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The Effects of Child Restraint System Use and Motor Vehicle Collision Severity on Injury Patterns and Severity in Children 8 Years Old and Younger.

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Abstract

Motor vehicle collisions (MVCs) are a leading cause of injury and death for children under the age of 14 years in North America. Children, eight years old or younger, are required to use a child restraint system (CRS) when travelling in a vehicle in Canada. In the present study, the hypothesis that head injury severity of children in this age group, seated in rear rows of vehicles in MVCs, will be influenced by the types of restraint systems used was not supported by the data; however, other secondary aspects of collision data were explored. There were injury patterns that involved the head, thorax, and lower extremities. Head injury severity decreased when the number of rear row occupants increased. Winter cases were associated with more severe head injuries. Future studies of the relation between CRS types and designs, and trauma will be enhanced by larger sample sizes and more consistent data collection methods.

Keywords

Motor vehicle collision, MVC, children, child, infant, child restraint system, car seat, CRS, Canada, injury, head injury

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List of Abbreviations

AAP: American Academy of Pediatrics

AIS: Abbreviated Injury Scale

CRS: Child Restraint System

EBS: Equivalent Barrier Speed

FARS: Fatality Analysis Reporting System

FFCRS: Forward-Facing Child Restraint System

LHSC: London Health Sciences Centre

MAIS: Maximum Abbreviated Injury Scale

MOVES: Motor Vehicle Safety (Research Team)

MVC: Motor Vehicle Collision

NASS: National Automotive Sampling System

NHTSA: National Highway Traffic Safety Administration

OR: Odds Ratio

RFCRS: Rear-Facing Child Restraint System

SWCA: Southwestern Collision Analysis

TC: Transport Canada

Chapter 1

1 INTRODUCTION

Motor vehicle collisions (MVCs) are currently the leading cause of death for individuals under the age of 18 years (1). MVCs are the major contributor for deaths of individuals under 14 years in North America (2). MVCs are the leading cause of unintentional injury deaths for individuals 5-24 years of age and second for individuals under the age of 5 years (3). MVC-related injuries resulted in death for 20,488 children 14 and younger between 2001 and 2010 in the United States, and over two million in this age group were assessed at hospitals because of their injuries (4).

1.1 Rear Seat Safety

More than half of rear seated MVC occupants are children under the age of 12 years, with almost half of those being between the ages of 6 and 12 years (5). In 2002, the American Academy of Pediatrics (AAP) published a series of recommendations for child restraint systems (CRSs). These recommendations came after more than 500 children under the age of five in the front passenger seat died as a result of an MVC, with the majority of those children being unrestrained or improperly restrained (6). The AAP published a total of 17 recommendations focused on seat selection, installation of the seat in the vehicle, and the placement of the child in the seat. The aims of these recommendations were: children should be in an appropriately sized seat for their age and body weight: the seats should be anchored to the vehicle in a way that restricts movement of the seat but still supports the child, and the placement and restraint of the child should not negatively impact the child's health while restrained but positioned to ensure optimal safety should a collision occur (6). In a study from 1998 by Braver et al. they observed that seating children in the rear rows decreases the risk of death by over 30% in fatal collisions (7).

Arbogast et al. compared the injury risk for children sitting in the back and the front rows of vehicles (8). The children were either using a CRS, seatbelt, or were unrestrained. These researchers found that children sitting in the rear rows of a vehicle were 50-67% less likely to sustain an injury in comparison to their front seat counterparts (8). Specifically, children eight years old or younger, who were seated in the rear rows, were 69% less likely to sustain an injury (8).

Although the risk of serious injury and death in children has been reduced by seating them in the rear rows, they still do not have the same level of protection as those individuals seated in the front. The front row seats have been designed to withstand impact during a collision to either prevent or mitigate injuries. Bose et al. researched injury patterns in frontal collisions and rear-seated passengers. They found that rear seat advanced occupant protection systems have lagged behind front seat systems (9). They also found that compliance for restraint usage was decreased in the rear rows (9). Front seat occupants are protected by front and side airbags. The rear rows of vehicles have only benefited from the presence of side curtain airbags. There is relatively little, other than the adult-sized seatbelt or various CRSs, that can prevent impact with the interior compartment such as the seatback in front of the child occupant (7).

1.2 Child Safety Restraint Systems (CRS)

Child restraint systems (CRSs) are designed to address the morphological differences between adults and youth in the rear seat to provide adequate injury protection. Children have a different skeletal morphology and head size compared to an adolescent and a fully-grown adult. The majority of existing restraint devices in motor vehicles are designed to restrain a fully grown adult and not a small child. Current legislation in Ontario, under the *Highway Traffic Act,* requires all passengers to use a restraint system, whether that be a seat belt or CRS if they are travelling in a motor vehicle (10). This has increased the use of child restraint systems in motor vehicles.

1.3 CRS Types

CRSs are grouped into three main categories based on the age and weight of the child. Transport Canada outlines the distinct CRS stages required for restraining a child in a motor vehicle. They are rear-facing, forward-facing, booster seat, and finally the seatbelt (11). Figure 1-1 is a progression of CRS types with respect to ages and occupant requirements. Figure 1-1 is a figure from Transport Canada.

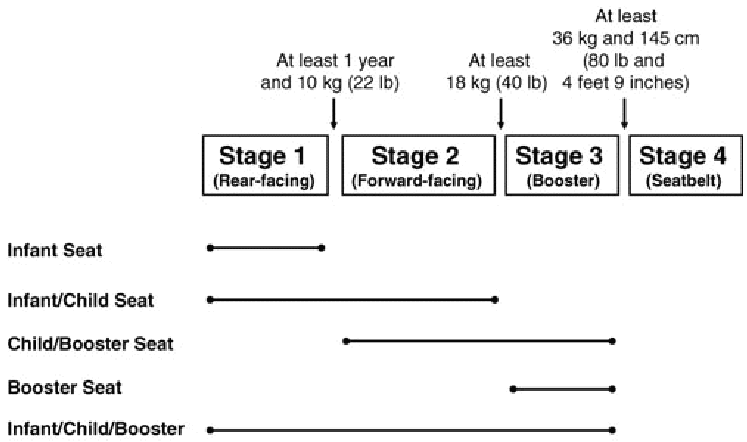

Figure 1-1 Appropriate restraint selection – stages versus restraint systems based on Transport Canada recommendations. (11)

The rear-facing CRS (RFCRS) is used for individuals from birth to approximately 2 years or 10kg. Children between 0-2 years use RFCRSs and transition to a forward-facing CRS (FFCRS) around two years old. They will remain in an FFCRS until four years of age. Children between 4 and 8 may fit either into an FFCRS or a booster seat. At eight years old, children typically progress from a booster seat into a seatbelt-only restraint system. Some children will be in combinations of CRS types as they grow. The designs of some CRS types are shown in Figure 1-2. Figure 1-2 is a figure from Transport Canada. The harness systems used in child seat CRSs are designed to redistribute the forces experienced during a collision across the rigid bony structures of the child's body.

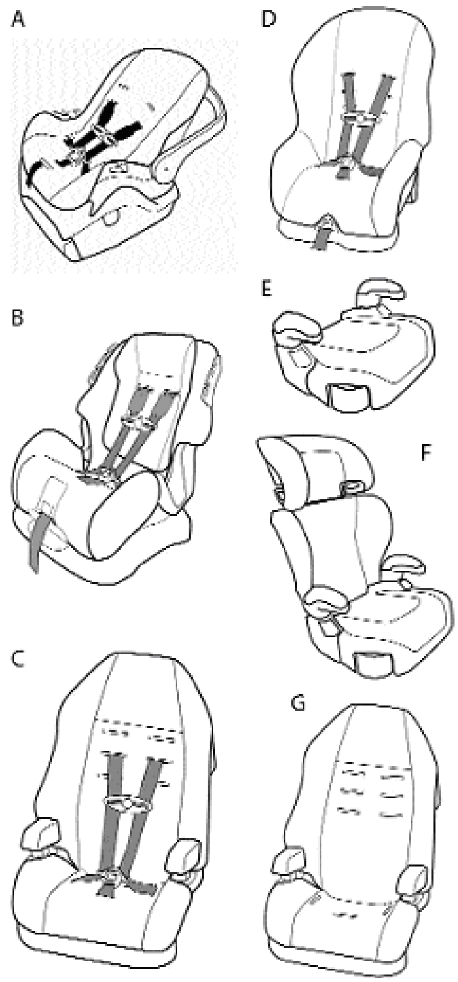

Figure 1-2 Appropriate restraint selection – stages versus car seats based on Transport Canada recommendations. A) Infant seat with base B) '3-in-1' convertible seat – infant/ child/booster seat. C) Infant/child/booster seat (child seat mode). D) Child/booster seat. E) Backless booster seat. F) High-back booster seat. G) Combination (child/booster) seat (belt-positioning booster seat mode) (11).

Rice et al. researched the effectiveness of CRSs for children under three years old and their risk for death when involved in an MVC. The death risk ratios showed that CRS use was twice as effective at preventing death than a lap-only seatbelt for children one year or younger; however, lap-only seatbelts were just as effective as a CRS for children between ages of two and three (12). These death risk ratios were less than the ratios for child occupants who were not using any type of restraint system. Another study showed that children restrained in child seats with an internal 5-point belt harness (rearward facing or forward facing) had a lower injury risk of head injury compared to older children restrained by only a lap-only seatbelt (13).

1.3.1 Rear-facing Infant Carrier (illustrated in Fig. 1-2 A)

Rear-facing infant carriers (see Figure 1-2 A) are designed to support and restrain children from birth to two years old, depending on the size of the child. Infant carriers can restrain infants who are up to 10 kg (approximately 20lbs) or 2 years old (14). There are two main designs of infant carriers. They either have an integrated base or a removable base. The infant carrier CRSs are designed to support the weak necks and large heads of infants. Since children need the extra support, the seats are angled back to prevent damage and injury to the infant's neck and head if a crash occurs.

1.3.2 Forward-facing Child Seat (illustrated in Fig 1-2 C)

They are designed to be an intermediate restraint system between an infant carrier for infants and a belt-positioning booster seat for older children. Forward facing child seats can be used for children between 10-18 kg (22-40lbs) and 1-4 years depending on the specific manufacturer guidelines (14).

1.3.3 Booster Seat (illustrated in Fig 1-2 E, F)

A booster seat is the final stage of a CRS before a child graduates to using only a lap and torso seatbelt. The booster seat may have a permanently attached high back, a low back, or a removable back. The transition from an FFCRS to the booster seat occurs when the individual has outgrown the weight limit for their FFCRS, which usually occurs around 35 pounds or 16 kilograms (11). Children who progress from a booster seat to a seatbelt only restraint need to be at least 4'9" tall. This height is reached between the ages of eight and twelve years. The legislation in every province varies, but the general rule is that graduation to a seatbelt only occurs in children who are eight years old, 4'9", and at least 18-36 kilograms (40-80 lb.) (14).

The booster seat system is designed to reorient and elevate a child's body to a more appropriate position allowing the use of a lap and torso seatbelt. The lap and torso seatbelt straps are relocated from the abdomen and neck regions to the pelvis/top of the lower limbs and the shoulder/collarbone regions. This repositioning allows the forces from the collision to be redistributed across the skeletal system of the individual instead of the soft tissues of the abdomen and neck. When a child has outgrown their booster seat, the child should be able to sit at the back of the vehicle seat with their knees bent and feet on the floor. The seatbelt must cross across the child's shoulder and centre of their torso when he/she is sitting on the vehicle seat.

Durbin et al. found that children using a booster seat had a 60% injury risk decrease during a collision compared to their seatbelt-only counterparts. (15)

1.3.4 Combination CRSs (illustrated in Fig 1-2 B, C, D, G)

There are a variety of CRSs that are combination seats. The specifics for the use and conformation of each seat type is specific to each manufacturer and model. The infant carrier/ child seat combination, which can be used as both a forward-facing and rear-facing CRS, is typically used for children from birth to up to four years, depending on the seat's height and weight limitations. This type of CRS seat is typically a five-point harness that straps across the thorax, abdomen, and lower extremities.

Another CRS combination seat type is the child seat/ booster seat combination. These seats can be used as FFCRSs. These seats typically have a removeable insert or adjustable harness system to allow use by smaller occupants. These harnesses usually have a five-point system that restrains the child 's body from above the clavicles and shoulders, down the torso and the iliac crests and lateral aspects of the lower limbs.

The most common combination CRS on the market is the infant carrier/ child seat/ booster seat CRS. These combination seats can be used in both rear-facing and forward-facing directions.

1.4 Head Injuries in MVCs

Trauma is the leading cause of death in children (16,17). Head injuries in children under one year of age are most commonly sustained in MVCs. Children in this age group had much higher incidence rates for head injury in comparison to older children, aged one to seven years in one study of children in MVCs (18). Infants have large heads and structural features in their neck/spine such as relatively weak neck muscles that make them more vulnerable to damage/injury in an MVC (19). Sweitzer et al. examined injury by restraint use for children nine years old younger in MVCs. They found that 80% of the fatalities were due to head injuries (20).

Serious brain injuries can have immediate and long-term effects that may not be fully manifest until a child is older (21). The second most common cause of cranial fractures in children in one study was motor vehicle collisions (20.8%), with the most common being falls (22). A study, conducted by Ma et al., found that there was less risk of head injuries (AIS 1-2) if in a booster seat and using a seatbelt (23).

1.5 Hypothesis

I hypothesize that the severity of head injuries in children who are eight years of age or younger seated in the rear seats of motor vehicles involved in collisions will be influenced by the types of restraint systems used.

1.6 Supplementary Research Questions

1. Do gender, age, and size, which are determinants of appropriate CRS type, influence head injury pattern and severity?
2. Are there relationships between head injuries and other injuries?
3. Are there other patterns of injuries influenced by CRS type?
4. Does the number of rear row occupants have a protective effect for head injury severity?
5. Are there seasonal differences in injury severity?
6. Does improper installation or misuse of CRSs affect head injury severity?
7. Do vehicle model and crash dynamics influence head injury severity?

1.7 Aims

Objective 1. Establish a database for individuals 8 years old or younger involved in motor vehicle collisions who are rear passengers.

Objective 2. Further subdivide these data based on complete collision profiles that include variables such as restraint use, collision geometry, occupant demographics, and injury characteristics.

Objective 3. Analyze the injuries, and lack thereof, sustained by the occupants during the collisions and determine their cause.

Objective 4. Analyze data using odds ratios and univariate linear regression analysis to determine which variable(s) is/are the most strongly associated with the head injury severity for occupants 8 years old or younger.

Chapter 2

2 METHODS

Qualitative and quantitative analyses of crash, vehicle, and injury data were prospectively collected from severe southwestern Ontario motor vehicle collisions (MVCs) involving rear occupants under 18 years of age that occurred between 2008 and 2016.

This research study was done with Western University Research Ethics Board approval (File No: 104890, - “A Multidisciplinary Team Approach to Prevent Motor Vehicle Crash-Related Injuries in South Western Ontario”- Dr. Douglas Fraser, principal investigator).

The necessary training modules for individual clinical research training required by the Lawson Health Research Institute were completed. Since the data were accessed from Transport Canada (TC), a federal agency, security clearance (category B) was applied for and granted by the Canadian Industrial Security Directorate.

2.1 Transport Canada’s Mandate

Transport Canada is involved with developing regulations and assisting legislative efforts that aim to monitor those facets of the Canadian transportation industry that impact the safety of the public.

Under the auspices of the *Motor Vehicle Safety Act*, TC develops, administers, and oversees policies, regulations, and standards for motor vehicle and commercial vehicle safe operation that are consistent across the country and harmonize with international standards (24). TC’s mandate is to reduce road-related injuries and deaths by ensuring that the motor vehicle industry consistently adheres to current safety standards. TC monitors the effectiveness of these safety standards and evaluates the potential of new safety devices in injury mitigation and prevention.

