154).

Falls-Related Injury

Similar to logistic regression results comparing all head injuries to non-head injuries, the adjusted regression model for the falls-related cohort found the odds of sustaining a head injury to be greatest among injuries occurring in the two largest urban centres of Nova Scotia (Sydney and Halifax). From an environmental perspective, the higher propensity for head injuries observed among urban areas may relate to factors occurring in either the home environment, the external environment (built environment, landscape, weather) or a combination of both. Falls occurring from a height (< 1meter, 1-6 meters and > 6 meters) were less likely to be associated with head injuries compared to falls occurring at the same level. These findings contradict injury patterns observed in the literature as previous studies have shown falls from greater heights result in more severe forms of injury, particularly head injuries.

Relative to other times, the odds of sustaining a head injury were higher between midnight to early morning hours. Although, these differences could not be directly ascertained from this present study, one can postulate that reduced visibility, fatigue or drowsiness, may have potentially contributed to the heightened susceptibility for head injuries during these times. In addition, a combination of intrinsic and extrinsic factors not measured in the current study may increase susceptibility for falls related injury. These factors may include: environmental (poor lighting, slippery floor surfaces), fatigue or drowsiness, the effects of medication use (e.g. antidepressants, sedatives and hypnotics), changes associated with aging (poor vision, cognitive impairment), other structural determinants such as income and education and intentional injuries (such as violence and assaults).

Limitations

There are several limitations to this study. Use of the NSTR's dataset captures only "major" traumas requiring hospitalization or trauma team activation as well as traumas resulting in death at the scene. Hence, the dataset does not capture minor and moderate injuries most likely seen on an outpatient basis (such as walk-in clinics and general practitioners offices) nor does it capture individuals treated for injuries in an Emergency Department and discharged without being admitted. Consequently, the study is unable to assess the true burden of the full spectrum of head injuries (minor, moderate and severe) in the province of Nova Scotia.

Trauma Registry abstracts data retrospectively from patient records. These patient records do not always have the variables sought by the NSTR limiting the completeness of the data. Furthermore, measures enabling quantification of motor vehicle collision severity as described in previous injury and biomechanical studies such as change in velocity of the vehicle at the point of impact, energy absorption, steering wheel and column deformity were not examined as this information is not routinely collected by NSTR. In addition, variability in head injury definition and case ascertainment are recurring problems of head injury epidemiology (224). This study identified major head injuries as an AIS ≥ 3 for the head (neck excluded) and meeting the NSTR inclusion of an ISS ≥ 12. It is recognized that isolated head injuries with an AIS = 3 and no other associated injury to other body regions would result in an ISS that is excluded from the NSTR. For example, an isolated blunt head injury with an AIS of 3 and resulting ISS of 9 that does not result in death or trauma team activation does not meet the minimum inclusion criteria of the NSTR. Although it is acknowledged that this is a limitation to the current study, it is also recognized that isolated head injuries with no other contributing injuries are very rare in the clinical setting. Despite these limitations, use of the NSTPR represents the most complete and province-wide data set to investigate the risk and protective factors for significant head injuries in the province of Nova Scotia.

CONCLUSION

Haddon's matrix, the most widely accepted paradigm for injury control, incorporates the epidemiologic triad of host, agent and environment in relation to three temporal dimensions (pre-injury, injury and post-injury). The combination of these two elements provides different windows of opportunity to intervene and prevent primary and secondary injury (64,65). Specifically, such matrices provide a means for identifying and considering, cell by cell, a) current and future allocation of healthcare resources, b) relevant injury research priorities, and c) the implementation of cost-effective countermeasure to reduce the burden of injuries (225).

Informed by Haddon's Matrix, this study highlights the importance of a systematic and comprehensive approach to identifying factors for head injury that are amenable to prevention. Given the exploratory nature of this research, it is recognized that further examination of determinants for head injury is still needed to better our understanding of risk patterns for head injury. Nevertheless, it is worthwhile to consider the public health and research implications of this study. The main objective of this research was to identify characteristics unique to major head injuries when compared to other major trauma groups. Although only a small number of factors emerged as unique to the head injury event, the implications for knowledge translation in the public health sector suggests that major head injuries share similar pre-event and event-related characteristics when compared to other major injuries. As such, comprehensive public health initiatives that address multiple risk factors can serve as a transformative force for the prevention of all types of injury including head-related injury.

The select number of unique factors identified in this study to play a role in head injury risk may be considered as part of any comprehensive injury prevention strategy. For effective health and risk communication, future public health injury prevention strategies may consider the inclusion of messages specific to these factors. In particular, messages highlighting the additional risk for falls-related head injuries (particularly during midnight and early morning hours) and strategies to prevent falls occurring at same level surfaces should be emphasized for future falls-prevention social marketing campaigns. Campaigns targeted to reduce MVC-related injury should continue to promote the importance of safety restraints (helmets, seatbelts, car seats, and airbags) in reducing injury severity. In addition, reducing the number of pedestrian-related head injuries is an important area for injury prevention. This may include messaging encouraging pedestrians to be aware of their surroundings when in contact with motor vehicles as well as ensuring pedestrians are visible to all drivers on the road. Further, environmental modifications such as traffic calming measures should be considered to reduce the number of vehicles in contact with pedestrians.

Future research activities should consider other important contextual factors involved in the injury event to assess the unique risk and protective profile of those involved in head injuries. Examining the effects of alcohol and drug use (particularly poly-pharmacy use) on head injury risk is an important area of research that warrants further investigation. In addition, research activities aimed to collect important data pertaining to the chain of events leading to injury that is not currently captured by the NSTR would further our understanding of those at higher risk for head injuries. Specifically, examining characteristics such as collision speed, degree of vehicle deformity, presence of passengers, and correct use of safety restraints are important factors to consider for MVC-related injury. Factors to consider for falls-related injury include such variables as presence of chronic or acute disease, nutritional status, physical activity levels, medication use, environmental risk factors, and history of previous falls. Research examining these important aspects of injury would be instrumental in informing future public health priority setting and decision making.

Table 10: Descriptive Statistics (Chi-Square) comparing major HI to major non-HI

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Total N	1617	1320	---
Age in Years, N (%)			
16-24	312 (19.3)	232 (17.6)	0.0001
25-39	277 (17.1)	258 (19.5)	
40-64	498 (30.8)	511 (38.7)	
65 and over	530 (32.8)	319 (24.2)	
Total	**1617 (100)**	**1320 (100)**	
Mean Age (and SD)	50.55 (22.9)	48.20 (20.7)	0.004
Gender, N (%)			
Male	1154 (71.4)	963 (73.0)	0.340
Female	463 (28.6)	357 (27.0)	
Total	**1617 (100)**	**1320 (100)**	
ISS mean (and SD)	28.93 (16.5)	21.38 (11.9)	0.0001
Day of Trauma			
Weekday	1037 (64.1)	831 (63.0)	0.281
Weekend	559 (34.6)	487 (36.9)	
Unknown	21 (1.3)	2 (0.2)	
Total	**1617 (100)**	**1320 (100)**	
Injury Place			
Home	467 (28.9)	272 (20.6)	0.0001
Street	741 (45.8)	740 (56.1)	
Other	320 (19.8)	251 (19.0)	
Unknown	89 (5.5)	57 (4.3)	
Total	**1617 (100)**	**1320 (100)**	
Time of Trauma			
00:00 a.m. – 06:59 a.m.	256 (15.8)	147 (11.1)	
7:00 a.m. – 11:59 a.m	215 (13.3)	228 (17.3)	0.0001
12:00 p.m. – 18:59 p.m.	368 (22.8)	381 (28.9)	
19:00 p.m. – 23:59 p.m.	241 (14.9)	198 (15.0)	
Unknown	537 (33.2)	366 (27.7)	
Total	**1617 (100)**	**1320 (100)**	
Season of Trauma			
Fall	444 (27.5)	349 (26.4)	0.154
Winter	375 (23.2)	278 (21.1)	
Spring	343 (21.2)	276 (20.9)	
Summer	449 (27.8)	416 (31.5)	
Unknown	1 (0.1)	6 (0.4)	
Total	**1617 (100)**	**1320 (100)**	

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Location of Injury			
DHA 1 – South Shore	99 (6.1)	117 (8.9)	0.0001
DHA 2- South West	85 (5.3)	93 (7.0)	
DHA 3 – Annapolis Valley	123 (7.6)	135 (10.2)	
DHA 4 – Colchester East Hants	108 (6.7)	109 (8.3)	
DHA 5 – Cumberland	60 (3.7)	47 (3.6)	
DHA 6 – Pictou County	91 (5.6)	73 (5.5)	
DHA 7 – Gysborough	86 (5.3)	77 (5.8)	
DHA 8 – Cape Breton	268 (16.6)	190 (14.4)	
DHA 9 – Capital	609 (37.7)	392 (29.7)	
Unknown	88 (5.4)	87 (6.6)	
Total	**1617 (100)**	**1320 (100)**	
Mechanism of Injury			
MVC*	727 (45.0)	843 (63.9)	0.0001
Fall	674 (41.7)	373 (28.3)	
Other Blunt	216 (13.4)	104 (7.9)	
Total	**1617 (100)**	**1320 (100)**	
Alcohol Use			
No Blood Alcohol (BAC =0)	192 (11.9)	108 (8.2)	0.0001
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	64 (4.0)	34 (2.6)	
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	334 (20.7)	178 (13.5)	
Blood Alcohol Level Not Tested	1027 (63.5)	1000 (75.8)	
Total	**1617 (100)**	**1320 (100)**	
Drug Use			
Toxicology Screen Negative	221 (13.7)	94 (7.1)	0.0001
Toxicology Screen Positive	101 (6.2)	35 (2.7)	
Not Tested	1295 (80.1)	1191 (90.2)	
Total	**1617 (100)**	**1320 (100)**	

* MVC: Includes occupants of a motor vehicle and/or pedestrian and bicyclists struck by a motor vehicle that occurred on a street, highway or off-road

Table 11: Descriptive Statistics (Chi-Square) comparing MVC-related major head injuries to MVC-related major non-head injuries

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Total N	723	832	---
Age in Years, N (%)			0.0001
16-24	240 (33.2)	205 (24.6)	
25-39	163 (22.5)	193 (23.2)	
40-64	209 (28.9)	311 (37.4)	
65 and over	111 (15.4)	123 (14.8)	
Total	**723 (100)**	**832 (100)**	
Mean Age (and SD)	39.6 (19.8)	832 (42.5)	0.003
Gender, N (%)			
Male	528 (73.0)	599 (72.0)	0.649
Female	195 (27.0)	233 (28.0)	
Total	**723 (100)**	**832 (100)**	
ISS mean (and SD)	37.3 (18.8)	22.6 (12.1)	0.0001
Day of Trauma			
Weekday	435 (60.2)	501 (60.2)	0.984
Weekend	288 (39.8)	331 (39.8)	
Total	**723 (100)**	**832 (100)**	
Injury Place			
Street	665 (92.0)	721 (86.7)	0.010
Other	47 (6.5)	83 (10.0)	
Unknown	11 (1.5)	28 (3.4)	
Total	**723 (100)**	**832 (100)**	
Time of Trauma			
00:00 a.m. – 06:59 a.m.	152 (21.0)	113 (13.6)	0.002
7:00 a.m. – 11:59 a.m	93 (12.9)	133 (16.0)	
12:00 p.m. – 18:59 p.m.	221 (30.6)	251 (30.2)	
19:00 p.m. – 23:59 p.m.	153 (21.2)	140 (16.8)	
Unknown	104 (14.4)	195 (23.4)	
Total	**723 (100)**	**832 (100)**	
Season of Trauma			
Fall	212 (29.3)	220 (26.4)	0.300
Winter	158 (21.9)	169 (20.3)	
Spring	145 (20.1)	170 (20.4)	
Summer	208 (28.8)	273 (32.8)	
Total	**723 (100)**	**832 (100)**	

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Location of Injury			
DHA 1 – South Shore	50 (6.9)	69 (8.3)	0.256
DHA 2- South West	47 (6.5)	55 (6.6)	
DHA 3 – Annapolis Valley	74 (10.2)	96 (11.5)	
DHA 4 – Colchester East Hants	58 (8.0)	83 (10.0)	
DHA 5 – Cumberland	34 (4.7)	23 (2.8)	
DHA 6 – Pictou County	44 (6.1)	39 (4.7)	
DHA 7 – Gysborough	47 (6.5)	43 (5.2)	
DHA 8 – Cape Breton	115 (15.9)	121 (14.5)	
DHA 9 – Capital Health	214 (29.6)	242 (29.1)	
Unknown	40 (5.5)	61 (7.3)	
Total	**723 (100)**	**832 (100)**	
Vehicle Type			
Passenger Vehicle	395 (54.6)	445 (53.5)	0.0001
Light Trucks	79 (10.9)	98 (11.8)	
Motorcycle	63 (8.7)	105 (12.6)	
ATV	49 (6.8)	78 (9.4)	
Pedestrian	95 (13.1)	49 (5.9)	
Other	42 (5.8)	57 (6.9)	
Total	**723 (100)**	**832 (100)**	
Ejected from Vehicle			
No ejection	348 (48.1)	468 (56.3)	0.009
Full ejection	203 (28.1)	219 (26.3)	
Partial ejection	38 (5.3)	25 (3.0)	
Unknown	134 (18.5)	120 (14.4)	
Total	**723 (100)**	**832 (100)**	
Impact Type			
Approaching, Head On	167 (23.1)	209 (25.1)	
Single Motor Vehicle, Rollover	271 (37.5)	330 (39.7)	0.343
Sideswipe, T-bone	69 (9.5)	84 (10.1)	
Other	91 (12.6)	86 (10.3)	
Unknown	125 (17.3)	123 (14.8)	
Total	**723 (100)**	**832 (100)**	

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Restraint Use (Seatbelt, Helmet, Airbag)			
One Device Used	230 (31.8)	205 (24.6)	0.0001
More than One Device Used	291 (40.2)	387 (46.5)	
No Device Used	43 (5.9)	101 (12.1)	
Unknown	159 (22.0)	139 (16.7)	
Total	**723 (100)**	**832 (100)**	
Alcohol Use			
No Blood Alcohol (BAC =0)	124 (17.2)	91 (10.9)	0.0001
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	36 (5.0)	30 (3.6)	
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	195 (27.0)	144 (17.3)	
Blood Alcohol Level Not Tested	368 (50.9)	567 (68.1)	
Total	**723 (100)**	**832 (100)**	
Drug Use			
Toxicology Negative	153 (21.2)	73 (8.8)	0.0001
Toxicology Positive	63 (8.7)	30 (3.6)	
Not Tested	507 (70.1)	729 (87.6)	
Total	**723 (100)**	**832 (100)**	

Table 12: Descriptive Statistics (Chi-Square) comparing falls-related HI to falls-related major non-HI

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Total N	674	373	---
Age in Years, N (%)			
16-24	30 (4.5)	17 (4.6)	0.0001
25-39	41 (6.1)	42 (11.3)	
40-64	200 (29.7)	137 (36.7)	
65 and over	403 (59.8)	177 (47.5)	
Total	**674 (100)**	**373 (100)**	
Mean Age (and SD)	65.88 (18.9)	60.8 (19.5)	0.0001
Gender, N (%)			
Male	424 (62.9)	268 (71.8)	0.003
Female	250 (37.1)	105 (28.2)	
Total	**674 (100)**	**373 (100)**	
ISS mean (and SD)	21.7 (9.0)	18.5 (9.5)	0.0001
Day of Trauma			
Weekday	460 (68.2)	249 (66.8)	0.340
Weekend	199 (29.5)	123 (33.0)	
Unknown	15 (2.2)	1 (0.3)	
Total	**674 (100)**	**373 (100)**	
Injury Place			
Home	416 (61.7)	240 (64.3)	0.089
Street	38 (5.6)	10 (2.7)	
Other	182 (27.0)	101 (27.1)	
Unknown	38 (5.6)	22 (5.9)	
Total	**674 (100)**	**373 (100)**	
Time of Trauma			
00:00 a.m. – 06:59 a.m.	57 (8.5)	24 (6.4)	0.160
7:00 a.m. – 11:59 a.m	98 (14.5)	74 (19.8)	
12:00 p.m. – 18:59 p.m.	117 (17.4)	90 (24.1)	
19:00 p.m. – 23:59 p.m.	70 (10.4)	47 (12.6)	
Unknown	332 (49.3)	138 (37.0)	
Total	**674 (100)**	**373 (100)**	
Season of Trauma			
Fall	164 (24.3)	100 (26.8)	
Winter	175 (26.0)	89 (23.9)	
Spring	151 (22.4)	77 (20.6)	
Summer	181 (26.9)	107 (28.7)	
Total	**674 (100)**	**373 (100)**	