TC functions on behalf of the Minister of Transport. The Minister has the powers to initiate research, analysis, testing, and fees for funding of projects across the country. The Minister may, under the *Motor Vehicle Safety Act* (s.20(1)), “(a) conduct any research, studies, evaluations, and analyses that the Minister considers necessary for the administration of the Act,

(b) undertake research and development programs for the study of the impact of vehicles, drivers, streets/highways on road safety, energy conservation, and the environment and for the promotion of measures to control that impact,

(e) collect any information related to vehicles or equipment that the Minister considers to be in public interest,

(f) publish or otherwise disseminate any information, other than personal information relating to the activities of the Minister under this section."

2.2 The Role of the Western Motor Vehicle Safety Research Team

TC relies on research teams across Canada to collect information about crash scenes and vehicles, and to analyze collision dynamics and occupant kinematics to determine patterns of injuries.

The Motor Vehicle Safety (MOVES) research team at Western University is one of six research teams across Canada funded by TC under a contract with Western University. MOVES is the only team in Ontario. The MOVES research team collects real-world data that TC can correlate with its crash safety research. The MOVES team collaborates with various police services, the Office of the Chief Coroner for Ontario, the Office of the Ontario Fire Marshal, other motor vehicle and safety experts, insurance companies, provincial motor vehicle inspectors, car business owners, car salvage yards, and motor vehicle repair centres. The MOVES team partners with its subcontractor, Southwestern Collision Analysis (SWCA), based in London, Ontario. In addition to MVC investigations and reconstructions in the province, SWCA investigators also assess safety-related vehicle defects, train police for in-depth MVC investigations, provide traffic safety lectures to the general public and participate in road and motor vehicle safety research.

2.3 Database Creation

The database was compiled by MOVES/SWCA from the following studies directed by TC to create a uniform dataset:

- PROS- Pediatric Rear Occupant Study
- ROP- Rear Occupant Protection Study
- SID- Side Impact Study
- ASF- Special Investigations
- ACR- Air Cushion Restraint Study

The investigations of the MVCs for these various studies were done by SWCA in conjunction with local and regional police services. The information from the collisions of interest was integrated into final pseudo-anonymized investigation reports by SWCA investigators and provided to the TC Motor Vehicle Safety Directorate (Collision Investigations). These collision investigations were supplemented by injury information from the London Health Sciences Centre (LHSC) Level 1 Pediatric Trauma Centre (PTC). The collisions that involved full investigations by SWCA and TC involved severe collisions with occupants presenting to hospital for medical treatment. These collision investigations also included MVCs with occupants that were pronounced dead at the scene of the collision or in hospital some of whom had post-mortem examinations done to assist coroners' investigations to determine a cause of death. . The information that was collected from the collision profiles included information on collision identifiers, occupants, pre-collision and collision environment, and injury characteristics. The full table of variables and their definitions can be found in Appendix A (page 47).

The initial database for rear occupants under 18 years of age was the source of information for this study for occupants eight years old and younger. This subset was selected because occupants in this age range would be expected by law to be using a Child Restraint System (CRS) as required by Canadian legislation (Motor Vehicle Restraint Systems and Booster Seats Safety Regulations (SOR/2010-90)) (25).

2.4 Literature Review

To determine the most appropriate variables for this study, an extensive scoping and systematic literature search and review were done. This was conducted through the databases available to the Western University student community. The main search engine that was used was the Medline (OVID) database. This database searches through books, journals, and over 6000 different journals. Medline uses not only the National Library of Medicine journal citation database but also the Medical Subject Headings (MeSH) to help locate articles.

The literature search began with a broad scope of all motor vehicle collisions. This search was then narrowed down to North American studies to ensure that it was applicable to the current research study. Specifically, the focus of the literature search was later shifted to articles on pediatric occupants. Since children in motor vehicles are required to use a CRS, this was added into the literature search algorithm. When articles were found in the Medline OVID database, they were sorted based on their relevance to this study. Articles that included injury-specific research (e.g. renal injury), involved all-terrain vehicles, cyclists, motorcyclists, pedestrians, child abuse, sports-related, and other non-motor vehicle collision studies were excluded from the final literature review. The matrix that was used to determine article relevance to the study can be found in Appendix B (page 52).

2.5 Database Variables

Based on the literature search and review, the following dataset variables were grouped into categories: collision identifiers, occupant, pre-collision, collision, or injury characteristics as shown in Table 2-1.

Table 2-1 Variables Analyzed in the Rear-Seated Child MVC Occupant Injury Study.

COLLISION IDENTIFIERS	OCCUPANT	PRE-COLLISION	COLLISION	INJURY CHARACTER-ISTICS
• PAED NUMBER • TRANSPORT CANADA CASE NUMBER • VEHICLE NUMBER	• GENDER • AGE • HEIGHT (CM) • MASS (KG) • OCCU-PANT SEATING POSITION • NUMBER OF REAR ROW OCCU-PANTS • NUMBER OF PEDIAT-RIC OCCU-PANTS	• VEHICLE YEAR • SEASON • MONTH • YEAR • SEATBELT OR CRS USED • MANNER OF SEATBELT USE • CRS FORWARD VERSUS REARWARD • CRS TYPE • CRS DESIGN • IMPROPER CRS INSTALL-ATION • IMPROPER CRS USE	• NUMBER OF VEHICLES • COLLISION CONFIGU-RATION • INITIAL IMPACT TYPE • COLLISION SEVERITY • SURFACE CONTACTED • WINDSHIELD CONTACT • INTRUSION +/- • INTRUSION (CM) • OBJECT CONTACTED • PRINCIPLE DIRECTION OF FORCE • EVENT DATA RECORDER SPEED (KM/H) • EQUIVALENT BARRIER SPEED (KM/H) • ΔV (KM/H) • EJECTION	• NUMBER INJURED PEDIATRIC OCCUPANTS • NUMBER FATAL PEDIATRIC OCCUPANTS • INJURY SEVERITY • OVERALL MAIS • MAIS- HEAD • MAIS- FACE • MAIS- NECK • MAIS- CHEST • MAIS- ABDOMEN • MAIS- SPINE • MAIS- UPPER EXTREMITY • MAIS- LOWER EXTREMITY

2.6 Injury Analysis

The focus of this study was to determine whether these variables played any significant role regarding head injuries. The AIS (Abbreviated Injury Scale) version that was used for this study was the AIS-1998 (26). The AIS values were assigned to each injury by Kevin McClafferty at SWCA. The statistical software that was used to perform the analysis was IBM SPSS. Pearson’s correlations, Odds Ratios, and Univariate Regression statistical analyses were done to provide the relationships between the occupant, pre-collision, collision, and other injury variables with the Maximum Abbreviated Injury Scale (MAIS) value for the head (MAIS-HEAD).

2.7 Injury Classification and Location

Injuries are classified and reported using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) codes (27). These codes allow for standardized assessments and classifications of health problems and diseases. Part of the ICD-10 coding process is the AIS value, which categorizes the level of severity of the injury (26). This system categorizes injuries into relatively specific codes. These codes describe the location, type, and severity of the injury the individual sustained. The seven digits in the code specify these different descriptors of the injury sustained.

The AIS scale predicts the probability of death associated with a specific injury (Table 2-2) (26). In this study, cases of severe (MAIS-HEAD= 2-6) head injuries were compared to occupants with minor or no head injury (MAIS-HEAD= 0-1) to determine the likelihood of sustaining a severe head injury. AIS values of 7 and 9 were excluded from this study as they do not provide information on the probability of death or the severity of the injury. MAIS 2 was the minimum AIS value for severe head injuries as the probability of death is greater than zero. Also, in the peer-reviewed medical literature, MAIS 2 is used as the minimum threshold for severe injuries. The cases of severe head injury were examined in greater depth to describe underlying factors that might be contributing to these injuries.

Table 2-2 AIS Values and Probability of Death (26)

Values	Injury Severity	Probability of Death (%)
0	None	0
1	Minimal	0
2	Minor	1-2
3	Major	8-10
4	Severe	5-50
5	Critical	5-50
6	Fatal	100
7	Injury to body region with no further information	Unknown
9	Unspecified	Unknown

2.8 Statistical Analyses

Statistical analyses and consultation were provided by Dr. Jamie Seabrook from Brescia University College, London, Ontario. The data in the information spreadsheet were numerically coded within each variable to allow it to be used with statistical software. Using the IBM SPSS 2017 statistical software, MAIS-HEAD groupings were cross-tabulated with the variables in Table 2-1. The cross-tabulation gave the number of individuals sustaining no or minor head injuries and severe head injuries per category in each variable. Odds ratios and Fisher's Exact tests were performed on variables that had binary outcomes (yes/no, male/female). The dependent variable of MAIS-HEAD was used as a binary outcome (severe/not severe). Linear univariate regression was performed on variables that had non-binary outcomes. The dependent variable of MAIS-HEAD was used as a continuous scale from zero to six.

Using Equation 2-1 to calculate the odds ratio (OR) of population A (no or minor head injury) compared to population B (severe head injury) for each variable. The odds ratio is the likelihood of a favoured outcome in one category over the favoured outcome in another category. An odds ratio is used when all values being analyzed are five or greater.

Equation 2-1

$$\boldsymbol{OR = \frac{n_A/n_C}{n_B/n_D}}$$

n_A= $Total\ number\ of\ cases\ in\ population\ A$

n_B=$Total\ number\ of\ cases\ in\ population\ B$

n_C= $Total\ number\ of\ individuals\ in\ population\ A$ - n_A

n_D= $Total\ number\ of\ individuals\ in\ population\ B$ - n_B

The 95% confidence interval (CI) was used in this study to test for statistical significance of the odds ratios. Equation 2-2 shows how the confidence interval can be calculated for the OR and Equation 2-3 is the Standard Error of the Odds Ratio (SE(OR)).

Equation 2-2

$$\boldsymbol{95\%\ CI = e^{\ln(OR)\ \pm\ [1.96\ x\ SE(OR)]}}$$

Equation 2-3

$$\boldsymbol{SE(OR) = \sqrt{\frac{1}{n_A}+\frac{1}{n_B}+\frac{1}{n_C}+\frac{1}{n_D}}}$$

The Fisher’s Exact test was used in this study to examine the significance of association in a 2x2 table. The Fisher’s Exact test provides a similar statistical outcome to an odds ratio; however, it is used when at least one value being analyzed is less than five. Equation 2-4 shows how the Fisher’s Exact test can be calculated from the values in a 2x2 table.

Equation 2-4

$$\boldsymbol{Fisher's\ Exact\ Test\ p-value} = \frac{(n_A+n_B)!\,(n_C+n_D)!\,(n_A+n_C)!\,(n_B+n_D)!}{n_A!\,n_B!\,n_C!\,n_D!\,(n_A+n_B+n_C+n_D)!}$$

The Nagelkerke R^2 was used in the univariate regression analyses. This R^2 value adjusts for the typical Cox-Snell R^2 value to extend the range to one. The value states the amount of the variation in the data that can be explained by the variable under investigation. Equation 2-5 shows how the Nagelkerke R^2 can be calculated from the values calculated in the univariate regression.

Equation 2-5

$$\boldsymbol{Nagelkerke\ R^2} = \frac{1-\left[\frac{L(R)}{L(F)}\right]^{2/N}}{1-L(R)^{2/N}}$$

L(R)= Likelihood of intercept only model

L(F)= Likelihood of specified model

N= Number of observations

A p-value is the probability that a given event will occur. The p-value is used to reject the null hypothesis that a given event or result will happen by chance. A typical p-value cut off is 0.05; however, p-values of 0.05 and 0.01 are often used as levels of significance. A p-value of 0.05 means that there is 95% confidence that the true value of the statistic is within the confidence interval, a range of values that the true value is likely to fall. A p-value of less than 0.05 means that there is a 5% or less chance that the effect is due to chance alone. The smaller the p-value, the less likely that the alternate hypothesis will happen by chance or that there is a significant difference between the hypothesis being tested and the alternate hypothesis.

Chapter 3

3 RESULTS

3.1 Literature Review

The literature search and review that was performed based on the criteria listed in Appendix B included 286 articles. These articles were then screened a second time to exclude articles that involved all-terrain vehicles, cyclists, motorcyclists, pedestrians, child abuse, sports-related, and other non-motor vehicle collision studies. Using these exclusionary parameters, 100 articles remained. These articles were reviewed to determine if they were relevant to the study. Of the 100 articles, only 49 were applicable to this study. A list of the articles included in this study can be found in Appendix C (page 54).

3.2 London Health Sciences Centre (LHSC) Trauma Data

During the study period of 2008-2016, 267 cases were reviewed. These cases had 394 occupants. Of the 394 occupants, there were 189 males, 201 females, and four individuals of unknown gender, aged 0 to 18 years. From these 267 cases, 129 cases (182 occupants) were selected based on the occupants' age, eight years old and younger. Of these, 47 cases were determined to be complete because they included sufficient information about the variables outlined in Table 2-1. These complete cases included up to 62 occupants that could be analyzed; 36 males, 25 females, and 1 person whose gender was unidentified . Cases were skewed towards severe crashes. Severe crashes often were paired with more complete work-ups from police and SWCA investigation reports. All cases that were studied were assessed at LHSC, although some may have been missed during data collection. The collisions that resulted in child fatalities would have had information collected from either post-mortem examinations, police investigations, or clinical records or a combination of these sources. The raw data can be found in Appendices D-G (pages 61, 64, 67, 72, 77, 79, 82, 84, respectively) for complete case information based on occupant, pre-collision, collision, and variables, respectively.

3.3 Common Head Injuries

The head injuries noted in the 47 cases (62 occupants) were described as follows: (crush) massive destruction of both cranium (skull) and brain, basilar fracture, brainstem compression, brainstem hemorrhage, subarachnoid hemorrhage, cerebral concussion, cerebrum contusion (single, multiple, NFS [Not Further Specified]), diffuse axonal injury, cerebral edema (infarction, intraventricular hemorrhage, mild, NFS, subarachnoid), cerebral hematoma/hemorrhage (epidural/extradural-NFS, epidural/extradural, intracerebral subcortical hemorrhage, subdural, subdural-NFS, NFS), skull fracture, vault fracture (closed- simple; undisplaced; diastatic; linear, comminuted- compound; depressed; displaced). The head injury details came from clinical records and autopsy results (if fatal) from LHSC. These head injuries have been broken down by AIS severity level in Appendix H (pages 87-88).

3.4 Likelihood of Sustaining a Severe Head Injury Using Odds Ratio, Fisher's Exact Test, and Linear Univariate Regression

To test the likelihood of an occupant sustaining a severe head injury as a result of an MVC, injury data were acquired for occupants between the ages of 0 and 8 years. The injuries were coded using the Abbreviated Injury Scale (AIS) 1998. These codes represent specific injuries relating to craniocerebral injury. Injuries were separated into two categories based on the Maximum AIS (MAIS) value for the head region: no/minor head injury (MAIS 0-1) and severe head injury (MAIS 2-6). When the data were separated into the two categories (no/minor and severe head injury sustained), the odds ratios (OR) for sustaining a severe head injury was compared to the control group of having no to minor head injury. The OR and their 95% confidence interval (CI) were calculated using Equation 2-1 and 2-2 respectively (an example calculation for OR and its 95% CI can be found in Appendix I on page 89. The Fisher's Exact Test scores were calculated using Equation 2-4.

Table 3-1 shows the OR with the 95% CI, p-value, and Fisher's Exact test results for variables that had binary outcomes (either yes/no or male/female). Ejection results (Appendix J-17 on page 100) had a p-value of less than 0.01. However, ejection had values that were less than five included in the 2x2 table, so the p-value was substituted by the Fisher's Exact test value to provide a more accurate representation of the level of significance. Even when the value was substituted in for the level of significance, ejection remained significant. These observations indicate the gender, intrusion, and improper CRS installation/use do not play a significant role in determining whether a severe head injury will occur; however, ejection from the vehicle does. Complete data tables for each variable are shown in Appendix J (page 92). Occupant compartment intrusion impacts on injury patterns can be found in Appendix K (page 109).