Variable	Major Head Injury Cohort N (%)	Major Non-Head Injury Cohort N (%)	p-value
Location of Injury			
DHA 1 – South Shore	41 (6.1)	37 (9.9)	0.001
DHA 2- South West	26 (3.9)	24 (6.4)	
DHA 3 – Annapolis Valley	41 (6.1)	34 (9.1)	
DHA 4 – Colchester East Hants	37 (5.5)	19 (5.1)	
DHA 5 – Cumberland	22 (3.3)	17 (4.6)	
DHA 6 – Pictou County	38 (5.6)	27 (7.2)	
DHA 7 – Gysborough	31 (4.6)	28 (7.5)	
DHA 8 – Cape Breton	118 (17.5)	52 (13.9)	
DHA 9 – Capital Health	288 (42.7)	118 (31.6)	
Unknown	32 (4.7)	17 (4.6)	
Total	**674 (100)**	**373 (100)**	
Mechanism of Injury			
Fall (< 1 meter)	56 (8.3)	48 (12.9)	0.0001
Fall (1-6 meters)	136 (20.2)	150 (40.2)	
Fall (> 6 meters)	41 (6.1)	53 (14.2)	
Fall Not Further Specified	277 (41.1)	80 (21.4)	
Fall on the Same Level	164 (24.3)	42 (11.3)	
Total	**674 (100)**	**373 (100)**	
Intent of Injury			
Unintentional	635 (94.2)	354 (94.9)	0.916
Self-Inflicted	18 (2.7)	10 (2.7)	
Homicide/Assault	1 (0.1)	1 (0.3)	
Unknown	20 (3.0)	8 (2.1)	
Total	**674 (100)**	**373 (100)**	
Alcohol Use			
No Blood Alcohol (BAC =0)	46 (6.8)	10 (2.7)	
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	18 (2.7)	2 (0.5)	0.0001
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	89 (13.2)	26 (7.0)	
Blood Alcohol Level Not Tested	521 (77.3)	335 (89.8)	
Total	**674 (100)**	**373 (100)**	
Drug Use			
Toxicology Negative	45 (6.7)	12 (3.2)	0.005
Toxicology Positive	22 (3.3)	4 (1.1)	
Not Tested	607 (90.1)	357 (95.7)	
Total	**674 (100)**	**373 (100)**	

Table 13: Regression Model – All Major Injuries

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Gender								
Males	0.9	0.8 – 1.1	0.34	0.910	0.84	0.70 – 0.99	0.049	3.890
Females (Reference)	1.0	---	---	---	---	---	---	---
Age, y	1.01	1.0 – 1.01	0.004	8.315	1.0	0.99 – 1.01	0.117	2.457
ISS	1.0	1.0 – 1.1	0.0001	153.2	---	---	---	---
Day of Trauma								
Weekday (Reference)	1.0	---	---	---	---	---	---	---
Weekend	0.9	0.8 – 1.1	0.28	1.162	0.92	0.78 – 1.08	0.320	0.990
Injury Place								
Home (Reference)	1.0	---	---	---	---	---	---	---
Street	0.6	0.5 – 0.7	0.000	34.126	1.92	1.36 – 2.72	0.0001	13.459
Other	0.7	0.6 – 0.9	0.009	6.854	1.05	0.81 – 1.36	0.728	0.121
Time of Trauma								
00:00 a.m. – 06:59 a.m. (Reference)	1.0	---	---	---	---	---	---	---
7:00 a.m. – 11:59 a.m.	0.5	0.4 – 0.7	0.0001	19.1	0.59	0.43 – 0.80	0.001	11.609
12:00 p.m. – 18:59 p.m.	0.6	0.4 – 0.7	0.0001	21.6	0.65	0.49 – 0.85	0.002	9.932
19:00 p.m. – 23:59 p.m.	0.7	0.5 – 0.9	0.01	6.4	0.74	0.55 – 0.99	0.043	4.110
Season of Trauma								
Fall	1.2	1.0 – 1.4	0.096	2.773	1.17	0.95 – 1.43	0.137	2.211
Winter	1.3	0.9 – 1.4	0.033	4.563	1.20	0.86 – 1.33	0.100	2.704
Spring	1.2	1.0 – 1.5	0.182	1.780	1.07	0.97 – 1.49	0.542	0.373
Summer (Reference)	1.0	---	---	---	---	---	---	---
Location of Injury								
DHA 1 – South Shore (Reference)	1.0	---	---	---	---	---	---	---
DHA 2 – South West	1.1	0.7 – 1.6	0.7	0.144	0.96	0.64 – 1.47	0.865	0.029
DHA 3 – Annapolis Valley	1.1	0.7 – 1.5	0.7	0.160	1.06	0.72 – 1.54	0.780	0.078
DHA 4 – Colchester East Hants	1.2	0.8 – 1.7	0.4	0.672	1.17	0.79 – 1.74	0.434	0.613
DHA 5 – Cumberland	1.5	0.9 – 2.4	0.08	2.989	1.36	0.84 – 2.21	0.213	1.549
DHA 6 – Pictou County	1.5	1.0 – 2.2	0.06	3.464	1.35	0.88 – 2.07	0.170	1.885
DHA 7 – Gysborough	1.3	0.9 – 2.0	0.20	1.781	1.24	0.81 – 1.90	0.319	0.995
DHA 8 – Cape Breton	1.7	1.2 – 2.3	0.002	9.447	1.45	1.03 – 2.04	0.031	4.636
DHA9 – Capital Health	1.8	1.4 – 2.5	0.001	16.16	1.49	1.10 – 2.03	0.011	6.442
Mechanism								
MVC* (Reference)	1.0	---	---	---	---	---	---	---
Fall	2.1	1.8 – 2.5	0.0001	81.34	3.91	2.81 – 5.43	0.0001	66.214
Other Blunt	2.4	1.9 – 3.1	0.0001	45.96	4.0	2.82 – 5.68	0.0001	59.838

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Alcohol Use								
No Blood Alcohol (BAC =0)	1.0	---	---	---	---	---	---	---
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	1.1	0.7 – 1.7	0.815	0.055	1.11	0.67 – 1.82	0.688	0.162
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	1.1	0.8 – 1.4	0.722	0.126	1.09	0.79 – 1.51	0.591	0.288
Blood Alcohol Level Not Tested	0.6	0.4 – 0.7	0.0001	18.31	0.64	0.48 – 0.87	0.004	8.239
Drug Use								
Toxicology Negative (Reference)	1.0	---	---	---	---	---	---	---
Toxicology Positive	1.2	0.8 – 1.9	0.376	0.783	1.29	0.81 – 2.07	0.282	1.155
Not Tested	0.5	0.4 – 0.6	0.0001	35.45	0.53	0.39 – 0.72	0.0001	16.773
Nagelkerke R Square	---	---	---	---	0.130	---	---	---

Table 14: Regression Model – Motor Vehicle Collisions

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Gender								
Males	1.05	0.8 – 1.3	0.65	0.207	0.93	0.72- 1.20	0.597	0.279
Females (Reference)	1.0	---	---	---				
Age, y	0.99	1.0 – 1.0	0.003	8.536	1.0	0.99 – 1.00	0.078	3.110
ISS	1.1	1.1 – 1.1	0.0001	199.40	---	---	---	---
Day of Trauma								
Weekday (Reference)	1.0	---	---	---	---	---	---	---
Weekend	1.0	0.8 – 1.2	0.984	0.0001	0.95	0.76 – 1.19	0.669	0.182
Injury Place								
Street (Reference)	1.0	---	---	---	---	---	---	---
Other	0.6	0.4 – 0.9	0.10	6.571	0.51	0.31 – 0.84	0.008	7.070
Time of Trauma								
00:00 a.m. – 06:59 a.m. (Reference)	1.0	---	---	---	---	---	---	---
7:00 a.m. – 11:59 a.m.	0.5	0.4 – 0.7	0.006	12.701	0.73	0.48 – 1.10	0.129	2.305
12:00 p.m. – 18:59 p.m.	0.7	0.7 – 1.1	0.223	7.503	0.92	0.65 – 1.31	0.659	0.195
19:00 p.m. – 23:59 p.m.	0.8	0.3 – 0.6	0.000	1.4882	0.90	0.62 – 1.29	0.554	0.351
Season of Trauma								
Fall	1.3	0.8 – 1.6	0.078	3.111	1.29	0.97 – 1.71	0.083	3.006
Winter	1.2	0.9 – 1.6	0.155	2.021	1.17	0.86 – 1.61	0.322	0.983
Spring	1.1	0.8 – 1.5	0.439	0.600	1.02	0.75 – 1.39	0.903	0.015
Summer (Reference)	1.0	---	---	---	---	---	---	---
Location of Injury								
DHA 1 – South Shore (Reference)	1.0	---	---	---	---	---	---	---
DHA 2 – South West	1.2	0.7 – 2.0	0.544	0.368	0.90	0.51 – 1.60	0.723	0.125
DHA 3 – Annapolis Valley	1.1	0.7 – 1.7	0.798	0.065	0.93	0.56 – 1.54	0.770	0.086
DHA 4 – Colchester East Hants	1.0	0.6 – 1.6	0.886	0.021	0.84	0.50 – 1.44	0.532	0.390
DHA 5 – Cumberland	2.0	1.0 – 3.9	0.030	4.734	1.75	0.88 – 3.46	0.110	2.553
DHA 6 – Pictou County	1.6	0.9 – 2.7	0.124	2.365	1.42	0.78 – 2.60	0.254	1.302
DHA 7 – Gysborough	1.5	0.9 – 2.6	0.144	2.138	1.43	0.80 – 2.58	0.229	1.447
DHA8 – Cape Breton	1.3	0.8 – 2.0	0.232	1.430	1.14	0.71 – 1.83	0.600	0.275
DHA9 – Capital Health	1.2	0.8 – 1.8	0.339	0.916	0.99	0.64 – 1.53	0.955	0.003