Table 3-1 Crosstab Odds Ratio and Fisher's Exact Test of Occupant, Pre-collision, and Collision Variables with Binary Response Options

Variable	Odds Ratio	95% Confidence Interval	p-value	Fisher's Exact Test
Intrusion	3.1	0.75-12.55	0.108	0.128
Gender (M/F)	1.6	0.44-5.62	0.479	0.526
Ejection*	14.4	1.34-143.04	0.006	0.026
Improper CRS Installation	0.9	0.084-9.29	0.915	1.00
Improper CRS Use	0.6	0.06-6.49	0.692	1.00

* $p < 0.01$

Table 3-2 shows the results for univariate regression analysis for variables with non-binary response options. The dependent variable that was examined was MAIS-HEAD. It was examined using a continuous scale from 0-6 to allow for a univariate linear regression to be performed. The exp(B) in this table represents the OR. Table 3-2 also shows the 95% CI, p-value, and Nagelkerke R^2 for the variables with non-binary response options. The Nagelkerke R^2 was determined using Equation 2-4. The variables that showed a significant difference between the OR for minor to no head injury and severe head injury were MAIS-Overall, MAIS-Thorax, MAIS-Lower Extremities, and the number of rear row occupants. MAIS-Overall, MAIS-Thorax, and MAIS-Lower Extremities had p-values less than 0.01. The number of rear row occupants had a p-value of less than 0.05. These observations indicate that MAIS-Overall, Thorax, and Lower Extremities, along with the number of rear row occupants are significantly associated with severe head injuries..

Further investigation of CRS type on injury patterns can be found in Appendix L (page 110) . Seasonal patterns of injury can be found in Appendix M (page 113) . Improper use and installation of CRSs and their results on injury patterns can be found in Appendix N (page 115).

Table 3-2 Univariate Linear Regression of Occupant, Pre-collision, Collision, and Injury Variables with Non-binary Outcomes

Variable	Exp(B)	95% Confidence Interval	p-value	Nagelkerke R^2
Vehicle Year	n/a	n/a	0.130	0.225
Collision Configuration	0.08	0.56-1.5	0.733	0.003
EBS	1.3	0.84-1.97	0.253	0.040
Delta-v	1.2	0.91-1.55	0.207	0.044
Season	n/a	n/a	0.975	0.005
Occupant Seating Position	0.009	0.66-1.48	0.963	0
Age	1.1	0.87-1.46	0.353	0.022
Height	0.1	0.60-1.34	0.589	0.015
Mass	0.02	0.60-1.59	0.927	0
MAIS-Overall*	1.5	1.15-2.01	0.003	0.244
MAIS-Face	0.2	0.31-2.06	0.646	0.005
MAIS-Neck	0	0	0.999	0.035
MAIS-Thorax*	2.0	1.28-3.16	0.003	0.262
MAIS-Abdomen	1.3	0.81-1.97	0.314	0.024
MAIS-Spine	770524608.2	0	0.999	0.382
MAIS-Upper Extremities	1.4	0.57-3.62	0.442	0.014
MAIS-Lower Extremities*	2.5	1.26-4.85	0.008	0.183

CRS Type	1.0	0.998-1.001	0.623	0.006
CRS Design	1.0	0.999-1.001	0.822	0.001
Number of rear row occupants**	0.6	0.194-0.927	0.032	0.142

* $p < 0.01$, ** $p < 0.05$

Following the first set of univariate linear regression analyses, a second analysis was performed. The second analysis looked specifically at the variables that had significant p-values: MAIS-Thorax, MAIS-Lower Extremities, and the number of rear row occupants. MAIS-Overall was excluded from this analysis as it related directly to the highest AIS value an individual has. If the highest value for any body region (including the head) was 5, the MAIS-Overall value would be 5. It does not directly relate to head injury severity, but it is more a measure of overall injury severity an individual has sustained. This analysis was done to determine if these variables had any relationship with each other.

When controlling for MAIS-Thorax and MAIS-Lower Extremities, the number of rear row occupants had lower odds of involvement in severe head injury cases (OR=0.48, 95% CI= 0.21 to 1.3) Data were available for 62 occupants. The regression was not statistically significant (p=0.15) for the relationship between the number of rear row occupants and severe head injury.

When controlling for MAIS-Thorax and the number of rear row occupants, MAIS-Lower Extremities had higher odds of involvement in severe head injury cases (OR=1.8, 95% CI= 1.15 to 2.86) Data were available for 62 occupants. The regression was statistically significant (p=0.01) for the relationship between lower extremity injury and severe head injury.

When controlling for MAIS-Lower Extremities and the number of rear row occupants, MAIS-Thorax had higher odds of involvement in severe head injury cases (OR=2.2, 95% CI= 1.06 to 4.49). Data were available for 62 occupants. The regression was statistically significant (p=0.04) for the relationship between thoracic injury and severe head injury. The regression model explained 42.7% of the variance in the head injury (Nagelkerke R^2= 0.427).

A third set of univariate linear regression was performed when controlling for MAIS-Thorax and MAIS-Lower Extremities to determine if they had any stronger relationship with one another. When controlling for MAIS-Thorax, MAIS-Lower Extremities had higher odds of involvement in severe head injuries (OR=2.4, 95% CI= 1.2 to 4.7). The regression was statistically significant (p=0.012) for the relationship between lower extremity injury and severe head injury. When controlling for MAIS-Lower Extremities, MAIS-Thorax had higher odds of involvement in severe head injuries (OR=1.9, 95% CI= 1.2 to 2.9). The regression was statistically significant (p=0.005) for the relationship between thorax injury and severe head injury. The regression model explained 37.9% of the variance in the head injury (Nagelkerke R^2= 0.379).

3.5 Injury Sources

The contact points or possible sources contributing to the severe head injuries sustained by the occupants in this study were from surfaces within and exterior to the vehicle. In the vehicle interior, they were seat, back support, right frame or side window glass, loose objects, child safety seat or interior surface not otherwise specified. Contact points from outside of the occupant compartment were front bumper or exterior/other vehicle or the ground.

The probable contact points that contributed to thorax injuries were also from either inside or outside the vehicle occupant compartment. The interior injury sources were floor or console mount, shifter, seat, back support, child safety seat or not otherwise specified. The exterior contact point was the front of the other vehicle.

The possible contact points contributing to lower extremity injuries were from the interior of the vehicle occupant compartment. These were webbing/buckle belt restraint, seat, back support, child safety seat or not otherwise specified.

A comprehensive list of what surfaces/objects the child occupants contacted and the resulting AIS injury can be found in Appendix O (page 117).

Chapter 4

4 DISCUSSION

Head injuries are the most common and usually the most severe type of injury in child occupants involved in MVCs (19, 28). Craniocerebral trauma accounts for 1/3 of all fatalities of children injured in MVCs and is the most common serious injury sustained by children regardless of crash direction (29).

The current study examined how different occupant variables and pre-collision and collision factors affected head injury severity sustained by child occupants in MVCs.

In this study, research was conducted to answer the hypothesis that the severity of head injuries in children who are eight years of age or younger seated in the rear seats of motor vehicles involved in collisions will be influenced by the types of restraint systems used.

Data were also analyzed to address the supplementary research questions:

1. Do gender, age, and size, which are determinants of appropriate CRS type, influence head injury pattern and severity?
2. Are there relationships between head injuries and other injuries?
3. Are there other patterns of injuries influenced by CRS type?
4. Does the number of rear row occupants have a protective effect for head injury severity?
5. Are there seasonal differences in injury severity?
6. Does improper installation or misuse of CRSs affect head injury severity?
7. Do vehicle model and crash dynamics influence head injury severity?

4.1 Research Questions

4.1.1 Do gender, age, and size, which are determinants of the appropriate CRS type, influence head injury pattern and severity?

To determine whether gender, size (height and mass), and age influence the odds of sustaining a severe head injury from an MVC, the present study compared a population of 36 males and 25 females who were eight years old or younger. Gender, height, mass, and age were chosen because they are good indicators of the developmental stages of the head and body overall, CRS type and potential injury mechanisms (18, 30). Raw data can be found in Appendix J, Tables J-1 to J-4 (pages 92-94).

4.1.1.1 Gender

When the odds ratio (OR) was done on the gender of the occupant with regard to their head injury severity, the likelihood of sustaining a severe head injury for females versus males in an MVC was 1.58 (95% CI= 0.44-5.62) (Table 3-1). Although the OR states that females were more likely to sustain a severe head injury, this result was not significant (p= 0.479). This result suggested gender could not have an effect on head injury severity. This lack of a significant difference between males and females sustaining a severe head injury has been attributed in part to young children, regardless of gender, growing at about the same rate (18). In contrast to this observation and the result of the present study, other authors have described developing females as having stronger bones, ligaments, and muscles enabling them to tolerate more energy transfer and forces in an MVC (31).

4.1.1.2 Age

The ages of occupants in this study were available for 61 individuals. The OR for severe head injury was 1.13 (95% CI= 0.87-1.46), indicating that there was a slightly increased odds of sustaining severe head injury as occupant became older (Table 3-2). The result was not significant (p= 0.353). The univariate model also explained 2.2% of the variance in the data. The low Nagelkerke R^2 value meant that age was not a major factor influencing whether a severe head injury occurred.

4.1.1.3 Height and Mass

Height and mass values for the occupants involved in this study were limited. There were 29 occupants with height values and 42 occupants with mass values. The OR for sustaining a severe head injury with regards to height was 0.105 (95% CI= 0.60-1.34) (Table 3-2). This indicated that taller occupants in this study had a lower likelihood of sustaining a severe head injury. A Nagelkerke R^2 of 0.015 meant that 1.5% of the variance in the head injury severity could be attributed to the height of the occupant. The OR for the mass of the occupant was 0.023 (95% CI= 0.60-1.59) indicating that, like height, there was a trend for heavier occupants having a lower likelihood of sustaining a severe head injury. Neither the height nor mass results were significant with p-values of 0.589 and 0.927, respectively.

4.1.2 Are there relationships between head injuries and other injuries?

Head injuries are frequently due to contacts within the vehicle compartment. The most frequent contact points for head injuries are the front seat back, the rear seat back support, interior surfaces of the wall/door/window, intrusion into the occupant compartment, and other objects in the rear occupant compartment. Injuries also can occur due to non-head-contact events.

In addition to head trauma, injuries were categorized into occurring in eight body regions using the AIS-1998 scale: face, neck, thorax, abdomen, spine, upper extremities, and lower extremities. Raw data can be found in Appendix J, Tables J-19 to J-25 (page 104-108).

4.1.2.1 Face

The likelihood of sustaining a severe head injury when there were facial injuries was 0.199 (95% CI= 0.31-2.06) (Table 3-2, Table J-19, page 104). This suggested that when severe head injury occurred, it was less likely to be from facial impact. The result was not significant (p= 0.646).

4.1.2.2 Neck

In the present study, the likelihood of a coexisting severe head injury with a neck injury was 0 (95% CI= 0) (Table 3-2, Table J-20, page 104). No severe neck injuries were found in the present study associated with severe head injury. The neck injuries that were present were described as skin abrasions.

4.1.2.3 Thorax

Thoracic injuries can occur during a collision not only from contacting structures within and outside the occupant compartment but also from loading a restraint system.

The odds ratio of sustaining a severe head injury when there was a thoracic injury was 2.01 (95% CI= 1.28-3.16). The result was significant (p= 0.003) (Table 3-2, Table J-21, page 105). As thoracic injury severity increased (MAIS 3-4), head injury severity also increased. Thoracic injury, based on the univariate linear regression analysis, explained 26.2% of the variance in the head injury data

(Nagelkerke R^2= 0.262). In this study, thoracic injuries resulted from contacts within and outside the occupant compartment. When contacting the CRS was documented, occupants tended to have lower severity injuries to their thoracic region in a few cases (Appendix O, Table O-1. Page 117). Unfortunately, there was not enough detail in the database to definitively determine if seatbelt loading occurred with any of the occupants. The results of the present study support the observations of Arbogast et al. who found that coexisting head and thorax trauma was very common in children injured in MVCs (32).

4.1.2.4 Abdomen

The likelihood of abdominal and head injury severity being related was 1.26 (95% CI= 0.81-1.97). This was not a significant relationship (p= 0.314) (Table 3-2, Table J-22. Page 106). There was a trend. As abdominal severity increased (MAIS 2- 3), so did head injury severity. The abdominal injuries explained 2.4% of the variance in head injury severity (Nagelkerke R^2= 0.024).

If a CRS system is not properly positioned on an infant's or child's body, then abdominal injuries can be sustained during an MVC because of loading from the restraint system. Nance et al. found that properly restrained children were 3.5 times less likely to have an abdominal injury from an MVC (33).

4.1.2.5 Spine

Vertebral injuries causing spinal cord trauma can be life-altering and fatal (34). Cirak et al. studied spinal injuries and their mechanisms in children under the age of 14 years. They found that MVCs accounted for the majority of the children with spinal injuries and were most common for infants (29%) (37). They also found that the more severe spinal injuries were associated with trauma in other regions.

Cervical spine injuries indicative of sudden deceleration forces may be significant in cases of closed head injury (e.g. diffuse axonal injury) when there is no head contact (29). In the absence of head contact, trauma arising from abnormal neck movement during sudden deceleration can occur. One example would be in a frontal collision during which the mobile head and neck of a forward-facing child can be hyperflexed relative to the restrained torso.

Zuckerbraun et al. found that the incidence of cervical spine injuries was low in their MVC study (35). Stawicki et al. specifically studied cervical spine injuries and their relationship to MVCs. They found that when cervical spine injury occurred, there was likely a concomitant brain injury (36). They also found the cervical spine injuries are significantly related to restraint system use (36).

The likelihood of sustaining a severe head injury with a spine injury was 770524608.2 (95% CI= 0). This large value can be attributed to the lack of occupants with no or minor head injuries without significant spinal injuries (MAIS 1-2). Any MAIS 1 or MAIS 2 spine injuries observed were associated with severe head injuries. Although the odds ratio was large, there was no statistical significance ($p=0.99$) (Table 3-2, Table J-23, page 106). The regression model for this relationship explained 38.2% of the variance in head injury data (Nagelkerke $R^2 = 0.382$).

4.1.2.6 Upper Extremities

Loftis et al. conducted a study of the impact of CRS use and occupant age on injury severity in an MVC (38). The study included children up to the age of 12 years. Improperly restrained children were most common between the ages of four and eight years. Unrestrained and improperly restrained occupants were significantly more likely to have open head injuries and upper extremity trauma (38).

The likelihood of sustaining a severe head injury and an injury to the upper extremities was 1.44 (95% CI= 0.57-3.62) (Table 3-2, Table J-24, page 107). Although this was not statistically significant ($p=0.442$), there was a trend that severe head injuries were present when there were upper extremity injuries. The regression model explained 1.4% (Nagelkerke $R^2 = 0.014$) in the variance of head injury severity.

4.1.2.7 Lower Extremities

During an MVC, impact with the interior compartment, such as the seatback in front of the child occupant, can cause lower limb injuries as well as head and neck injuries (7). Howard et al. investigated side-impact collisions and injury mechanisms for child passengers. They found that lower extremity injuries were present more often in children under the age of six years compared to children seven years or older (39). They opined that this difference could be from the increased force from loading on the lower limbs due to CRS restraint location (39).

The present study confirmed the observations by Howard et al. The likelihood of sustaining a severe head injury and a lower extremity injury was 2.48 (95% CI= 1.26-4.85) (Table 3-2, Table J-25). This was significant (p=0.008). The lower extremity and head injury relationship, based on the univariate linear regression model, explained 18.3% (Nagelkerke R^2= 0.183) of the head injury data variance.

4.1.3 Is there a pattern of injuries based on CRS type and design?

Child restraint systems are available in a variety of types and designs in keeping with a child's development. Since each CRS type can differ in their positioning and method of restraint, different injury patterns are possible.

Preliminary work, done by the Western University MOVES team in 2017, found that there were five of thirteen infants aged less than twelve months who required admission to hospital or died of head injuries (MAIS 4-5) in rear-facing seats. This predisposition to head injury was attributed to the heads of these infants in rear-facing CRSs being located close to the back of the front seat (40). Three of six infants in CRSs with removable bases had severe head injuries (MAIS 4-5) and lower extremity trauma (femur fractures in two, thigh bruises in the third) (40). The other three infants had minimal or no head injury. In contrast, there were three infants in convertible CRS seats who had no or minimal head injury (40). In this preliminary research, the Western MOVES team also cited crash simulations reported in Consumers Reports that found that there was a lower incidence of dummy head contact with the front seatback in rear-facing convertible seats compared to infant carriers (40). This increased protection was attributed to the longer shell and shape of the convertible seats (40). Transport Canada performed 57 rear-facing car safety seat crash tests with the base attached; 10/57 (17.5%) dummy heads hit the front seat back with an impact of more than 80g which is considered the threshold for injury in the 2014 study by Stewart et al. (19, 40).

Based on a univariate linear regression (Table 3-2), neither CRS type nor design had a significant impact on head injury severity (p= 0.623 and p = 0.822, respectively). Data tables can be found in Tables J-9 and J-10. pages 97 and 98, respectively).

Since CRS type and design did not have an effect on head injury severity, the relationships with other body regions were examined to provide an injury potential injury profile for future research and analyses.

As seen in Table L-1(page 110), there was no unique injury pattern for each of the CRS types; however, there were some CRS types associated with more frequent injuries in certain body regions. For example, MAIS facial trauma was most frequent in booster seats and infant carrier/child seat/ booster seat combination.

Infant carriers had the highest average injury severity for the head and the upper and lower extremities of the occupants (Table L-2. Page 111). Infants in FFCRS child seats can sustain cervical spine trauma. In the preliminary study done by the Western MOVES team, there were two infants who sustained severe (MAIS 2 and 4) cervical spine injuries, but no severe head injuries observed out of eleven occupants who were in frontal collisions and in an FFCRS child seat (40).

Forward-facing, belt-positioning booster seats are the final type of CRS type before transitioning to seat belt use only. Booster seats were observed to have the highest average MAIS score for the abdominal injuries (Table L-2. Page 111). Booster seats elevate the occupant allowing optimum seatbelt fit. If lap/torso belts are not snug across the occupant's pelvis and iliac crests, the belts can ride up the abdomen causing injuries to manifest as the "seatbelt sign" (16). Seatbelt–loading injuries include hip and abdominal cutaneous contusions, pelvic and lumbar fractures, and intra-abdominal trauma (41).

There are CRSs that are combination seats that can be used as infant carriers, child seats, or booster seats depending on the type of CRS combination seat. The infant carrier/ child seat combination seats observed in this study had the highest injury severity for the thorax, abdomen, and spine (Table L-2). In this type of CRS seat, the restraint system is typically a five-point harness that straps across the thorax, abdomen, and lower extremities. As observed in this study, pediatric occupants sustained an injury of the torso including the spine and to a lesser degree, the lower extremities.

4.1.4 Does the number of rear row occupants have a protective effect for head injury severity?

The number of rear row occupants in a vehicle could potentially increase the chance of sustaining injuries in an MVC because of impacts with other passengers especially if they are unrestrained. For example, in the preliminary study by the Western University MOVES team in 2017, an impact from an unrestrained passenger likely contributed to the fatal injuries in one child (40).

In the present study, the number of rear row occupants included all occupants. The likelihood of the number of rear row occupants being a factor associated with severe head injuries in a pediatric occupant was surprisingly only 0.58 (95% CI= 0.194-0.927). This was significant ($p= 0.032$). The univariate linear regression model explained 14.2% of the variance in the head injury severities (Nagelkerke R^2= 0.142). When there were two or more occupants in the rear rows of a vehicle, head injury severity decreased. The data table can be found in Table J-6 (page 95).

A possible reason for this counterintuitive result could be that when there were more occupants in the rear rows, more attention was paid to proper restraint use and positioning of a child. Improper CRS use and prior faulty installation may have been factors resulting in a lone child occupant striking the vehicle interior. Alternatively, children impacting fellow passengers could have been less prone to injury compared to contact with less forgiving surfaces.

4.1.5 Are there seasonal differences in injury severity?

The amount of outer clothing layers worn by the pediatric occupants could be a factor influencing injury patterns and their severity. For example, in the winter, children who are restrained in a CRS while dressed in their bulky outdoor clothing may not be restrained effectively during a collision. Conversely, CRS harness straps may not be readjusted during the transition to warmer months. A loose fit can result in a child slipping out of a restraint system.

Lemieux et al. studied collisions in the Hamilton-Wentworth Niagara region occurring during a five-year period to determine a seasonal collision profile. They found that more collisions occurred in the summer and fall months (42). The increase in the summer months was consistent with more people travelling with their children for recreational activities (42). They attributed the increase of collisions in the fall to the start of the new school year and consequently increased driving by caregivers of children to school and related activities (42). Lemieux et al. also found that fewer collisions were happening during the winter months (42). In contrast to Lemieux et al., Toro et al. found no significant differences in the number of seasonal collisions and fatalities (43).

In the present study, the likelihood of acquiring a severe head injury during a particular season could not be determined. The data table can be found in Table J-8 (page 97). There was a trend to more severe head injuries occurring in the summer and fall months reflecting that more collisions happened during those seasons as reported by Lemieux et al. (42). The injury prevalence rates and average severity by body region compared to the season can be found in Tables 3-5 and 3-6, respectively. In the fall, upper and lower extremity injuries were more frequent than any other season. Summer cases had the highest average injury severity for the thorax and abdomen. The highest average MAIS values for the head, spine, and upper and lower extremities were seen in winter (Table M-2. Page 114).

4.1.6 Does improper installation or use of CRSs affect head injury severity?

When used properly and appropriately, CRSs do protect children from severe injuries in MVCs. In 2008, the Canadian Pediatric Society made recommendations for transporting infants in vehicles. The recommendations paralleled the AAP policy statements made in 2002 for appropriate CRS use for children (14). Compared to no restraints and seatbelts, CRSs are effective in infants and toddlers under 2-year years of age (12).

Stewart et al. found that properly restrained occupants have a 12.7x lower likelihood of having injuries in an MVC (19). Research done by Hanna found that if children were using the proper restraints based on their size and age, they had a significantly lower chance of having a severe or fatal injury (18).

Sauber-Schatz et al. found that CRS proper use reduces death risk for infants under 1 year by 71%, children 1-4 years by 54%, and 4-8-year olds by 45% (43). Optimally restrained children between 1 and 3 years are less likely to have neck/back/abdominal injuries and to be hospitalized compared to unrestrained children (44).

When used properly, CRSs reduce an occupant’s risk of contacts within the vehicle or ejection. Lee et al. found that restraint use compliance was higher in younger children (0-3 years) than in older children (4-9 years) (45). Although compliance decreased with age, only half of the occupants in this study were still using a restraint system when they were older (45).

In 2005, Durbin et al. looked into appropriate restraint use for children under 16 years old in MVCs and the resulting injury patterns. Eighty percent of these children sat in the rear rows of the vehicle, but only 50% of all the children in the study were restrained appropriately for their age, sex, and weight (46). Children with restraint errors were 1.8 times more at risk of an injury than the properly restrained children, with unrestrained children being 3 times more at risk (46). Berg et al. examined seating position and restraint use for child occupants in MVC. They found that more than 40% of the child occupants were unrestrained (17). Although sitting in the rear offered a significant amount of protection, there was more protection if the occupant was properly restrained.

McMurray et al. compared rear-facing and forward-facing child restraint systems and resulting injury patterns in children who were under the age of two years. They found that children in RFCRSs had lower injury rates than those seated in FFRCSs (47). They supported a recommendation that children stay in a rear-facing seat as long as possible to prevent injury during an MVC (47).

Ma et al. investigated the effectiveness of booster seats in preventing injuries compared with a seatbelt alone or no restraint use for children under 10 years old. They found that children using booster seats and seatbelts were at less risk for low severity head injuries; however, they were at an increased risk for neck and chest injuries when using a booster seat (23). This was attributed to a change in their centre of gravity and a redistribution of force across the child's torso (23). Ma et al. also noted, based on the National Highway Traffic Safety Administration data that CRSs were estimated to be misused in 72.6% of MVCs (23).

Wiacek et al. found that the two most frequently occurring sources of injury in the properly restrained child occupants were the belt restraint and the front seat back support. In general, abdomen and torso injuries were associated with the belt restraint loading, and head and extremity injuries were from contact with the back of the front seats (48).

In a 2018 study, the Western MOVES Research Team investigated frontal impact collisions involving pediatric occupants between three and twelve years old who used booster seats- seatbelt restraints. Serious restraint misuse included not wearing a seatbelt or not using the proper type of restraint for the occupant's mass, height, and age (49). Severe injuries to the head, thorax, and abdomen were observed. Although no statistical analysis was performed in this study, trends were found. Proper CRS use could have mitigated against the potential for serious head injury (49).

In the present study, the odds of sustaining a severe head injury when a CRS was installed improperly was 0.88 (95% CI= 0.084-9.29). The odds of sustaining a severe head injury when there was improper use of a CRS was 0.63 (95% CI= 0.06-6.49). Improper installation and use were not significant factors (both had a Fisher's Exact test= 1.00) affecting head injury severity for occupants using a CRS. Data tables can be found in Tables J-11 and J-12 (page 99) . These results in the study likely result from small sample reflected by the large confidence intervals. There was information for only 33 occupants. This sample size may not be representative of the entire CRS-using population. Trends were noted. When a CRS was improperly installed or used, the head, face abdomen and lower extremity appeared to be particularly predisposed to trauma in MVCs (Table N-1 and N-2, pages 115 and 116, respectively).

Rear seat geometry and CRSs were studied by Bilston et al. They found that vehicle seats and often are too long for children (50). Booster seats are often not large enough for older children who are too small to fit into the seatbelt alone category (50). There is often a mismatch between seat geometry and the MVC occupants. This mismatch gives the potential for restraint use error and injury to occur.

Bohman et al. asked parents and children who were using booster seats during frontal collisions their opinions about booster seats. This study was done to determine how best to promote the proper use of booster seat CRSs. Many parents said that if a booster seat were more convenient and accessible they would be more able to use it to restrain their child properly (51). The authors also noted that encouraging children, who do not fit the physical requirements of a seatbelt-alone restraint system to use a booster seat, decreases the misuse and non-use scenarios (51).

A study conducted by Hu et al. investigating seatbelt design and anchorage, and seat lengths to determine how modifications to existing systems would affect adults and children. There were modifications that were age-specific (5). They suggested that rear seats in vehicles be modified to incorporate an adjustable restraint system (5).

Beringer-Brown et al. also studied child restraint misuse and some strategies to mitigate misuse. They found that the major misuses of a CRS arose because of various factors: a system was inappropriate for the child’s size; the seatbelt was not sufficiently tight to hold the CRS to the vehicle; the anchoring system was not used, and the CRS was not tight against the child (52). If a child restraint is not secured to the vehicle, it will dislodge during an MVC adding to the potential for injury for not only the child but also other occupants in the vehicle. Movement of the child out of the restraint can lead to contacts within the vehicle compartment such as the side walls, and the back of the front row seats (52). Durbin et al. found similar results in their study in 2005 on the effect of seating position and appropriate restraint use (44).

In 2006, the National Child Restraint Survey found that only 63% of infants and 28% of children between four and eight years were using the appropriate CRS and using it properly. According to the Canadian Pediatric Society, the most common errors or misuses for CRSs are not securing the seat tightly to the vehicle, not securing the child snuggly to the CRS, and the chest clip not being at the armpit level (14). These can be combined with other errors such as not anchoring tethers, using a CRS in front of an airbag, wrong angles of installation, improper seatbelt/restraint routing, and not restraining the child at all (14).

Previous work done by Charyk Stewart et al. examined the injury patterns for children and adolescents involved in MVC in the London and Windsor, Ontario regions. They noted that children (eight years old and younger) were more likely to have severe head injuries when they were not using the appropriate restraint systems (53). Proper restraint use has been observed to decline as a child's age increases and associated with the status of other occupants' restraint use and driver impairment by drugs and/or alcohol (44). Nance et al. child occupants, between the ages of 4 and 15 years, using seatbelts alone were at twice the risk of head injury than using a CRS but half the risk of those that were unrestrained (33).

Wiacek et al. investigated rear occupant safety in frontal impact MVCs in America. The researchers found that being improperly restrained and age-inappropriate CRS use (most commonly booster-aged children restrained by a seat belt only) were factors in many of the severe injury cases (48). Many of these occupants contacted the front seat back. The occupant was not properly restrained or in an improper child seat and slipped out of the restraint system during the crash, contacting the seat back (48).

4.1.7 Do vehicle model and crash dynamics influence head injury severity?

4.1.7.1 Vehicle Model

Older vehicle models have been shown to have lower rates of severe injuries/fatalities in comparison to new vehicle models. Research has shown that since the development of front seat protective measures, the force of the collision has been redistributed to the rear seat occupants (54). Winston et al. examined vehicle model year restraint protection for drivers and rear-seated children. They found that in newer vehicles the drivers had significantly improved safety features; however, children in the rear seats using seat belts did not experience the same improvement in safety technology (54).

Kent et al. also examined vehicle model years and found that newer vehicles have stiffer front ends. The stiffer front end allows less damage to the vehicle, but the occupant experiences a higher crash pulse force; therefore, occupants without more advanced seatbelt and restraint designs, such as pretensioners and load limiters, may sustain more injuries (30).

4.1.7.2 Crash Dynamics

Crash dynamics factors - change in velocity during the collision (delta-v), equivalent barrier speed (EBS), configuration of the collision, and intrusion into the vehicle compartment - were investigated to determine their association with head injury severity.

Bendjellal et al. studied child protection in side impacts. They found that the velocity of the collision correlated with injury severity (55).

Winston et al. noted that crash testing is more frequently performed for front seat occupants than rear seat occupants (54). Stewart et al. noticed in their study that infants were sustaining injuries at 44.6 +/- 4.2 mph on average (19). In the United States, CRSs are tested at 19.9 mph (32 km/hr.) and 29.8 mph (48 km/hr.) (19). This testing standard is below the average collision speed causing trauma in the real-world collisions. This suggests that CRSs are not designed to provide adequate protection preventing severe trauma such as head injuries in infants (19). In Canada, the testing standard for certification of rear-facing infant carrier CRSs is 48 km/hr. (30 mph) (40).

4.1.7.2.1 Delta-v

Delta-v values were determined from event data recorders inside vehicles. Delta-v showed a slightly increased odds in severe head injury cases (OR=1.19, 95% CI= 0.91 to 1.55). The data table can be found in Table J-16 (p.102). The average delta-v for the collisions that resulted in severe head injuries in 10 children was severe (54.7 km/hr.). The result was not statistically significant (p= 0.21). The regression model explained 4.4% of the variance in the head injury severity.

4.1.7.2.2 Equivalent Barrier Speed (EBS)

The equivalent barrier speed (EBS) of a collision describes the change in speed that a vehicle experiences during a collision as if it were hitting a stationary barrier. The calculation of EBS is based on crush damage to a vehicle. EBS showed an increased odd of involvement in severe head injury cases (OR=1.283, 95% CI= 0.84 to 1.97, p=0.25). The data table can be found in Table J-15 (page 101). The average EBS for the collisions that resulted in severe head injuries in 10 children was severe (45.8 km/hr.). The regression was not statistically significant (p= 0.25). The regression model explained 4% of the variance in the head injury.

4.1.7.2.3 Collision Configuration

Types of MVCs include vehicle-to-vehicle, vehicle- fixed object and vehicle-animate object. The direction or configuration of the collision force can be frontal (head-on, offset frontal), side, rear, and roll over. The severity of the MVC is determined by factors such as the damage to the vehicle, injuries to the passengers, and the change in velocity upon collision (32). If the impact is on the same side of the vehicle as the occupant (near-side), the resulting injuries are due either to the CRS, the door, or intrusion; however, for occupants not sitting in the seat nearest the impact (far-side) injuries can arise from contacting the front seat back (32). Rollovers have the highest risk of severe injuries of all crash configurations. For example, a study by Hanna (2010) stated that rollovers occurred the least frequently of all the configurations, but they had the highest incidence rates of severe injuries (18).