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Vehicle Type								
Passenger Vehicle (Reference)	1.0	---	---	---	---	---	---	---
Light Trucks	0.9	0.7 – 1.3	0.562	0.336	0.88	0.62 – 1.25	0.459	0.548
Motorcycle	0.7	0.5 – 0.6	0.024	5.083	0.62	0.39 – 0.98	0.041	4.194
ATV	0.7	0.5 – 1.0	0.076	3.144	0.92	0.53 – 1.58	0.757	0.095
Pedestrian	2.2	1.5 – 3.2	0.000	17.09	2.92	1.54 – 5.54	0.001	10.75
Other	0.8	0.5 – 1.3	0.386	0.751	1.12	0.67 – 1.88	0.663	0.190
Ejected from Vehicle								
Full ejection	1.2	0.98 – 1.6	0.067	3.349	1.42	1.03 – 1.96	0.035	4.460
Partial ejection	2.0	1.2 – 3.5	0.007	7.167	1.83	1.05 – 3.20	0.034	4.512
No ejection (Reference)	1.0	---	---	---	---	---	---	---
Impact Type								
Approaching, Head On (Reference)	1.0	---	---	---	---	---	---	---
Single Motor Vehicle, Rollover	1.0	0.8 – 1.3	0.836	0.043	0.90	0.67 – 1.22	0.511	0.432
Sideswipe, T-bone	1.0	0.7 – 1.5	0.886	0.021	1.21	0.81 – 1.81	0.348	0.882
Other	1.3	0.9 – 1.9	0.124	2.362	1.29	0.87 – 1.91	0.207	1.595
Restraint Use (Seatbelt, Helmet, Airbag)								
One Device Used	0.7	0.5 – 0.9	0.001	10.503	0.99	0.73 – 1.32	0.925	0.009
More than One Device Used	0.4	0.3 – 0.6	0.0001	22.154	0.57	0.36 – 0.90	0.017	5.748
No Device Used (Reference)	1.0	---	---	---	---	---	---	---
Alcohol Use								
No Blood Alcohol (BAC =0)	1.0	---	---	---	---	---	---	---
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	0.9	0.5 – 1.5	0.653	0.202	0.90	0.50 – 1.64	0.731	0.118
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	1.0	0.7 – 1.4	0.972	0.001	1.06	0.71 – 1.57	0.784	0.075
Blood Alcohol Level Not Tested	0.5	0.4 – 0.6	0.0001	23.375	0.73	0.50 – 1.05	0.086	2.947
Drug Use								
Toxicology Negative (Reference)	1.0	---	---	---	---	---	---	---
Toxicology Positive	1.0	0.6 – 1.7	0.994	0.000	1.03	0.60 – 1.77	0.904	0.015
Not Tested	0.3	0.2 – 0.4	0.000	51.611	0.46	0.32 – 0.66	0.0001	17.26
Nagelkerke R Square	---	---	---	---	0.151	---	---	---

Table 15: Regression Model - Falls

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Gender								
Males	0.7	0.5 – 0.9	0.004	8.519	0.91	0.65 – 1.26	0.552	0.354
Females (Reference)	1.0	---	---	---	---	---	---	---
Age, y	1.0	1.0 – 1.0	0.0001	16.496	1.01	1.00 – 1.02	0.033	4.548
ISS	1.0	1.0 – 1.1	0.0001	26.079	---	---	---	---
Day of Trauma								
Weekday (Reference)	1.0	---	---	---	---	---	---	---
Weekend	0.9	0.7 – 1.6	0.340	0.910	0.92	0.68 – 1.26	0.613	0.256
Injury Place								
Home (Reference)	1.0	---	---	---	---	---	---	---
Street	2.2	1.1 – 4.5	0.031	4.637	1.48	0.67 – 3.30	0.335	0.929
Other	1.0	0.8 – 1.4	0.793	0.069	1.36	0.96 – 1.92	0.083	3.002
Time of Trauma								
00:00 a.m. – 06:59 a.m. (Reference)	1.0	---	---	---	---	---	---	---
7:00 a.m. – 11:59 a.m.	0.6	0.3 – 0.98	0.043	4.114	0.60	0.32 – 1.14	0.119	2.433
12:00 p.m. – 18:59 p.m.	0.5	0.3 – 0.9	0.032	4.605	0.60	0.32 – 1.11	0.101	2.683
19:00 p.m. – 23:59 p.m.	0.6	0.3 – 1.5	0.130	2.298	0.40	0.21 – 0.80	0.009	6.873
Season of Trauma								
Fall	1.0	0.7 – 1.4	0.860	0.031	0.90	0.61 – 1.34	0.603	0.270
Winter	1.2	0.8 – 1.6	0.399	0.712	1.09	0.73 – 1.62	0.678	0.173
Spring	1.2	0.8 – 1.7	0.426	0.634	0.91	0.60 – 1.37	0.637	0.222
Summer (Reference)	1.0	---	---	---	---	---	---	---
Location of Injury								
DHA 1 – South Shore (Reference)	1.0	---	---	---	---	---	---	---
DHA 2 – South West	1.0	0.5 – 2.0	0.950	0.004	0.83	0.37 – 1.84	0.640	0.219
DHA 3 – Annapolis Valley	1.0	0.6 – 2.0	0.794	0.068	1.03	0.50 – 2.10	0.940	0.006
DHA 4 – Colchester East Hants	1.8	0.9 – 3.6	0.119	2.425	1.71	0.77 – 3.77	0.188	1.734
DHA 5 – Cumberland	1.2	0.5 – 2.5	0.694	0.155	0.84	0.36 – 1.99	0.698	0.150
DHA 6 – Pictou County	1.3	0.7 – 2.5	0.480	0.498	1.19	0.57 – 2.48	0.643	0.215
DHA 7 – Gysborough	1.0	0.5 – 2.0	0.998	0.000	0.82	0.38 – 1.76	0.614	0.255
DHA8 – Cape Breton	2.0	1.2 – 3.6	0.011	6.494	1.88	1.02 – 3.45	0.042	4.116
DHA9 – Capital Health	2.2	1.3 – 3.6	0.002	9.840	1.91	1.10 – 3.31	0.022	5.242

	Model 1 (unadjusted)				Model 2 (adjusted)			
Independent Variables	**OR**	**95% CI**	**p-value**	**Wald**	**OR**	**95% CI**	**p-value**	**Wald**
Mechanism of Injury								
Fall (< 1 meter)	0.3	0.2 – 0.5	0.000	21.274	0.29	0.17 – 0.51	0.0001	19.57
Fall (1-6 meters)	0.2	0.2 – 0.6	0.000	0.210	0.23	0.14 – 0.37	0.0001	37.67
Fall (> 6 meters)	0.2	0.2 – 0.3	0.000	0.270	0.14	0.08 – 0.28	0.0001	33.56
Fall Not Further Specified	0.9	0.6 – 1.4	0.575	0.215	0.86	0.55 – 1.33	0.486	0.484
Fall on the Same Level (Reference)	1.0	---	---	---	---	---	---	---
Alcohol Use								
No Blood Alcohol (BAC=0)	1.0	---	---	---	---	---	---	---
Positive Blood Alcohol Level, Below Legal Limit (0 mmol/L < BAC < 17 mmol/L)	2.0	0.4 – 9.8	0.415	0.665	1.58	0.29 – 8.52	0.594	0.284
Positive Blood Alcohol, Above the Legal Limit (≥ 17 mmol/L)	0.7	0.3 – 1.7	0.475	0.509	0.77	0.32 – 1.89	0.574	0.316
Blood Alcohol Level Not Tested	0.3	0.2 – 0.7	0.002	9.286	0.19	0.08 – 0.45	0.0001	14.30
Drug Use								
Toxicology Negative (Reference)	1.0	---	---	---	---	---	---	---
Toxicology Positive	1.5	0.4 – 5.0	0.545	0.366	2.74	0.72 – 10.50	0.141	2.165
Not Tested	0.5	0.2 – 0.9	0.017	5.687	1.01	0.45 – 2.29	0.973	0.001
Nagelkerke R Square	---	---	---	---	0.250	---	---	---

CHAPTER 6: SUMMARY AND CONCLUSIONS

The purpose of this thesis was to describe the epidemiology of major head injuries among those aged 16 and over in the province of Nova Scotia during the period of April 1st, 2000 to March 31st, 2007. Examining patterns of head injury specific to the major external causes of injury (MVCs and falls) was also conducted in order to provide insight into which groups are most at risk for these types of injuries and thus potentially guide injury prevention initiatives.

A total of 1798 patients experienced a major head injury during the study period with 1330 (74%) head injury events sustained by males and 468 (26%) head injury events sustained by females. A large proportion of head injuries were observed in the two largest urban centres of Nova Scotia with 292 (16%) reported in the Cape Breton Health Authority (city: Sydney) and 660 (37%) reported in the Capital Health District Authority (city: Halifax). Unintentional injuries were most common (78%) among the head injured cohort, followed by self-inflicted injuries (10%) and assaults (9%). Motor vehicle collisions were the most common external mechanism of head injury accounting for 40% of all major head injuries while falls followed closely as the second leading cause of major head injury (38%). Age and gender differences by external causes of head injury have been reported in the literature and are reflected in our data. Specifically, high rates of MVC head injury were found among males in all age groups, particularly for those aged 16 to 24 years. Conversely, high rates of falls-related injury were the most common mechanism of injury for both males and females among those aged 65 years and over.