Bazarian et al. found that occupants involved in lateral (side) impact MVCs were 2.6 times more likely to have a traumatic brain injury following the collision (56). Occupants in near-side collisions were at a greater risk for severe head injuries (33). Seatback or side interior contact points were found to be due to vehicle movement and pre-crash driving maneuvers, allowing occupants' torsos to roll-out of the CRSs (29).

In the present study, the most common collision configuration was side impact (39%) with head-on collisions being the second most common (33%). Side collisions had the highest number of severe head injuries (7 occupants), but they constituted 64% of the total severe head injuries sustained in this study. Frontal collisions had 2 occupants with severe head injuries but were only 18% of the total severe head injuries in the study (Table J-13). Collision configuration showed a lower odds of involvement in severe head injury cases (OR=0.082, 95% CI= 0.56 to 1.50). The result was not statistically significant (p=0.733). The model explained 0.3% of the variance in the head injury. (Table 3-2; Table J-13, page 100)

Occupants seated in outboard seating positions (210, 230) were more likely to sustain a severe head injury than occupants in any other seating position (Table J-5. Page 95).

Viano and Parenteau found that the safety of a particular seat was dependent on the principal direction of force (57). The lowest risk was in the center of the row seat, the highest risk being the second-row right-side seat in rollovers and the near-side seat in a side impact MVC (56).

Howard et al. found that for side impacts, each seating position was related to a different source of injury (39). Near-side seat injuries were either in direct contact with the vehicle interior or vehicle compartment intrusion (39). Non-contact injuries such as of the neck were possible. The centre seat occupant, if unrestrained, could contact a door. If the centre seat occupant was restrained, they could sustain low severity injuries from contacting other occupants or a door due to intrusion. Far-side seating location reduced the possibility of severe injuries during a side impact MVC. Howard et al. found that the risk of death for a near-side occupant was significantly higher for unrestrained and restrained occupants compared to the centre seating position (39).

4.1.7.2.4 Intrusion

Intruded vehicles showed a higher odd in severe head injury cases (OR=3.067, 95% CI= 0.75 to 12.55). The data can be found in Table J-14 (page 100). The odds ratio was not statistically significant (Fisher's Exact test= 0.128). Occupants with severe head injuries in MVCs that had intrusion into the occupant compartment also sustained injuries to their chest, abdomen, and both the upper and lower extremities (Table K-1, page 109). Howard et al. found that injuries to the thorax, abdomen, pelvis, and extremities were frequently caused by intrusion, a similar pattern seen in the present study (39). Belwaldi et al. found that children's heads were most commonly injured because of roof contact. Also, half of the head injuries were caused by intrusion over 20cm into the occupant compartment (3).

4.1.7.2.5 Ejection

Cases with complete or partial ejection showed a higher odd of involvement in severe head injury cases (OR=14.4, 95% CI= 1.34 to 143.04). The data can be found in Table J-17 (page 103). The odds ratio was statistically significant (Fisher's Exact test= 0.026). The majority of the pediatric occupants who were ejected had improperly installed CRSs, were misusing their CRS, or were not using any type of restraint system. These occupants sustained severe head injuries and injuries to their face, thorax, and lower extremities. The occupants with severe head injuries accounted for 75% (3 of 4) of all occupants ejected during an MVC. The collision configurations for the occupants that were ejected were side impacts (75%) and rollovers (25%).

When an occupant is ejected from the vehicle during an MVC, they may or may not still be in their CRS. If they are still in their CRS when ejected, it may provide some protection for the child's head and neck when the CRS lands outside of the vehicle. The ejected occupant who is not in the CRS may sustain greater injury upon contacting the ground or other landing surface.

4.2 Limitations

Some of the challenges that this study faced were small final sample size, missing data, conflicting or incomplete injury information, and data derived from single-centre study.

The overall sample population of 394 occupants (<18 years) and 182 (≤8 years) was small and limited statistical analyses to determine the significance of the variables studied. The study was limited to London Health Sciences Centre (LHSC) and its patient intake for Southwestern Ontario. The study was not representative of the all MVCs involving child occupants who were uninjured and did not need medical assessment. Only 62 occupants had a sufficient number of variables to analyze. Not all of the variables were consistently completed. These variables included CRS status, use, installation, type, design, and the direction the CRS was facing. Without this information, this study was unable to include about 2/3 (264 of 326) of the occupants in the database.

Other authors in the literature also noted similar limitations in their studies. Ma et al. noted that in the National Automotive Sampling (NASS) database 30% had no height measurements, 14.4% had an unknown restraint system status; there was no information on restraint misuse (23). Lee et al. noted that in the Fatality Analysis Reporting System (FARS) dataset, restraint use was not clarified or missing entirely (45). Rice et al. also noted that in the FARS database, there was missing data for the type of restraint system use (12).

As the study progressed, some of the children who presented to LHSC had incomplete or conflicting injury information that required verification; however, because of staff turnover in the LHSC trauma program, this could not be addressed by accessing the LHSC's trauma program's database.

4.3 Further Studies

A larger more representative sample size for a future study could be achieved by involving more trauma centres and police collision investigation teams. Observations and analyses from a larger study could potentially assist not only in better correlation of real-world data with simulated crash testing conducted by Transport Canada but also in the development on improved safety features by manufacturers of vehicles and child restraint systems.

More consistency in data collection during police investigations as well as hospitals using a standardized approach for data collection would remedy the relative lack of information for future studies. A more complete profile would mean a more accurate representation of significant injury trends in the real-world that could provide more robust evidence-based and focused research campaigns for CRS use and child injury prevention.

4.4 Conclusions

The hypothesis that the severity of head injuries for rear-seated occupants eight years old or younger in motor vehicle collisions would be influenced by the types of restraint system used was not supported by the results of this study. Small sample sizes, incomplete data, and a study group skewed to children who presented to hospital involved in severe collisions may have been factors that resulted in this hypothesis not being supported. Although the hypothesis was not supported, the other supplementary research questions addressed in this study provided some interesting results.

Gender, age, height, and mass did not significantly influence head injury severity in an MVC, but each showed trends. There was a trend toward females having more severe head injuries. As occupants became older, they were at a slightly increased risk of having a severe head injury. Taller and/or heavier occupants were less likely to have a severe head injury.

Occupants, eight years old or younger, who sustained a severe head injury, had a statistically significant increased likelihood of sustaining injuries to the thorax and lower extremities. There were trends showing that if a severe head injury occurred, there was an increased likelihood of having an injury in the abdomen, spine, and upper extremities.

Although CRS type and design did not have a statistically significant impact on injury severity; there were injury patterns present in the results. Children in rear-facing infant carriers were more likely to have head and extremity injuries. A few children in forward-facing CRSs had neck injuries. Children using booster seats frequently had abdominal injuries.

The number of rear row occupants appeared to be protective, as the number of rear row occupants increased pediatric occupants were significantly less likely to have a severe head injury.

The most severe head and lower extremity injuries occurred in the winter, while the summer had more severe injuries to the thorax and abdomen.

Improper installation and misuse of CRSs showed that there was a higher prevalence and severity of injuries to the head, face, abdomen, and lower extremities.

Higher speed collisions were associated with severe head injuries. Collision configurations of side and head-on collisions were most frequent. Occupants sitting in the outboard seats (against the wall/door of the vehicle) were more likely to have a severe head injury. Occupant compartment intrusion showed a trend for rear-seated pediatric occupants to be three times more likely to have a severe head injury when intrusion was present. Occupant ejection had a significant impact on head injury severity. If a pediatric occupant was ejected completely or partially from the vehicle during an MVC, they were 14 times more likely to get a severe head injury.

In conclusion, there are many factors that influence head injury severity for pediatric occupants who are in an MVC. The inconclusive results of this study provide future research directions for the determination of which occupant, pre-collision, and collision factors are significant in leading to child occupants sustaining severe head trauma. This research would be beneficial for not only people travelling in motor vehicles but also police and other investigators, health care providers, and motor vehicle safety researchers and regulators.

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Appendices

A. Variables Under Investigation

Table A-1 Variables available for database for investigation

COLLISION IDENT-IFIERS	OCCUPANT	PRE-COLLISION	COLLISION	INJURY CHARACTE-RISTICS
• PAED NUM-BER[1] • TRANS-PORT CANADA CASE NUM-BER[2] • VEHICLE NUMBER[3]	• GENDER • AGE • HEIGHT (CM) • MASS (KG) • OCCU-PANT SEATING POSITION[4] • NUMBER OF REAR OCCU-PANTS • NUMBER OF PEDI-ATRIC OCCU-PANTS • DRIVER'S LICENSE SUSPE-NDED • DRIVER AGE • DRIVER GENDER	• CASE VEHICLE • VEHICLE YEAR • VEHICLE MAKE • VEHICLE MODEL • VEHICLE BODY TYPE • VEHICLE MASS (KG) • VEHICLE WHEEL BASE (CM) • POSTED SPEED LIMIT (KM/HR) • ENVIRONMENT CONDITION[5] • ENVIRONMENT CONDITION 2[6] • LIGHTING[7] • TRAFFIC CONTROL • ROAD CHARACTER – R1[8,9] • ROAD CHARACTER – R2[10] • ROAD SURFACE – R1[11] • ROAD SURFACE – R2 • ROAD CONDITION – R1[12] • ROAD CONDITION – R2	• COLLISION SEVERITY[26] • NUMBER OF VEHICLES • COLLISION CONFIGURATION[27] • SURFACE CONTACTED[28] • WINDSHIELD CONTACT • INTRUSION[29] • INTRUSION (CM) • OBJECT CONTACTED[30] • PRINCIPLE DIRECTION OF FORCE[31] • EVENT DATA RECORDER SPEED (KM/H)[32] • EQUIVALENT BARRIER SPEED (KM/H)[33] • ΔV (KM/H)[34] • ACCIDENT LOCATION[35] • IMPACT LOCATION[36] • APPARENT DRIVER ACTION – D1 • APPARENT DRIVER ACTION – D2	• NUMBER INJURED PEDIA-TRIC OCCU-PANTS • NUMBER FATAL PEDIA-TRIC OCCU-PANTS • INJURY SEVERITY • OVERALL MAIS[41] • MAIS-HEAD • MAIS-FACE • MAIS-NECK • MAIS-CHEST • MAIS-ABDO-MEN

	• DRIVER LICENSE	• ROAD SURFACE CONDITION – R1[13] • ROAD SURFACE CONDITION – R2 • ROAD ALIGNMENT – R1[14] • ROAD ALIGNMENT – R2 • VEHICLE TYPE – V1[15,16] • VEHICLE TYPE – V2[17] • VEHICLE CONDITION – V1[18] • VEHICLE CONDITION – V2 • DRIVER/ PEDESTRIAN CONDITION – D1[19] • DRIVER/ PEDESTRIAN CONDITION – D2 • ROAD JURISDICTION[20] • AMBIENT TEMPERATURE (C) • TIME OF DAY • SEASON • LOCATION (URBAN vs. RURAL)[21] • SEATBELT OR CRS USED[22] • MANNER OF SEATBELT USE[23] • CRS FORWARD vs REARWARD • CRS TYPE[24] • CRS DESIGN[25] • IMPROPER CRS INSTALLATION • IMPROPER CRS USE	• CLASSIFICATION OF ACCIDENT[37] • INITIAL IMPACT TYPE[38] • VEHICLE DAMAGE – V1[39] • VEHICLE DAMAGE – V2 • LOCATION OF DAMAGE/AREA OF IMPACT – V1 – INITIAL IMPACT[40] • LOCATION OF DAMAGE/AREA OF IMPACT – V2 – INITIAL IMPACT • EJECTION	• MAIS-SPINE • MAIS-UPPER EXTR-EMITY • MAIS-LOWER EXTR-EMITY

[1]LHSC Pediatric Case Number

[2]Transport Canada Case Investigation Identifier

[3]Vehicle number in the collision, where vehicle 1 is the investigated case vehicle having pediatric occupants and all subsequent vehicles listed are other vehicles involved in the collision in order of involvement

[4]Seating position of pediatric occupant in rear rows, where the first digit is the row number relative to the driver's seat and the second digit is seating position from left to right (e.g. 220 would be the second row and the second seat from the left, or middle seat)

[5]Weather and visibility information on the road of the case vehicle

[6]Weather and visibility information on the road of the non-case vehicle

[7]Natural or artificial lighting conditions

[8]Type of roadway (i.e. undivided, divided, highway, etc)

[9]R1 refers to the road on which the case vehicle was travelling

[10]R2 refers to the road on which the non-case vehicle was travelling

[11]Type of material used for the roadway (i.e. asphalt, gravel, dirt, etc)

[12] Condition of the roadway (i.e. good, under construction, etc)

[13]Any debris or objects on the road surface (i.e. snow, spilled fluid, ice, etc)

[14]Shape of the road (i.e. straight, curved, hill, level, etc)

[15]General vehicle descriptions (i.e. automobile, transport truck, pickup truck, minivan, etc)

[16]V1 is the case vehicle, usually the investigated vehicle

[17]V2 is the non-case vehicle

[18]Whether or not the vehicle had defects or other issues prior to the collision

[19]The driver/pedestrian condition refers to the apparent cognitive state of the driver or pedestrian (depending on the individual that is under investigation) while involved in the collision (e.g. inattentive, impaired by alcohol, etc).

[20]Municipal, provincial, federal power to make law enforcement decisions on the roadway

[21]Rural roads are classified by a speed limit exceeding 60km/hr. at collision site, primary or secondary highways, or local rural roads. Urban roads are classified by metropolitan streets/roads or a speed limit of less than 60km/hr. at the collision site

[22]Whether a child restraint system or seatbelt was used or both

[23]Manner of seatbelt use with regards to whether the seatbelt was used properly, other descriptions of the actual use of the seatbelt, not used at all, or not applicable

[24]Child Restraint System Type refers to the basic conformation of the CRS, such as infant carrier, child seat, booster seat, or a combination

[25]Child Restraint System Design refers to the specific features of the CRS such as base type for an infant carrier, harness design for child seats, and back height for booster seats

[26]Classifying a collision as severe if it resulted in a fatality

[27]The type of collision (i.e. head-on, side, rear, etc). This excluded collisions with pedestrians, cyclists, motorcyclists, all-terrain vehicles, watercraft, and aircraft.

[28]What the case vehicle struck and the aspect of the vehicle impacted

[29]Intrusion into the occupant compartment by external forces exerted upon the vehicle’s frame. The degree of deformation measured in cm.

[30]Object contacted refers to what the vehicle impacted during the collision (i.e. vehicle, embankment, wall, tree, ground, etc).

[31]The point of initial impact to the vehicle on a 360-degree scale or 12-hour clock. (e.g. a perfectly aligned frontal collision contacting the centre of the front surface of the vehicle would be 12 o'clock. The front right corner would be a 1 o'clock point of initial impact)

[32]Speed captured by the onboard event data recorder. The event data recorder is a device installed to record technical vehicle and occupant information for a brief period before, during, and after a triggering event, typically a crash or near-crash event.

[33]Based on the amount of energy transfer using crush measurements to calculate the equivalent speed of the vehicle as if it had contacted a solid barrier.

[34]Change in velocity during the collision experienced by the vehicle determined by the event data recorder in the vehicle or calculated using damage analysis with stiffness values that are calculated from crash test data

[35]Accident location refers to what type of roadway geometry was involved (i.e. non-intersection, at/near private drive, at intersection, etc.)

[36]Where the vehicle collision occurred on the roadway (i.e. intersection, non-intersection, etc)

[37]Whether the collision resulted in a fatality

[38]How the vehicle travelled toward object impacted (i.e. angle, approaching, rear, etc)

[39]Amount of damage the vehicle sustained (i.e. demolished, severe, etc)

[40]Location of damage on the case vehicle (i.e. right front corner, left centre, front complete, etc)

[41]Maximum Abbreviated Injury value for the entire body. This indicates the highest AIS sustained for the body regardless of body region.

B. Literature Review Search Term Matrix

The literature review that was completed for this study was done using the matrix shown in table B-1. The key terms/concepts were broken down into numerous Medical Subject Headings (MeSH) and potential keywords of interest. These were inputted into the Medline database search engine one at a time decreasing the total number of viable articles that relate to this study.

Table B-1 Literature Review Search Matrix

Concept	Medline MeSH terms	Keywords
Head Injury	exp cerebrovascular trauma/ or carotid artery injuries/ or craniocerebral trauma/ or brain injuries/ or exp brain hemorrhage, traumatic/ or exp brain injuries, diffuse/ or brain concussion/ or brain contusion/ or exp cerebrospinal fluid leak/ or head injuries, closed/ or head injuries, penetrating/ or intracranial hemorrhage, traumatic/ or hematoma, epidural, cranial/ or hematoma, subdural/ or hematoma, subdural, acute/ or hematoma, subdural, intracranial/ or exp skull fractures/ or exp spinal cord injuries/	head inj*, brain inj*, cerebrovascular trauma* or carotid artery injur* or craniocerebral trauma* or brain injur* or brain hemorrhage, traumatic or brain injur*, diffuse or brain concussion* or brain contusion* or cerebrospinal fluid leak* or head injur*, closed or head injur*, penetrat* or intracranial hemorrhage, traum* or hematoma, epidural, cranial or hematoma, subdural or hematoma, subdural, acute or hematoma, subdural, intracranial or skull fracture* or spinal cord injuries
Car accident	Accidents, Traffic/	Motor vehicle collision* or motor vehicle accident* or car crash or car accident* or automobile collision* or automobile accident*or truck crash* or mvc or traffic accident
Child	exp child/ or child, preschool/ or infant/ or infant, newborn/	child* or kid* or children* or infant* or toddler* or preschool child* or newborn*
North America	north america/ or exp canada/ or exp united states/	canad* or north america* or america* or united states of america*

Child restraints	Child restraint system	child restraint system* or car seat* or infant carrier* or booster seat* or rear-facing child restraint* or forward-facing child restraint* or child safety seat* or infant seat* or toddler seat*

C. Literature Search Results

The following articles were relevant to the current study.

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D.Raw Data- Occupant Variables

Table D-1 Raw data for occupant variables: gender, age, height, and mass

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	GENDER	AGE (YEARS)	HEIGHT (CM)	MASS (KG)
PAED-001	ROP31608	2	FEMALE	8	125	25
PAED-004	ROP31610	2	FEMALE	8	142	40
PAED-005	ROP31611	1	MALE	7	125	25
PAED-005	ROP31611	1	FEMALE	7	139	30
PAED-006	SID71633	2	MALE	1	83	18
PAED-007	SID71634	1	MALE	4	UNK	UNK
PAED-007	SID71634	1	MALE	2	UNK	UNK
PAED-011	ROP31616	1	MALE	5	112	19.4
PAED-026	ROP31617	2	FEMALE	8	UNK	31
PAED-026	ROP31617	2	MALE	4	UNK	UNK
PAED-026	ROP31617	2	FEMALE	6	UNK	UNK
PAED-030	SID71638	2	MALE	0	UNK	5.2
PAED-030	SID71638	2	MALE	2	UNK	14
PAED-030	SID71638	2	MALE	3	95	16.2
PAED-034	PROS1603	2	FEMALE	0	60	6.3
PAED-034	PROS1603	2	FEMALE	2	90	12.9
PAED-047	ASF71606	1	MALE	0	UNK	UNK
PAED-047	ASF71606	1	MALE	2	90	14
PAED-047	ASF71606	1	MALE	4	UNK	UNK
PAED-049	PROS1604	2	FEMALE	5	-	-
PAED-050	ASF71607	2	FEMALE	3	UNK	UNK
PAED-055	ROP31601	2	FEMALE	8	130	30
PAED-057	ROP31604	1	MALE	3	UNK	UNK
PAED-061	-	2	MALE	0	-	-
PAED-062	SID71639	1	MALE	0	62	6.2
PAED-062	SID71639	1	MALE	4	105	16.6
PAED-062	SID71639	1	FEMALE	6	120	22.4
PAED-065	PROS1609	1	MALE	5	UNK	20
PAED-071	ASF71609	1	FEMALE	2	UNK	UNK
PAED-071	ASF71609	1	FEMALE	4	UNK	UNK
PAED-075	PROS1610	1	FEMALE	7	115	20

PAED-087	ASF71611	2	MALE	3	86	16
PAED-087	ASF71611	2	FEMALE	5	92	20
PAED-087	ASF71611	2	FEMALE	8	107	25
PAED-093	ASF71614	1	MALE	5	112	20
PAED-097	ROP31623	2	FEMALE	0	74	10.4
PAED-097	ROP31623	2	FEMALE	2	97	15.8
PAED-097	ROP31623	2	FEMALE	4	110	22.5
PAED-100	ASF71610	2	MALE	0	UNK	UNK
PAED-100	ASF71610	2	MALE	2	UNK	UNK
PAED-104	SID71620	1	MALE	5	UNK	UNK
PAED-105	SID71629	1	MALE	1	UNK	UNK
PAED-105	SID71629	1	MALE	4	UNK	UNK
PAED-106	SID71635	1	FEMALE	4	UNK	UNK
PAED-106	SID71635	1	FEMALE	6	UNK	UNK
PAED-106	SID71635	1	MALE	5	UNK	UNK
PAED-109	ROP31605	2	MALE	4	109	21
PAED-109	ROP31605	2	MALE	5	119	24
PAED-110	ROP31606	2	MALE	3	102	20
PAED-111	ROP31607	1	FEMALE	2	85	13
PAED-113	ROP31613	1	MALE	6	115	22.7
PAED-116	ASF61604	1	FEMALE	0	61	6.5
PAED-118	ASF61632	2	FEMALE	0	67	8
PAED-119	ASF61633	1	MALE	5	122	23
PAED-121	ASF61644	1	FEMALE	8	122	31
PAED-121	ASF61644	1	MALE	4	97	18
PAED-122	ASF61650	1	-	-	UNK	UNK
PAED-124	ASF61665	1	MALE	3	UNK	UNK
PAED-125	ASF61666	1	MALE	3	UNK	UNK
PAED-125	ASF61666	1	FEMALE	1	UNK	UNK
PAED-125	ASF61666	1	MALE	5	UNK	UNK
PAED-131	ROP31624	1	MALE	4	UNK	20
PAED-137	PROS1612		FEMALE	1	UNK	14
PAED-149	ASF71616	1	MALE	3	UNK	UNK
PAED-149	ASF71616	1	MALE	6	UNK	UNK
PAED-154	ROP31625	2	FEMALE	6	UNK	24.7
PAED-182	SID71648	2	-	3	UNK	5
PAED-183	ROP31626	1	MALE	1	UNK	10
PAED-183	ROP31626	1	MALE	2	UNK	15

PAED-193	PROS1617	2	FEMALE	2	UNK	17
PAED-193	PROS1617	2	FEMALE	4	UNK	UNK
PAED-193	PROS1617	2	MALE	6	UNK	UNK
PAED-193	PROS1617	2	MALE	7	UNK	26
PAED-205	ASF71619	1	MALE	1	UNK	8.1
PAED-211	ROP31628	1	MALE	1	UNK	UNK
PAED-212	ROP31627	1	MALE	0	58	4.5

Table D-2 Raw data for occupant variables: occupant seating position, number of rear row occupants, and number of pediatric occupants

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	OCCUPANT SEATING POSITION	NUMBER OF REAR ROW OCCUPANTS	NUMBER OF PEDIATRIC OCCUPANTS
PAED-001	ROP31608	2	0230	1	2
PAED-004	ROP31610	2	0230	2	2
PAED-005	ROP31611	1	0210	2	2
PAED-005	ROP31611	1	0230	2	2
PAED-006	SID71633	2	0230	1	1
PAED-007	SID71634	1	0230	2	2
PAED-007	SID71634	1	0210	2	2
PAED-011	ROP31616	1	0210	1	1
PAED-026	ROP31617	2	0210	5	5
PAED-026	ROP31617	2	0320	5	5
PAED-026	ROP31617	2	0310	5	5
PAED-030	SID71638	2	0230	3	3
PAED-030	SID71638	2	0210	3	3
PAED-030	SID71638	2	0320	3	3
PAED-034	PROS1603	2	0210	2	2
PAED-034	PROS1603	2	0230	2	2
PAED-047	ASF71606	1	0230	3	3
PAED-047	ASF71606	1	0220	3	3
PAED-047	ASF71606	1	0210	3	3
PAED-049	PROS1604	2	0220	1	2
PAED-050	ASF71607	2	0230	1	1
PAED-055	ROP31601	2	0210	1	1
PAED-057	ROP31604	1	0210	1	1
PAED-061	-	2	0210	2	2
PAED-062	SID71639	1	0220	3	3

PAED-062	SID71639	1	0210	3	3
PAED-062	SID71639	1	0230	3	3
PAED-065	PROS1609	1	0230	1	1
PAED-071	ASF71609	1	0991	2	2
PAED-071	ASF71609	1	0291	2	2
PAED-075	PROS1610	1	0230	1	1
PAED-087	ASF71611	2	0210	3	3
PAED-087	ASF71611	2	0230	3	3
PAED-087	ASF71611	2	0220	3	3
PAED-093	ASF71614	1	0230	1	1
PAED-097	ROP31623	2	0320	3	3
PAED-097	ROP31623	2	0310	3	3
PAED-097	ROP31623	2	0330	3	3
PAED-100	ASF71610	2	0210	2	2
PAED-100	ASF71610	2	0230	2	2
PAED-104	SID71620	1	0310	1	1
PAED-105	SID71629	1	0230	2	2
PAED-105	SID71629	1	0210	2	2
PAED-106	SID71635	1	0220	3	4
PAED-106	SID71635	1	0210	3	4
PAED-106	SID71635	1	0230	3	4
PAED-109	ROP31605	2	0230	2	2
PAED-109	ROP31605	2	0210	2	2
PAED-110	ROP31606	2	0230	1	1
PAED-111	ROP31607	1	0230	1	2
PAED-113	ROP31613	1	0210	1	1
PAED-116	ASF61604	1	0290	1	1
PAED-118	ASF61632	2	0230	1	1
PAED-119	ASF61633	1	0210	1	1
PAED-121	ASF61644	1	0210	2	2
PAED-121	ASF61644	1	0230	2	2
PAED-122	ASF61650	1	0990	1	1
PAED-124	ASF61665	1	0230	1	1
PAED-125	ASF61666	1	0230	3	4
PAED-125	ASF61666	1	0220	3	4
PAED-125	ASF61666	1	0210	3	4
PAED-131	ROP31624	1	0230	1	1
PAED-137	PROS1612		0230	1	1

PAED-149	ASF71616	1	0210	2	2
PAED-149	ASF71616	1	0230	2	2
PAED-154	ROP31625	2	0230	1	1
PAED-182	SID71648	2	0210	1	1
PAED-183	ROP31626	1	0230	2	2
PAED-183	ROP31626	1	0210	2	2
PAED-193	PROS1617	2	0230	4	4
PAED-193	PROS1617	2	0210	4	4
PAED-193	PROS1617	2	0330	4	4
PAED-193	PROS1617	2	0310	4	4
PAED-205	ASF71619	1	0220	1	1
PAED-211	ROP31628	1	0230	2	2
PAED-212	ROP31627	1	0220	1	1

E. Raw Data- Precollision Factors

Table E-1 Raw data for precollision factors: vehicle year, season, month, year

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	VEHICLE YEAR	SEASON	MONTH	YEAR
PAED-001	ROP31608	2	2003	FALL	Nov	2013
PAED-004	ROP31610	2	2006	WINTER	Jan	2014
PAED-005	ROP31611	1	2008	WINTER	Feb	2014
PAED-005	ROP31611	1	2008	WINTER	Feb	2014
PAED-006	SID71633	2	2012	WINTER	Feb	2014
PAED-007	SID71634	1	2007	SPRING	Mar	2014
PAED-007	SID71634	1	2007	SPRING	Mar	2014
PAED-011	ROP31616	1	2006	SPRING	May	2014
PAED-026	ROP31617	2	1997	SUMMER	Jul	2014
PAED-026	ROP31617	2	1997	SUMMER	Jul	2014
PAED-026	ROP31617	2	1997	SUMMER	Jul	2014
PAED-030	SID71638	2	2011	SUMMER	Jul	2014
PAED-030	SID71638	2	2011	SUMMER	Jul	2014
PAED-030	SID71638	2	2011	SUMMER	Jul	2014
PAED-034	PROS1603	2	2011	SUMMER	Aug	2014
PAED-034	PROS1603	2	2011	SUMMER	Aug	2014
PAED-047	ASF71606	1	2013	FALL	Oct	2014
PAED-047	ASF71606	1	2013	FALL	Oct	2014
PAED-047	ASF71606	1	2013	FALL	Oct	2014
PAED-049	PROS1604	2	2005	SUMMER	Aug	2014

PAED-050	ASF71607	2	2006	FALL	Sep	2014
PAED-055	ROP31601	2	2008	WINTER	Feb	2011
PAED-057	ROP31604	1	1999	SUMMER	Jul	2012
PAED-061	-	2	2007	FALL	Nov	2014
PAED-062	SID71639	1	2006	FALL	Nov	2014
PAED-062	SID71639	1	2006	FALL	Nov	2014
PAED-062	SID71639	1	2006	FALL	Nov	2014
PAED-065	PROS1609	1	2007	WINTER	Dec	2014
PAED-071	ASF71609	1	2002	WINTER	Dec	2014
PAED-071	ASF71609	1	2002	WINTER	Dec	2014
PAED-075	PROS1610	1	2009	WINTER	Jan	2015
PAED-087	ASF71611	2	2005	WINTER	Feb	2015
PAED-087	ASF71611	2	2005	WINTER	Feb	2015
PAED-087	ASF71611	2	2005	WINTER	Feb	2015
PAED-093	ASF71614	1	2005	SPRING	Mar	2015
PAED-097	ROP31623	2	2010	SPRING	Apr	2015
PAED-097	ROP31623	2	2010	SPRING	Apr	2015
PAED-097	ROP31623	2	2010	SPRING	Apr	2015
PAED-100	ASF71610	2	2008	SPRING	Apr	2015
PAED-100	ASF71610	2	2008	SPRING	Apr	2015
PAED-104	SID71620	1	2010	SUMMER	Jul	2013
PAED-105	SID71629	1	2005	SUMMER	Aug	2013
PAED-105	SID71629	1	2005	SPRING	Aug	2013
PAED-106	SID71635	1	2007	SUMMER	Aug	2013

PAED-106	SID71635	1	2007	SPRING	May	2014
PAED-106	SID71635	1	2007	SPRING	May	2014
PAED-109	ROP31605	2	2009	SUMMER	Jun	2013
PAED-109	ROP31605	2	2009	SUMMER	Jun	2013
PAED-110	ROP31606	2	2013	SUMMER	Jun	2013
PAED-111	ROP31607	1	2007	SUMMER	Aug	2013
PAED-113	ROP31613	1	2012	SPRING	Mar	2014
PAED-116	ASF61604	1	2006	FALL	Oct	2009
PAED-118	ASF61632	2	2006	SUMMER	Aug	2010
PAED-119	ASF61633	1	2000	WINTER	Dec	2008
PAED-121	ASF61644	1	2006	FALL	Sep	2011
PAED-121	ASF61644	1	2006	FALL	Sep	2011
PAED-122	ASF61650	1	2007	SUMMER	Jun	2012
PAED-124	ASF61665	1	2004	FALL	Nov	2012
PAED-125	ASF61666	1	2012	WINTER	Dec	2012
PAED-125	ASF61666	1	2012	WINTER	Dec	2012
PAED-125	ASF61666	1	2012	WINTER	Dec	2012
PAED-131	ROP31624	1	2008	SPRING	May	2015
PAED-137	PROS1612	-	2008	SUMMER	Jun	2015
PAED-149	ASF71616	1	2012	SUMMER	Jun	2015
PAED-149	ASF71616	1	2012	SUMMER	Jun	2015
PAED-154	ROP31625	2	2006	SUMMER	Jul	2015
PAED-182	SID71648	2	2009	FALL	Oct	2015
PAED-183	ROP31626	1	2010	FALL	Oct	2015