Recognizing the importance of drug and alcohol as modifiable risk factors for injury, this study evaluated the prevalence of intoxication among head trauma patients particularly by major external causes of injury. Of those tested for blood alcohol concentration (BAC), approximately 348/527 (66%) of head injured males and 75/115 (65%) of head injured females had BACs greater than zero, suggesting that alcohol had been a contributor to the head injury event. Further, 55% of all head injuries where blood alcohol levels were tested involved levels above the legal limit, with similar rates observed among head injuries sustained during MVCs and falls (54% versus 58% respectively). The potential for testing bias may exist in this present study as reported by others (116,117). In this study population, BAC testing may not be requested even if obvious signs of alcohol impairment are observed, if testing would not materially assist in determining patient disposition. Therefore, the influence of alcohol on head injury may be severely underestimated in this studied cohort.

A second goal of this thesis was to examine risk and protective factors unique to head injuries when compared to major traumas involving injury to other body regions. As noted above, falls and motor-vehicle collisions were major causes of head injury. Recognizing the potentially unique factors for head injury that may be associated with each of these two leading mechanisms of injury, separate analyses were conducted for those involved in falls- and MVC-related injuries**.**

A total of 2937 patients experienced a major injury during the study period with 1617 (55%) of these involving major injury to the head (AIS $\geq$ 3). Of the 1555 patients that were involved in a MVC injury, a total of 723 (46%) patients sustained injury to the head. Conversely, a total of 1047 patients were involved in a falls-related injury with 674 (64%) of these patients sustaining a head injury.

Adjusted multivariate regression for all major traumas found females were more likely than males to have received a head injury, and head injuries were more likely to occur on the street rather than in the home. Head injuries were more likely to occur between midnight and 6:59 a.m. relative to other times. In addition, head injuries were observed to be higher in the two largest urban centres of Nova Scotia (Capital District Health Centre and Cape Breton Health Authority) relative to other regions. Head injuries were also four times more likely to occur during a fall-event relative to an MVC-event. Interestingly, alcohol consumption and drug use were not associated with the likelihood of major head injury relative to major non-head injury. However, only 43% of patients with major head injuries and 34% of patients with major traumas to other body regions were tested for BAC. A different association may have emerged if BAC testing were conducted for all major traumas emphasizing the importance of public policies that enforce mandatory BAC testing for all patients who sustain serious injury.

Adjusted regression models comparing MVC-related head injuries to MVC-related non-head injuries found the odds of receiving a head injury was higher among pedestrians when compared to other vehicle types. An increased risk for head injury among pedestrians is congruent with other studies that have demonstrated that compared to injured vehicle occupants, pedestrians are more likely to sustain multisystem injuries, have higher injury severity scores and incur a greater risk for mortality (215,216). Conversely, the odds of being severely injured and receiving a head injury were lower among motorcyclists when compared to other vehicle types. The lower odds for head injury observed among motorcycle occupants suggests a high compliance in helmet wearing and not surprisingly resulted in greater protection from serious injury to the head. Those ejected from their vehicle (suggesting that safety restraint was not used) resulted in a 42% to 82% increased risk for head injury. Compared to traumas events where no safety restraint was used, major traumas involving more than one safety device (seatbelt, helmet or airbag deployment) resulted in a 43% reduction in head injury risk. These findings underscore the importance of safety device use in reducing risk for injury, and head injury specifically.

Adjusted regression models for the falls-related cohort found age to be an important factor for head injury compared to non-head injury, with older adults at an increased risk. Risk for head injuries was found to be highest in the two largest urban centres of Nova Scotia (Halifax and Sydney) relative to other regions while head injuries were less likely to occur between 19:00 p.m. and 23:59 p.m. relative to midnight and 6:59 a.m. From an environmental perspective, the higher propensity for head injuries observed among urban areas may relate to factors occurring in either the home environment, the external environment (built environment, landscape or weather) or a combination of both. Relative to falls occurring at the same level, head injuries were less likely to occur from any of the three categorized heights (<1 meter, 1-6 meters, > 6 meters). These findings suggest reaction time to an injurious event may play an important role in injuries arising from vertical deceleration from heights.

Injuries have traditionally been viewed as “accidents” or random chance events. This perception has resulted in the historical neglect of injury prevention policies and programs (27). Identifying and positioning injuries as a major public health problem over the past few decades has resulted in greater awareness that like most other diseases, injuries can be predicted and prevented (70,206). This study aimed to examine key variables for head injury in an effort to identify important demographic, environmental and human factors amenable to prevention. Understanding the risk and protective factors specific to head injuries is important to public health practitioners as it can inform prevention programming and related injury policy efforts. It is also likely to be of value in the clinical setting when triaging and treating trauma victims. This study serves to provide a baseline population-based assessment of major head injuries that will be useful in assessing the success of future public policy changes. The high number of head injuries observed among those injured in MVCs and falls justify on-going programs for prevention and control tailored to these specific areas. Several public health policy initiatives in Canada have assisted in the reduction of MVC-related injury and head injury severity over the last few decades. Such efforts include environmental policies (traffic-calming measures, vehicle safety) and enforcement policies (road-side checks, random breath testing, and safety restraints legislation). Continued vigilance in implementing and enforcing these and other relevant injury prevention initiatives will assist in the effort to reduce the number of injuries (and head injuries specifically) that occur every year in the province of Nova Scotia.

This study found pedestrians to be at increased risk for head injuries, highlighting the importance of injury prevention efforts targeted to this segmented group. Strategies aimed to reduce pedestrian-related injury may include public health campaigns aimed to educate pedestrians on the importance of being aware of surrounding traffic, wearing reflective clothing to increase visibility, and refraining from devices that may distract (e.g. use of cell phones and music players). In addition, environmental modifications such as traffic calming measures which divert high-volume, high-speed traffic away from residential areas can be instrumental in preventing pedestrian injuries (226). With an aging population and the greater risk of falls among older adults, falls prevention measures will continue to play an important role in Nova Scotia. This study found falls occurring at the same level as the individual to be at higher risk for head injuries. Future injury prevention strategies may wish to consider relevant strategies that minimize the risk for injury specific to these types of falls.

Continued surveillance using population-based registries such as the NSTR can serve as important tools to assess the effectiveness of current public health policies and prevention strategies; in addition, they can help to establish and respond to emerging head injury trends. It is recognized that other important behavioural and contextual factors involved in the injury event may be needed to fully appreciate the unique risk and protective factors pertaining to head injuries. Research activities aimed to collect important data pertaining to the chain of events leading to injury that is not currently captured by the NSTR would further our understanding of those at higher risk for head injuries. Specifically, examining characteristics such as collision speed, degree of vehicle deformity, presence of passengers, and correct use of safety restraints are important factors to consider for MVC-related injury. Important factors related to falls-related injury include such variables as: presence of chronic or acute disease, nutritional status, physical activity levels, medication use, environmental risk factors, and history of previous falls. Examining the effects of alcohol and drug use (particularly poly-pharmacy use) on head injury risk is also an important area of research that should be further explored. In addition, the NSTR currently lacks information that captures the broader social determinants health. Understanding the etiologic association between major head injuries and factors such as income, education and the social and physical environment are important to explore. In addition, greater data linkages between the NSTR and other datasets would help address current gaps in knowledge. For example, data linkages with the Nova Scotia Prescription Monitoring Program can serve as an important data source to assist in understanding the relationship between prescription drug use and its relationship with the timing and occurrence of major head injuries. Further, a core function of epidemiology is to quantify the risk of developing an outcome of interest (i.e. injury) given a specified exposure. Future studies should therefore consider the use of exposure data on injury risk. For MVC injury, this may include data that captures the distance travelled, the number of trips or the number of hours spent in a motor vehicle. This information will build on the results and recommendations of this study and will allow for more informed prioritization of injury control policies and evidence-based prevention programs.

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APPENDIX 1: ABBREVIATED INJURY SCALE (AIS)

Abbreviated Injury Scale (AIS) (55,227,228)

First introduced in 1969, the Abbreviated Injury Scale (AIS) is an anatomical scoring system used to rank the severity of injury in one of seven body regions: head and neck, face, chest and thorax, abdomen, extremities, external/burns. Monitored by a scaling committee of the Association for the Advancement of Automobile Medicine, the AIS has undergone multiple revisions and now provides a reasonably accurate ranking of the severity of injury. The latest iteration of the AIS is the 1990 revisions although a 1998 revision is used in some areas.