PAED-183	ROP31626	1	2010	FALL	Oct	2015
PAED-193	PROS1617	2	2007	FALL	Nov	2015
PAED-193	PROS1617	2	2007	FALL	Nov	2015
PAED-193	PROS1617	2	2007	FALL	Nov	2015
PAED-193	PROS1617	2	2007	FALL	Nov	2015
PAED-205	ASF71619	1	2002	WINTER	Jan	2016
PAED-211	ROP31628	1	2007	WINTER	Jan	2016
PAED-212	ROP31627	1	2012	WINTER	Dec	2015

Table E-2 Raw data for precollision factors: seatbelt or CRS used, restraint status, and CRS forward versus rearward

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	SEATBELT OR CRS USED	RESTRAINT	CRS FORWARD VERSUS REARWARD
PAED-001	ROP31608	2	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-004	ROP31610	2	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-005	ROP31611	1	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-005	ROP31611	1	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-006	SID71633	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-007	SID71634	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-007	SID71634	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD

PAED-011	ROP31616	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-026	ROP31617	2	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-026	ROP31617	2	UNK	CHILD SAFETY SEAT USED INCORRECTLY	FORWARD
PAED-026	ROP31617	2	BOTH	CHILD SAFETY SEAT USED INCORRECTLY	FORWARD
PAED-030	SID71638	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	UNK
PAED-030	SID71638	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-030	SID71638	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-034	PROS1603	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-034	PROS1603	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-047	ASF71606	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-047	ASF71606	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-047	ASF71606	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-049	PROS1604	2	UNK	CHILD SAFETY SEAT USED INCORRECTLY	UNK
PAED-050	ASF71607	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-055	ROP31601	2	BOTH	LAP AND SHOULDER BELT	FORWARD

PAED-057	ROP31604	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-061	-	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	UNK
PAED-062	SID71639	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-062	SID71639	1	CRS	CHILD SAFETY SEAT USED INCORRECTLY	FORWARD
PAED-062	SID71639	1	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-065	PROS1609	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-071	ASF71609	1	UNK	EQUIPMENT NOT USED BUT AVAILABLE	UNK
PAED-071	ASF71609	1	UNK	USE UNK	UNK
PAED-075	PROS1610	1	UNK	USE UNK	FORWARD
PAED-087	ASF71611	2	CRS	EQUIPMENT NOT USED BUT AVAILABLE	FORWARD
PAED-087	ASF71611	2	CRS	EQUIPMENT NOT USED BUT AVAILABLE	UNK
PAED-087	ASF71611	2	CRS	EQUIPMENT NOT USED BUT AVAILABLE	UNK
PAED-093	ASF71614	1	CRS	EQUIPMENT NOT USED BUT AVAILABLE	FORWARD
PAED-097	ROP31623	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-097	ROP31623	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-097	ROP31623	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD

PAED-100	ASF71610	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-100	ASF71610	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-104	SID71620	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-105	SID71629	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-105	SID71629	1	BOTH	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-106	SID71635	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-106	SID71635	1	SEATBELT	LAP AND SHOULDER BELT	FORWARD
PAED-106	SID71635	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-109	ROP31605	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-109	ROP31605	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-110	ROP31606	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-111	ROP31607	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-113	ROP31613	1	CRS	CHILD SAFETY SEAT USED INCORRECTLY	FORWARD
PAED-116	ASF61604	1	CRS	CHILD SAFETY SEAT USED INCORRECTLY	REARWARD
PAED-118	ASF61632	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD

PAED-119	ASF61633	1	BOTH	LAP AND SHOULDER BELT	FORWARD
PAED-121	ASF61644	1	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-121	ASF61644	1	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-122	ASF61650	1	UNK	NO EQUIPMENT AVAILABLE	UNK
PAED-124	ASF61665	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-125	ASF61666	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-125	ASF61666	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-125	ASF61666	1	BOTH	LAP AND SHOULDER BELT	FORWARD
PAED-131	ROP31624	1	UNK	USE UNK	UNK
PAED-137	PROS1612	UNK	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-149	ASF71616	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	UNK
PAED-149	ASF71616	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-154	ROP31625	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-182	SID71648	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-183	ROP31626	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	UNK
PAED-183	ROP31626	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	UNK

PAED-193	PROS1617	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-193	PROS1617	2	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-193	PROS1617	2	SEATBELT	LAP AND SHOULDER BELT	UNK
PAED-193	PROS1617	2	CRS	OTHER SAFETY EQUIPMENT USED	FORWARD
PAED-205	ASF71619	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	FORWARD
PAED-211	ROP31628	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD
PAED-212	ROP31627	1	CRS	CHILD SAFETY SEAT USED CORRECTLY	REARWARD

Table E-3 Raw data table for precollision factors: CRS type, CRS design, improper installation and improper use

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	CRS TYPE	CRS DESIGN	IMPROPER INSTALL	IMPROPER USE
PAED-001	ROP31608	2	UNK	UNK	UNK	UNK
PAED-004	ROP31610	2	UNK	UNK	UNK	UNK
PAED-005	ROP31611	1	UNK	UNK	UNK	UNK
PAED-005	ROP31611	1	UNK	UNK	UNK	UNK
PAED-006	SID71633	2	INFANT / CHILD SEAT	FIVE-POINT HARNESS	NO	NO
PAED-007	SID71634	1	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	NO	NO
PAED-007	SID71634	1	INFANT / CHILD SEAT	FIVE-POINT HARNESS	NO	NO
PAED-011	ROP31616	1	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	UNK	UNK

PAED-026	ROP31617	2	UNK	UNK	UNK	UNK
PAED-026	ROP31617	2	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	NO	YES
PAED-026	ROP31617	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	YES
PAED-030	SID71638	2	UNK	UNK	UNK	UNK
PAED-030	SID71638	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-030	SID71638	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	YES
PAED-034	PROS1603	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-034	PROS1603	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-047	ASF71606	1	INFANT CARRIER	REMOVEABLE BASE	YES	NO
PAED-047	ASF71606	1	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-047	ASF71606	1	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-049	PROS1604	2	UNK	UNK	UNK	UNK
PAED-050	ASF71607	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-055	ROP31601	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-057	ROP31604	1	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-061	-	2	UNK	UNK	UNK	UNK
PAED-062	SID71639	1	INFANT CARRIER	UNK	NO	NO

PAED-062	SID71639	1	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	YES	YES
PAED-062	SID71639	1	UNK	UNK	UNK	UNK
PAED-065	PROS1609	1	CHILD / BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	UNK	UNK
PAED-071	ASF71609	1	UNK	UNK	UNK	UNK
PAED-071	ASF71609	1	UNK	UNK	UNK	UNK
PAED-075	PROS1610	1	BOOSTER SEAT	UNK	UNK	UNK
PAED-087	ASF71611	2	BOOSTER SEAT	LOW BACK (BACKLESS)	YES	YES
PAED-087	ASF71611	2	UNK	UNK	UNK	UNK
PAED-087	ASF71611	2	UNK	UNK	UNK	UNK
PAED-093	ASF71614	1	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	YES	YES
PAED-097	ROP31623	2	INFANT CARRIER	UNK	UNK	UNK
PAED-097	ROP31623	2	INFANT / CHILD SEAT	FIVE-POINT HARNESS	UNK	NO
PAED-097	ROP31623	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-100	ASF71610	2	INFANT / CHILD SEAT	FIVE-POINT HARNESS	NO	NO
PAED-100	ASF71610	2	INFANT CARRIER	REMOVEABLE BASE	NO	UNK
PAED-104	SID71620	1	CHILD / BOOSTER SEAT	HIGH BACK - ONE PIECE	NO	YES
PAED-105	SID71629	1	INFANT / CHILD SEAT	FIVE-POINT HARNESS	NO	NO
PAED-105	SID71629	1	CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-106	SID71635	1	INFANT / CHILD SEAT	FIVE-POINT HARNESS	YES	NO
PAED-106	SID71635	1	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO

PAED-106	SID71635	1	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-109	ROP31605	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-109	ROP31605	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-110	ROP31606	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	NO
PAED-111	ROP31607	1	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	NO	NO
PAED-113	ROP31613	1	BOOSTER SEAT	HIGH BACK - ONE PIECE	NO	UNK
PAED-116	ASF61604	1	INFANT CARRIER	REMOVEABLE BASE/FIVE-POINT HARNESS	YES	YES
PAED-118	ASF61632	2	INFANT / CHILD / BOOSTER SEAT	INTEGRATED BASE/ FIVE-POINT HARNESS/ HIGH BACK-ONE PIECE	NO	NO
PAED-119	ASF61633	1	BOOSTER SEAT	HIGH BACK - ONE PIECE	NO	NO
PAED-121	ASF61644	1	UNK	UNK	UNK	UNK
PAED-121	ASF61644	1	UNK	UNK	UNK	UNK
PAED-122	ASF61650	1	UNK	UNK	UNK	UNK
PAED-124	ASF61665	1	CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	UNK	UNK
PAED-125	ASF61666	1	CHILD SEAT	UNK	UNK	UNK
PAED-125	ASF61666	1	CHILD SEAT	UNK	UNK	UNK
PAED-125	ASF61666	1	BOOSTER SEAT	UNK	UNK	UNK
PAED-131	ROP31624	1	UNK	UNK	UNK	UNK
PAED-137	PROS1612	UNK	CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	UNK	UNK
PAED-149	ASF71616	1	INFANT / CHILD SEAT	FIVE-POINT HARNESS	UNK	UNK

PAED-149	ASF71616	1	BOOSTER SEAT	HIGH BACK - REMOVABLE BACK	NO	YES
PAED-154	ROP31625	2	BOOSTER SEAT	LOW BACK (BACKLESS)	NO	UNK
PAED-182	SID71648	2	INFANT CARRIER	REMOVEABLE BASE	UNK	UNK
PAED-183	ROP31626	1	UNK	UNK	UNK	UNK
PAED-183	ROP31626	1	UNK	UNK	UNK	UNK
PAED-193	PROS1617	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	UNK	UNK
PAED-193	PROS1617	2	INFANT / CHILD / BOOSTER SEAT	FIVE-POINT HARNESS	UNK	YES
PAED-193	PROS1617	2	UNK	UNK	UNK	UNK
PAED-193	PROS1617	2	BOOSTER SEAT	LOW BACK (BACKLESS)	UNK	UNK
PAED-205	ASF71619	1	BOOSTER SEAT	LOW BACK (BACKLESS)	UNK	UNK
PAED-211	ROP31628	1	INFANT / CHILD SEAT	FIVE-POINT HARNESS	NO	NO
PAED-212	ROP31627	1	INFANT CARRIER	REMOVEABLE BASE	YES	YES

F. Raw Data- Collision Variables

Table F-1 Raw data for collision factors: configuration, initial impact type, and intrusion

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	CONFIGU-RATION	INITIAL IMPACT TYPE	INTR-USIO N	INTR-USION (CM)
PAED-001	ROP31608	2	SIDE	APPROACHING	NO	N/A
PAED-004	ROP31610	2	HEAD-ON	APPROACHING	NO	N/A
PAED-005	ROP31611	1	SIDE	REAR END	YES	25
PAED-005	ROP31611	1	SIDE	REAR END	YES	25
PAED-006	SID71633	2	ROLLOVER	ANGLE	NO	N/A
PAED-007	SID71634	1	SIDE	SIDESWIPE	YES	10
PAED-007	SID71634	1	SIDE	SIDESWIPE	YES	10
PAED-011	ROP31616	1	FIXED OBJECT	SMV OTHER	NO	N/A
PAED-026	ROP31617	2	HEAD-ON	APPROACHING	YES	40
PAED-026	ROP31617	2	HEAD-ON	APPROACHING	YES	40
PAED-026	ROP31617	2	HEAD-ON	APPROACHING	YES	40
PAED-030	SID71638	2	SIDE	ANGLE	YES	30
PAED-030	SID71638	2	SIDE	ANGLE	YES	30
PAED-030	SID71638	2	SIDE	ANGLE	YES	30
PAED-034	PROS1603	2	HEAD-ON	APPROACHING	YES	5
PAED-034	PROS1603	2	HEAD-ON	APPROACHING	YES	5
PAED-047	ASF71606	1	FIXED OBJECT	SMV OTHER	NO	N/A
PAED-047	ASF71606	1	FIXED OBJECT	SMV OTHER	NO	N/A
PAED-047	ASF71606	1	FIXED OBJECT	SMV OTHER	NO	N/A
PAED-049	PROS1604	2	SIDE	UNK	YES	10
PAED-050	ASF71607	2	HEAD-ON	APPROACHING	YES	30
PAED-055	ROP31601	2	HEAD-ON	APPROACHING	YES	5
PAED-057	ROP31604	1	SIDE UNDERRIDE	APPROACHING	YES	40
PAED-061	-	2	REAR-END	REAR END	UNK	N/A
PAED-062	SID71639	1	ROLLOVER	SMV OTHER	NO	N/A
PAED-062	SID71639	1	ROLLOVER	SMV OTHER	NO	N/A
PAED-062	SID71639	1	ROLLOVER	SMV OTHER	NO	N/A

PAED-065	PROS1609	1	HEAD-ON	REAR END	YES	30
PAED-071	ASF71609	1	ROLLOVER	SMV OTHER	NO	N/A
PAED-071	ASF71609	1	ROLLOVER	SMV OTHER	NO	N/A
PAED-075	PROS1610	1	SIDE	ANGLE	YES	25
PAED-087	ASF71611	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-087	ASF71611	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-087	ASF71611	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-093	ASF71614	1	SIDE	APPROACHING	YES	20
PAED-097	ROP31623	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-097	ROP31623	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-097	ROP31623	2	SIDE	TURNING MOVEMENT	NO	N/A
PAED-100	ASF71610	2	SIDE	TURNING MOVEMENT	YES	5
PAED-100	ASF71610	2	SIDE	TURNING MOVEMENT	YES	5
PAED-104	SID71620	1	SIDE	ANGLE	YES	20
PAED-105	SID71629	1	SIDE	ANGLE	YES	30
PAED-105	SID71629	1	SIDE	ANGLE	YES	30
PAED-106	SID71635	1	SIDE	TURNING MOVEMENT	YES	50
PAED-106	SID71635	1	SIDE	TURNING MOVEMENT	YES	50
PAED-106	SID71635	1	SIDE	TURNING MOVEMENT	YES	50
PAED-109	ROP31605	2	REAR-END	REAR END	NO	N/A
PAED-109	ROP31605	2	REAR-END	REAR END	NO	N/A
PAED-110	ROP31606	2	SIDE	APPROACHING	NO	N/A
PAED-111	ROP31607	1	HEAD-ON	APPROACHING	YES	15
PAED-113	ROP31613	1	HEAD-ON	UNK	YES	25
PAED-116	ASF61604	1	SIDE	UNK	YES	30
PAED-118	ASF61632	2	REAR-END	UNK	YES	40
PAED-119	ASF61633	1	ROLLOVER	UNK	YES	30