Injuries are ranked on a scale of 1 to 6, with 1 being minor, 5 severe and 6 an unsurvivable injury. The scale is not meant to represent a comprehensive measure of severity but rather represents the “threat to life” associated with an injury. In addition, the AIS is not a true severity scale. In other words, the difference between AIS1 and AIS2 is not the same as that between AIS4 and AIS5. The AIS and its closely related Injury Severity Score are derived from patient records by trained data abstractors.

AIS Score	Injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Unsurvivable

APPENDIX 2: INJURY SEVERITY SCORE (ISS)

Injury Severity Score (ISS) (28,229,230)

The Injury Severity Score (ISS) is an anatomical scoring system that accounts for multiple injuries. Each injury is assigned an Abbreviated Injury Scale (AIS) score and is allocated to one of six body regions: head, face, chest, abdomen, extremities including pelvis, and external. Only the highest AIS score for each body region is used. The three 3 most severely injured body regions have their score squared and the total sum produces the injury severity score.

The ISS score ranges in value from 0 to 75. The higher the ISS, the greater the severity of injury. Injuries with an AIS score of 6 (unsurvivable injury) is automatically assigned a value of 75. The ISS score is virtually the only anatomical scoring system in use and correlates linearly with mortality, morbidity, hospital stay and other measures of severity. A limitation to the ISS is that many different injury patterns can yield the same ISS score and injuries to different body regions are not weighted. Furthermore, any errors in AIS scoring increases errors in the ISS.

An example of the ISS calculation is shown below:

Region	**Injury Description**	**AIS**	**Square Top Three**
Head & Neck Injury	Closed non-depressed vault skull fracture	2	
Face Injury	No injury	0	
Chest and Thoracic Spine Injury	Flail Chest Rib Fracture	4 1	16
Abdomen or Pelvic Contents & Lumbar Spine Injury	Minor Contusion of Liver Complex Rupture Spleen	2 5	25
Extremities or Pelvic Girdle	Open tibial fracture	3	9
External/Burns	No injury	0	
		Injury Severity Score:	**50**

APPENDIX 3: HADDON'S MATRIX (HM)

Table 1. Variables Related to Motor Vehicle Collision (MVC) Injury Using Haddon's Matrix (231,232)

	Host (Drivers involved in MVC injury)	**Agent/Vectors** (Mechanical energy/Motor vehicle)	**Physical Environment**	**Social Environment**
Pre-crash (Factors prior to the injury)	Age Gender Pre-existing Health Conditions Alcohol intake Drug intake (licit and illicit drugs) Driver experience and judgment	Type of vehicle Condition of brakes, tires Speed of car Vehicle design Occupant restraint system	Road conditions Climatic conditions Day/Time of injury Speed limit Traffic regulations Highway design (road curvature, intersections)	Beliefs of restraint use Enforcement of speed limits Societal attitudes towards risk taking and impaired driving Driver inattention Drinking patterns Social acceptability/social norms related to impaired driving Risk taking behaviour
Injury (The injury event)	Driver's ability to control vehicle and avoid obstacles Use of restraint and protective equipment	Restraint use (i.e.: seatbelt) Protective devices (i.e.: airbags) Side impact protection	Road conditions Speed limits Road signs Lighting Physical obstacles (i.e.: trees, electrical poles)	Road/highway design (guard rails, breakaway poles) Societal attitudes and laws regarding seatbelt use
Post-injury (Treatment and follow up following head injury)	Age Severity of Injuries Pre-existing health conditions	Integrity of fuel system or fire proof gasoline tanks	Emergency medical agencies involved Location of trauma centre	EMS response time Trauma care systems

Table 2. Variables Related to Falls Using Haddon's Matrix (231,232)

	Host (Individual involved in fall-related injury)	**Agent/Vectors** (Mechanical energy/Motor vehicle)	**Physical Environment**	**Social Environment**
Pre-event (Factors prior to the injury)	Age Gender Alcohol intake Drug intake (licit and illicit drugs) Occupation	The forces and severity of a potential fall – for example, includes the height of equipment being used	Access to hazard-free space Use of preventive measures (i.e. guard rails, non-slip mats)	Awareness of fall risks among parents, older adults, healthcare providers and community Actions taken to prevent injury in the home, school or workplace Beliefs of personal protective equipment
Injury (The injury event)	Cognitive impairments/ Physical development Use of protective equipment	Protective gear (i.e. helmets) Force- height of fall Ability of ground surface or flooring to absorb impact	Height of fall Surface or objects fallen upon Fall hazards Presence of impact-absorbing surfaces	Awareness of potentially serious injuries associated with falls, including concussion and brain injury Witnesses to the event
Post-injury (Treatment and follow up following head injury	Age Severity of injuries Pre-existing health conditions	A history of falls or injuries may change an individuals risk taking behaviour	Emergency medical agencies involved Location of trauma centre	EMS response time Trauma care systems

APPENDIX 4: MECHANISMS OF INJURY INCLUDED IN THE NSTR

Table A
ICD 10-CA Trauma Registry Inclusions (Effective April 1, 2001)

Code Category	Definition
V01 – V09	Pedestrian injured in transport accident
V10 – V19	Pedal cyclist injured in transport accident
V20 – V29	Motor cycle rider injured in transport accident
V30 – V39	Occupant of 3 wheeled MV injured in transport accident
V40 – V49	Car occupant injured in transport accident
V50 – V59	Occupant of pick-up truck or van injured in transport accident
V60 – V69	Occupant of heavy transport vehicle injured in transport accident
V70 – V79	Bus occupant injured in transport accident
V80 – V89	Other land transport accidents (includes ATV)
V90 – V94	Water transport accidents
V95 – V97	Other and unspecified transport accidents
W00 – W19	Falls
W20 – W49	Exposure to inanimate mechanical forces (including noise)
W50 – W64	Exposure to animate mechanical forces
W85 – W99	Exposure to electrical current, radiation and extreme ambient air temperature and pressure
X00 – X09	Exposure to smoke, fire and flames
X10 – X19	Contact with heat and hot substances
X30 – X39	Exposure to forces of nature (includes heat, cold, volcanoes and floods)
X72 – X84	Intentional self-harm, excluding drownings, suffocation and poisoning
X86	Assault by corrosive substance
X93 – Y05	Homicide and injury purposely inflicted by others
Y07 – Y09	Other maltreatment syndromes, including physical abuse
Y22 – Y34	Injuries with undetermined intent
Y35.0 - .1, Y35.3 - .7	Legal interventions excluding those by gas
Y36	Operations of war

APPENDIX 5: MECHANISMS OF INJURY EXCLUDED IN THE NSTR

Table B
ICD 10-CA Trauma Registry Exclusions (Effective April 1, 2001)

Code Category	**Definition**
W65 – W74	Accidental drowning and submersion
W75 – W84	Other accidental threats to breathing
X20 – X29	Contact with venomous animals and plants
X40 – X49	Accidental poisoning and exposure to noxious substances
X50 – X57	Over exertion, travel and privation
X58 – X59	Accidental exposure to other and unspecified factors
X60 – X69	Intentional self-harm by poisoning
X70	Intentional self-harm by hanging, strangulation and suffocation
X71	Intentional self-harm by drowning and submersion
X85, X87 – X92	Intentional harm (assaults)
Y06	Neglect and abandonment
Y10 – Y19	Poisonings by undetermined intent
Y20 – Y21	Hangings, drownings by undetermined intent
Y35.2	Legal interventions involving gas
Y40 – Y84	Complications of medical/surgical care (including adverse effects of medications)
Y85 – Y89	Sequelae of external causes of morbidity and mortality
Y90 – Y98	Supplementary factors related to causes of morbidity and mortality classified elsewhere

APPENDIX 6: NSTR INCLUSION AND EXCLUSION CRITERIA

The following criteria are needed in order to be included into the NSTR's Major Injury Dataset:

"Injuries resulting from a transfer of energy (mechanical, chemical, or thermal) and resulting in an anatomical lesion due to an appropriate mechanism described by the Inclusion ICD-10-CA External Cause of Injury codes (Appendix 1) **AND**

- ISS $\geq$ 12 for blunt or burn trauma, **OR**
- ISS $\geq$ 9 for penetrating trauma, **OR**
- Trauma Team activation with/without admission to acute care facility
- Death in the emergency department due to appropriate mechanism of injury, **OR**
- Death within 24 hours of admission to district or tertiary trauma centre due to appropriate mechanism of injury, **OR**
- Death at the scene of injury due to appropriate mechanism, **OR**
- Predetermined inclusion at another trauma center, where the individual has been treated and admitted, prior to transfer to a second, or third trauma center for continuing care of initial injury.

Exclusions to the NSTPR include all injuries where there is lack of anatomical lesion included in the injury diagnoses (such as drownings, asphyxia, medical errors, etc.) and discharges from the Emergency Department (36)."

APPENDIX 7: SELECTION OF HEAD INJURIES WITH AIS ≥ 3

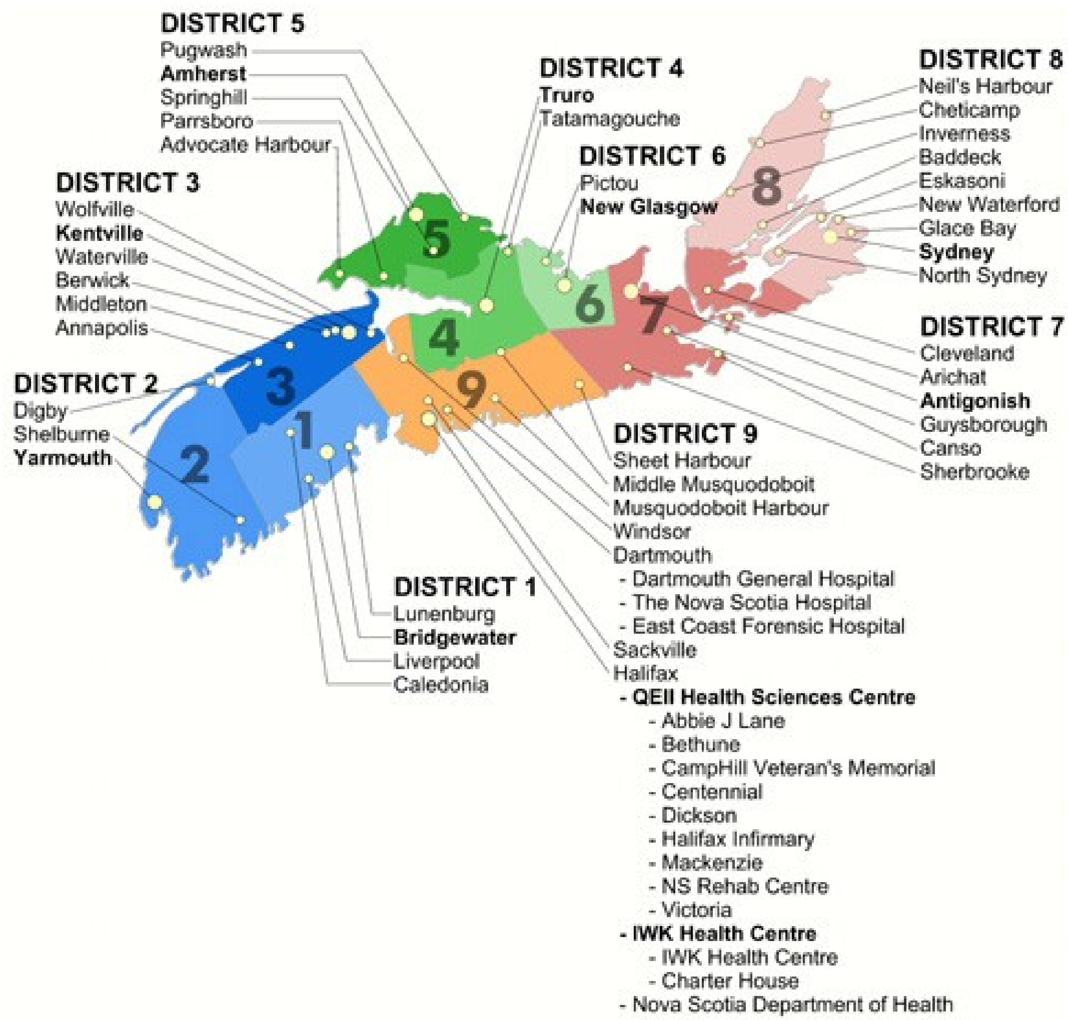
For this research project, head injuries with an AIS ≥ 3 (neck excluded) were identified by the NSTR registry using the following diagnostic codes.

AIS Numerical Identifier	Description of Head Injury
113000.6	Massive destruction of both cranium (skull) and brain (crush)
116002.3	Penetrating injury, superficial (≤ 2 cm beneath entrance)
116004.5	Penetrating injury, major (> 2 cm penetration)
110606.3	Scalp laceration with blood loss > 20% by volume
110806.3	Scalp avulsion with blood loss > 20% by volume
110808.3	Scalp avulsion, total scalp loss
120202.5 to 122899.3	All intracranial vessel injuries
140202.5 to 140799.3	All internal organ injuries (brain stem, cerebellum, cerebrum, pituitary)
150200.3 to 150206.4	All basal skull fractures
150404.3 to 150408.4	Vault skull fractures (comminuted, compound, depressed, displaced, complex, open with torn, exposed or loss of brain tissue, massively depressed)
160204.3 to 160214.5	Unconsciousness < 1hr with neurological deficit >24 hours unconscious
160408.3	Awake post resuscitation or on initial observation at scene (GCS 15), prior unconsciousness but length of time NFS, with neurological deficit
160412.3	Awake post resuscitation or on initial observation at scene (GCS 15), amnesia (no recollection of injury), with neurological deficit
160416.3	Awake post resuscitation or on initial observation at scene (GCS 15), unconscious known to be < 1 hour, with neurological deficit
160604.3	Lethargic, stuporous, obtunded post resuscitation or on initial observation at scene, no prior unconsciousness, with neurological deficit
160608.3	Lethargic, stuporous, obtunted post resuscitation or on initial observation at scene, prior unconsciousness but length of time NFS, with neurological deficit
160612.3	Lethargic, stuporous, obtunted post resuscitation or on initial observation at scene, unconsciousness known to be < 1 hour, with neurological deficit

AIS Numerical Identifier	Description of Head Injury
160614.3 to 160616.4	Lethargic, stuporous obtunted post resuscitation or on initial observation at scene, 1-6 hours unconsciousness, with/without neurological deficit
160899.3	Unconsciousness post resuscitation or on initial observation at scene (unresponsive to verbal command or painful stimuli; GCS $\leq$ 8) NFS
160804.3	Unconscious post resuscitation or on initial observation at scene, length of unconsciousness NFS, with neurological deficit
160806.3 to 160808.4	Unconscious post resuscitation or on initial observation at scene, unconsciousness known to be < 1 hour, with/without neurological deficit
160810.3 to 160812.4	Unconsciousness post resuscitation or on initial observation at scene, 1-6 hours, unconsciousness, with/without neurological deficit
160814.4 to 160816.5	Unconsciousness post resuscitation or on initial observation at scene, 6-24 hours, unconsciousness, with/without neurological deficit
160818.5	Unconsciousness post resuscitation or on initial observation at scene, >24 hours unconsciousness
160820.4 to 160822.5	Unconsciousness post resuscitation or on initial observation at scene, appropriate movements, but only upon painful stimuli no matter the length of unconsciousness, with/without neurological deficit
160824.5	Unconsciousness post resuscitation or on initial observation at scene, inappropriate movements (decerebrate, decorticate, flaccid, no response to pain) no matter the length of unconsciousness, with/without neurological deficit.

APPENDIX 8: LOCATION OF THE DISTRICT HEALTH AUTHORITIES

The location of Nova Scotia's 9 District Health Authorities are shown below (233).



APPENDIX 9: SELECTION CRITERIA FOR REGRESSION ANALYSIS

Figure 5: Selection Criteria for Regression Analysis (All Head Injuries)

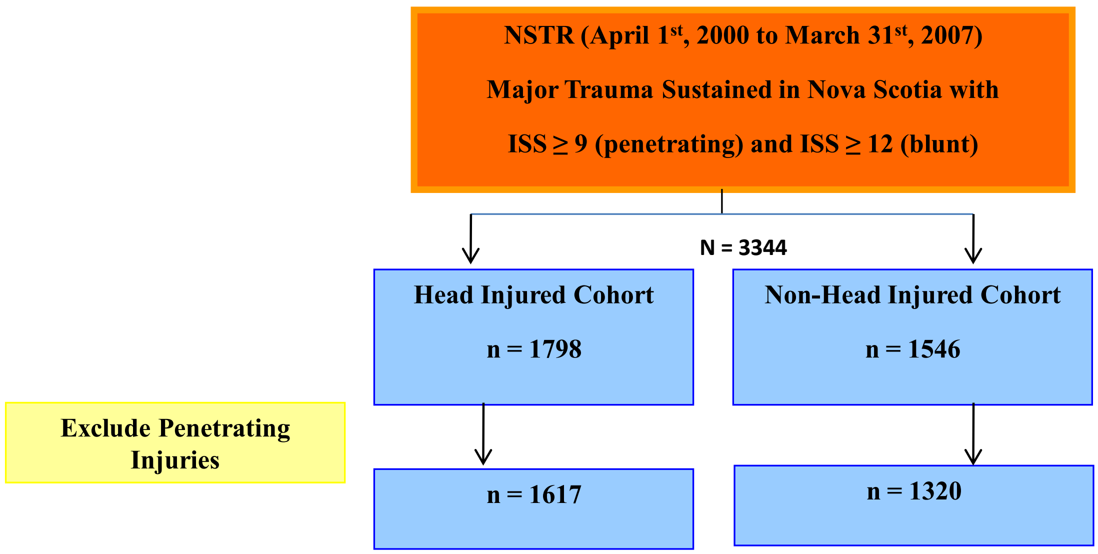


Figure 6: Selection Criteria for Regression Analysis (MVC Model)

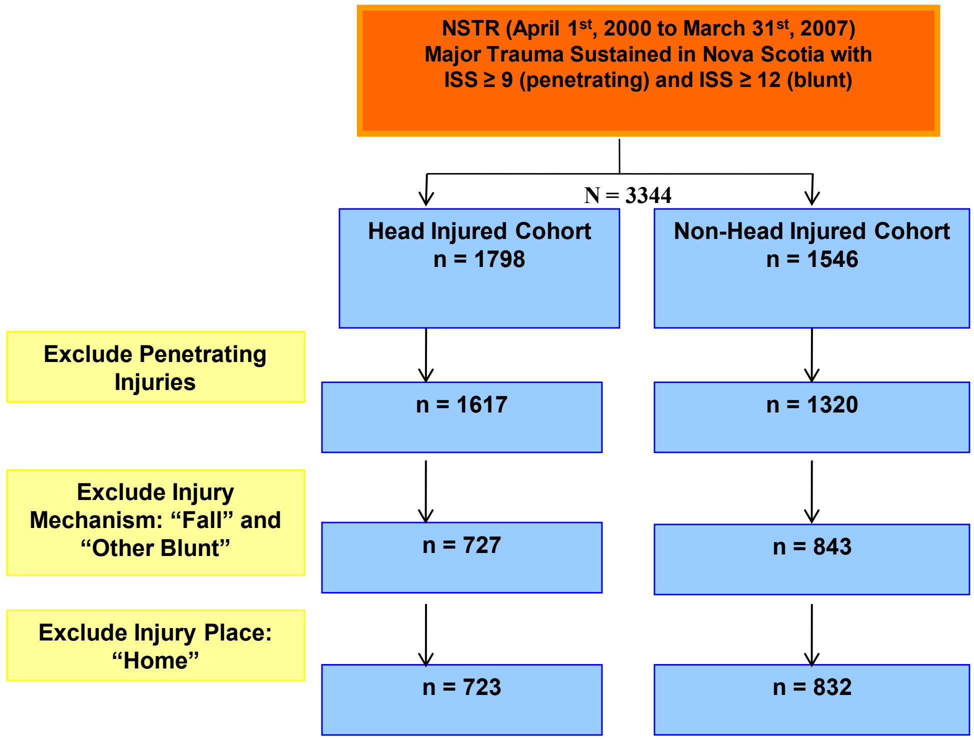
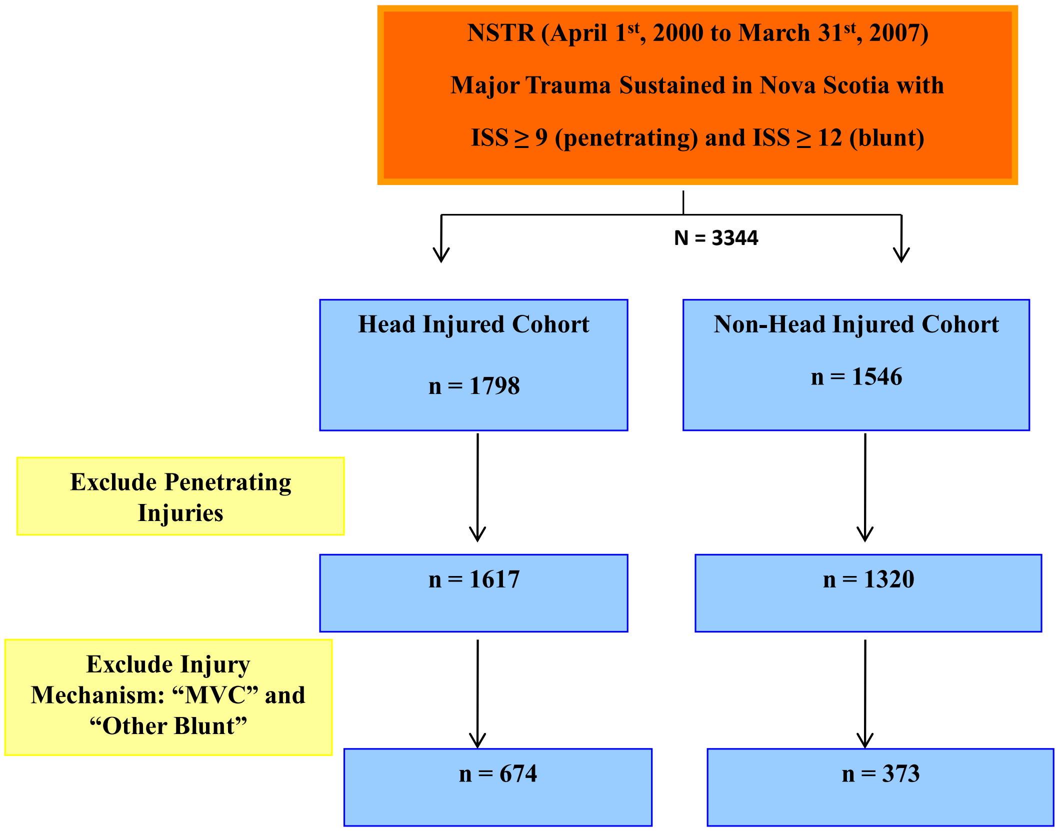


Figure 7: Selection Criteria for Regression Analysis (Falls Model)



APPENDIX 10: MULTICOLLINEARITY DIAGNOSTICS

TABLE 16: MULTICOLLINEARITY DIAGNOSTICS – FULL MODEL

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Tolerance (TOL)**	**VIF**
ISS	0.010	0.001	0.292	15.990	0.000	0.879	1.138
Age	0.001	0.000	0.045	2.305	0.021	0.776	1.289
Gender	-0.048	0.020	-0.043	-2.443	0.015	0.925	1.081
Injury Place	-0.017	0.011	-0.027	-1.540	0.124	0.920	1.087
Day of Trauma	0.012	0.017	0.013	0.727	0.467	0.985	1.015
DHA	0.013	0.003	0.074	4.253	0.000	0.977	1.024
Injury Time	0.007	0.006	0.021	1.169	0.243	0.939	1.066
Seasons	0.011	0.008	0.026	1.484	0.138	0.990	1.010
Mechanism	0.178	0.013	0.243	13.213	0.000	0.863	1.158
Alcohol Level	-0.038	0.011	-0.074	-3.593	0.000	0.693	1.443
Drug Use	-0.044	0.016	-0.057	-2.756	0.006	0.687	1.456

TABLE 17: MULTICOLLINEARITY DIAGNOSTICS – MVC MODEL

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Tolerance (TOL)**	**VIF**
Gender	-0.023	0.026	-0.021	-0.887	0.375	0.939	1.065
Age	-0.001	0.001	-0.047	-2.005	0.045	0.915	1.093
ISS	0.011	0.001	0.397	16.756	0.000	0.905	1.105
Day of Trauma	-0.002	0.023	-0.002	-0.066	0.947	0.964	1.037
Injury Place	-0.079	0.031	-0.065	-2.582	0.010	0.807	1.239
Time of Trauma	-0.015	0.009	-0.041	-1.778	0.076	0.952	1.050
Seasons	0.013	0.010	0.029	1.260	0.208	0.973	1.028
DHA	0.003	0.004	0.018	0.787	0.431	0.980	1.020
Vehicle Type	0.004	0.009	0.012	0.401	0.689	0.553	1.808
Ejected from Vehicle	0.039	0.012	0.086	3.174	0.002	0.687	1.455
Impact Type	0.029	0.009	0.080	3.170	0.002	0.801	1.249
Restraint Use	-0.011	0.012	-0.024	-0.981	0.327	0.857	1.167
Alcohol Use	-0.024	0.013	-0.052	-1.943	0.052	0.719	1.392
Drug Use	-0.052	0.019	-0.075	-2.767	0.006	0.690	1.448

TABLE 18: MULTICOLLINEARITY DIAGNOSTICS – FALLS MODEL

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Tolerance (TOL)**	**VIF**
ISS	0.007	0.002	0.139	4.564	0.000	0.936	1.068
Age	0.004	0.001	0.165	4.878	0.000	0.762	1.312
Gender	-0.063	0.032	-0.063	-2.000	0.046	0.886	1.128
DHA	0.020	0.005	0.119	3.978	0.000	0.982	1.018
Time of Trauma	0.024	0.010	0.070	2.320	0.021	0.963	1.038
Day of Trauma	0.004	0.028	0.004	0.131	0.896	0.978	1.022
Injury Place	0.024	0.014	0.052	1.676	0.094	0.921	1.085
Seasons	0.014	0.012	0.034	1.143	0.253	0.992	1.008
Mechanism	0.008	0.009	0.026	0.881	0.379	0.982	1.018
Alcohol Use	-0.088	0.022	-0.139	-3.980	0.000	0.712	1.404
Drug Use	-0.039	0.035	-0.039	-1.126	0.260	0.726	1.378