PAED-121	ASF61644	1	HEAD-ON	UNK	YES	5
PAED-121	ASF61644	1	HEAD-ON	UNK	YES	5
PAED-122	ASF61650	1	OTHER	UNK	NO	N/A
PAED-124	ASF61665	1	SIDE	APPROACHING	YES	20
PAED-125	ASF61666	1	ROLLOVER	APPROACHING	YES	20
PAED-125	ASF61666	1	ROLLOVER	APPROACHING	YES	20
PAED-125	ASF61666	1	ROLLOVER	APPROACHING	YES	20
PAED-131	ROP31624	1	FIXED OBJECT	SMV OTHER	YES	30
PAED-137	PROS1612		HEAD-ON	ANGLE	NO	N/A
PAED-149	ASF71616	1	HEAD-ON	APPROACHING	YES	100
PAED-149	ASF71616	1	HEAD-ON	APPROACHING	YES	100
PAED-154	ROP31625	2	HEAD-ON	APPROACHING	NO	N/A
PAED-182	SID71648	2	SIDE	ANGLE	YES	20
PAED-183	ROP31626	1	REAR-END	REAR END	NO	N/A
PAED-183	ROP31626	1	REAR-END	REAR END	NO	N/A
PAED-193	PROS1617	2	HEAD-ON	APPROACHING	YES	35
PAED-193	PROS1617	2	HEAD-ON	APPROACHING	YES	35
PAED-193	PROS1617	2	HEAD-ON	APPROACHING	YES	35
PAED-193	PROS1617	2	HEAD-ON	APPROACHING	YES	35
PAED-205	ASF71619	1	SIDE	APPROACHING	YES	25
PAED-211	ROP31628	1	HEAD-ON	SMV OTHER	NO	N/A
PAED-212	ROP31627	1	FIXED OBJECT	SMV OTHER	NO	N/A

Table F-2. Raw data for collision factors: EDR speed, PDOF, EBS, delta-v, and ejection

PAED NUMBER	TRANSPORT CANADA CASE NUMBER	VEHICLE NUMBER	EDR SPEED (KM/H)	PDOF	EBS (KM/H)	ΔV (KM/H)	EJECTION
PAED-001	ROP31608	2	N/A	360	59	50	NO
PAED-004	ROP31610	2	UNK	360	37	36	NO
PAED-005	ROP31611	1	0	360	31	32	NO
PAED-005	ROP31611	1	N/A	360	31	32	NO
PAED-006	SID71633	2	N/A	315	23	24	NO
PAED-007	SID71634	1	N/A	289	42	47	NO
PAED-007	SID71634	1	82	289	42	47	NO
PAED-011	ROP31616	1	55	360	29	29	NO
PAED-026	ROP31617	2	N/A	355	53	47	NO
PAED-026	ROP31617	2	96	355	53	47	NO

PAED-026	ROP31617	2	N/A	355	53	47	NO
PAED-030	SID71638	2	N/A	325	28	40	NO
PAED-030	SID71638	2	N/A	325	28	40	NO
PAED-030	SID71638	2	109	325	28	40	NO
PAED-034	PROS1603	2	N/A	360	42	62	NO
PAED-034	PROS1603	2	158.2	360	42	62	NO
PAED-047	ASF71606	1	86	360	41	41	NO
PAED-047	ASF71606	1	UNK	360	41	41	NO
PAED-047	ASF71606	1	88	360	41	41	NO
PAED-049	PROS1604	2	3	68	47	39	-
PAED-050	ASF71607	2	N/A	330	25	27	NO
PAED-055	ROP31601	2	105	360	41	59	NO
PAED-057	ROP31604	1	N/A	360	51	48	NO
PAED-061	-	2	125	UNK	UNK	UNK	NO
PAED-062	SID71639	1	N/A	0	UNK	UNK	NO
PAED-062	SID71639	1	N/A	0	UNK	UNK	NO
PAED-062	SID71639	1	N/A	0	UNK	UNK	NO
PAED-065	PROS1609	1	90	360	42	62	NO
PAED-071	ASF71609	1	N/A	0	UNK	UNK	COMPLETE
PAED-071	ASF71609	1	101	0	UNK	UNK	NO
PAED-075	PROS1610	1	N/A	300	-	-	NO
PAED-087	ASF71611	2	N/A	360	23	35	NO
PAED-087	ASF71611	2	84	360	23	35	PARTIAL
PAED-087	ASF71611	2	31	360	23	35	COMPLETE
PAED-093	ASF71614	1	N/A	60	21	32	COMPLETE
PAED-097	ROP31623	2	N/A	345	42	39	NO
PAED-097	ROP31623	2	N/A	345	42	39	NO
PAED-097	ROP31623	2	N/A	345	42	39	NO
PAED-100	ASF71610	2	100	360	45	47	NO
PAED-100	ASF71610	2	100	360	45	47	NO
PAED-104	SID71620	1	28	60	21	30	NO
PAED-105	SID71629	1	26	45	28	34	NO
PAED-105	SID71629	1	26	45	28	34	NO
PAED-106	SID71635	1	N/A	45	41	41	NO
PAED-106	SID71635	1	N/A	45	41	41	NO

PAED-106	SID71635	1	N/A	45	41	41	NO
PAED-109	ROP31605	2	N/A	180	14	17	NO
PAED-109	ROP31605	2	N/A	180	14	17	NO
PAED-110	ROP31606	2	N/A	350	29	22	NO
PAED-111	ROP31607	1	88	345	68	67	NO
PAED-113	ROP31613	1	105	344	97	72	NO
PAED-116	ASF61604	1	N/A	277	29	44	COMPLETE
PAED-118	ASF61632	2	N/A	180	56	46	NO
PAED-119	ASF61633	1	N/A	90	17	17	NO
PAED-121	ASF61644	1	90	360	UNK	60	NO
PAED-121	ASF61644	1	90	360	UNK	60	NO
PAED-122	ASF61650	1	N/A	UNK	UNK	UNK	-
PAED-124	ASF61665	1	N/A	100	41	44	NO
PAED-125	ASF61666	1	102	0	UNK	13	NO
PAED-125	ASF61666	1	102	0	UNK	13	NO
PAED-125	ASF61666	1	102	0	UNK	13	NO
PAED-131	ROP31624	1	106	360	66	66	NO
PAED-137	PROS1612		UNK	360	UNK	UNK	NO
PAED-149	ASF71616	1	N/A	360	UNK	130	NO
PAED-149	ASF71616	1	N/A	360	UNK	130	NO
PAED-154	ROP31625	2	N/A	20	24	26	NO
PAED-182	SID71648	2	96	312	54	52	NO
PAED-183	ROP31626	1	88	360	31	29	NO
PAED-183	ROP31626	1	88	360	31	29	NO
PAED-193	PROS1617	2	N/A	360	55	56	NO
PAED-193	PROS1617	2	N/A	360	55	56	NO
PAED-193	PROS1617	2	N/A	360	55	56	NO
PAED-193	PROS1617	2	N/A	360	55	56	NO
PAED-205	ASF71619	1	N/A	290	25	23	NO
PAED-211	ROP31628	1	60	23	48	50	NO
PAED-212	ROP31627	1	97	360	34	46	NO

G.Raw Data- Injury Variables

Table G-1 Raw data for injury variables: number of injured pediatric occupants, injury severity, MAIS-overall, MAIS-head, MAIS-face, and MAIS-neck

PAED NUMBER	TRANSP-ORT CANADA CASE NUMBER	VEHI-CLE NUM-BER	NUM-BER OF INJU-RED PEDS	INJURY SEVE-RITY	MAIS-OVE-RALL	MAIS-HEAD	MAIS-FACE	MAIS-NECK
PAED-001	ROP31608	2	2	MAJOR	3	3	3	0
PAED-004	ROP31610	2	2	MAJOR	2	1	1	0
PAED-005	ROP31611	1	2	MAJOR	4	0	0	0
PAED-005	ROP31611	1	2	MAJOR	3	0	1	0
PAED-006	SID71633	2	0	NONE	0	0	0	0
PAED-007	SID71634	1	2	MINOR	1	0	1	0
PAED-007	SID71634	1	2	UNK	9	UNK	UNK	UNK
PAED-011	ROP31616	1	1	MINOR	2	2	1	0
PAED-026	ROP31617	2	5	MAJOR	2	0	1	0
PAED-026	ROP31617	2	5	MINOR	9	0	1	0
PAED-026	ROP31617	2	5	UNK	9	UNK	UNK	UNK
PAED-030	SID71638	2	3	MINOR	0	0	0	0
PAED-030	SID71638	2	3	MAJOR	2	0	2	0
PAED-030	SID71638	2	3	MINOR	1	0	1	0
PAED-034	PROS1603	2	2	MINOR	4	0	1	1
PAED-034	PROS1603	2	2	MINIMA L	1	0	1	1
PAED-047	ASF71606	1	1	NONE	0	0	0	0
PAED-047	ASF71606	1	1	MINOR	1	0	1	0
PAED-047	ASF71606	1	1	NONE	0	0	0	0
PAED-049	PROS1604	2	2	UNK	4	UNK	UNK	UNK
PAED-050	ASF71607	2	1	MINOR	1	0	0	0
PAED-055	ROP31601	2	1	UNK	1	UNK	UNK	UNK
PAED-057	ROP31604	1	1	MAJOR	4	4	0	0
PAED-061	-	2	2	NONE	0	0	0	0
PAED-062	SID71639	1	1	NONE	0	0	0	0
PAED-062	SID71639	1	1	NONE	0	0	0	0
PAED-062	SID71639	1	1	MINOR	1	0	1	0
PAED-065	PROS1609	1	1	MINOR	1	0	0	0
PAED-071	ASF71609	1	0	FATAL	9	UNK	UNK	UNK

PAED-071	ASF71609	1	0	NONE	0	0	0	0
PAED-075	PROS1610	1	1	MAJOR	5	3	0	0
PAED-087	ASF71611	2	3	MAJOR	1	0	1	0
PAED-087	ASF71611	2	3	MAJOR	5	5	1	0
PAED-087	ASF71611	2	3	MAJOR	5	5	1	0
PAED-093	ASF71614	1	1	MAJOR	2	0	2	0
PAED-097	ROP31623	2	3	MINOR	1	0	1	1
PAED-097	ROP31623	2	3	MINOR	1	0	0	0
PAED-097	ROP31623	2	3	MINOR	1	0	0	0
PAED-100	ASF71610	2	2	UNK	UNK	UNK	UNK	UNK
PAED-100	ASF71610	2	2	UNK	UNK	UNK	UNK	UNK
PAED-104	SID71620	1	0	NONE	0	0	0	0
PAED-105	SID71629	1	2	MAJOR	5	5	0	0
PAED-105	SID71629	1	2	-	1	-	-	-
PAED-106	SID71635	1	1	NONE	0	0	0	0
PAED-106	SID71635	1	1	NONE	0	0	0	0
PAED-106	SID71635	1	1	NONE	9	0	0	0
PAED-109	ROP31605	2	0	NONE	0	0	0	0
PAED-109	ROP31605	2	0	NONE	0	0	0	0
PAED-110	ROP31606	2	1	MINOR	1	1	1	0
PAED-111	ROP31607	1	2	MINOR	1	0	1	0
PAED-113	ROP31613	1	0	FATAL	5	5	0	0
PAED-116	ASF61604	1	1	MAJOR	4	5	0	0
PAED-118	ASF61632	2	1	MAJOR	5	5	0	0
PAED-119	ASF61633	1	1	UNK	3	UNK	UNK	UNK
PAED-121	ASF61644	1	2	MAJOR	2	0	2	0
PAED-121	ASF61644	1	2	MAJOR	9	0	2	0
PAED-122	ASF61650	1	0	MINOR	2	2	0	0
PAED-124	ASF61665	1	0	FATAL	7	7	0	0
PAED-125	ASF61666	1	4	MINIMA L	9	UNK	UNK	UNK
PAED-125	ASF61666	1	4	UNK	9	UNK	UNK	UNK
PAED-125	ASF61666	1	4	UNK	9	UNK	UNK	UNK
PAED-131	ROP31624	1	0	MINIMA L	1	0	1	0
PAED-137	PROS1612	-	0	NONE	0	0	0	0
PAED-149	ASF71616	1	0	FATAL	6	6	0	0
PAED-149	ASF71616	1	0	FATAL	7	0	0	0

PAED-154	ROP31625	2	1	MINIMA L	1	0	1	0
PAED-182	SID71648	2	0	FATAL	3	3	1	0
PAED-183	ROP31626	1	2	MAJOR	0	0	0	0
PAED-183	ROP31626	1	2	MAJOR	0	0	0	0
PAED-193	PROS1617	2	4	MAJOR	2	0	1	0
PAED-193	PROS1617	2	4	MAJOR	1	0	0	0
PAED-193	PROS1617	2	4	MAJOR	3	0	0	0
PAED-193	PROS1617	2	4	MAJOR	3	3	0	0
PAED-205	ASF71619	1	1	MINIMA L	1	0	1	0
PAED-211	ROP31628	1	2	MINIMA L	1	0	1	0
PAED-212	ROP31627	1	0	FATAL	7	7	0	0

Table G-2 Raw data for injury variables: MAIS-thorax, MAIS-abdomen, MAIS-spine, MAIS-upper extremities, and MAIS-lower extremities

PAED NUMBER	TRANS-PORT CANADA CASE NUMBER	VEHI-CLE NUM-BER	MAIS-THORAX	MAIS-ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
PAED-001	ROP31608	2	3	0	1	0	1
PAED-004	ROP31610	2	0	1	0	2	0
PAED-005	ROP31611	1	0	3	0	2	4
PAED-005	ROP31611	1	0	3	0	0	1
PAED-006	SID71633	2	0	0	0	0	0
PAED-007	SID71634	1	0	0	0	0	0
PAED-007	SID71634	1	UNK	UNK	UNK	UNK	UNK
PAED-011	ROP31616	1	0	0	0	0	0
PAED-026	ROP31617	2	0	0	0	0	2
PAED-026	ROP31617	2	0	0	0	0	2
PAED-026	ROP31617	2	UNK	UNK	UNK	UNK	UNK
PAED-030	SID71638	2	0	0	0	0	0
PAED-030	SID71638	2	0	2	0	0	0
PAED-030	SID71638	2	0	0	0	0	0
PAED-034	PROS1603	2	1	0	0	0	0
PAED-034	PROS1603	2	1	0	0	0	0
PAED-047	ASF71606	1	0	0	0	0	0
PAED-047	ASF71606	1	0	0	0	1	0

PAED-047	ASF71606	1	0	0	0	0	0
PAED-049	PROS1604	2	UNK	UNK	UNK	UNK	UNK
PAED-050	ASF71607	2	0	0	0	1	0
PAED-055	ROP31601	2	UNK	UNK	UNK	UNK	UNK
PAED-057	ROP31604	1	0	0	0	0	3
PAED-061	-	2	0	0	0	0	0
PAED-062	SID71639	1	0	0	0	0	0
PAED-062	SID71639	1	0	0	0	0	0
PAED-062	SID71639	1	0	0	0	0	0
PAED-065	PROS1609	1	0	0	0	1	0
PAED-071	ASF71609	1	UNK	UNK	UNK	UNK	UNK
PAED-071	ASF71609	1	0	0	0	0	0
PAED-075	PROS1610	1	0	0	0	0	1
PAED-087	ASF71611	2	0	0	0	0	0
PAED-087	ASF71611	2	3	0	2	0	2
PAED-087	ASF71611	2	4	0	0	0	2
PAED-093	ASF71614	1	0	0	0	0	0
PAED-097	ROP31623	2	0	0	0	0	0
PAED-097	ROP31623	2	0	0	0	1	0
PAED-097	ROP31623	2	0	0	0	1	0
PAED-100	ASF71610	2	UNK	UNK	UNK	UNK	UNK
PAED-100	ASF71610	2	UNK	UNK	UNK	UNK	UNK
PAED-104	SID71620	1	0	0	0	0	0
PAED-105	SID71629	1	4	3	2	0	1
PAED-105	SID71629	1	-	-	-	-	-
PAED-106	SID71635	1	0	0	0	0	0
PAED-106	SID71635	1	0	0	0	0	0
PAED-106	SID71635	1	0	0	0	0	0
PAED-109	ROP31605	2	0	0	0	0	0
PAED-109	ROP31605	2	0	0	0	0	0
PAED-110	ROP31606	2	0	0	0	0	0
PAED-111	ROP31607	1	0	0	0	0	0
PAED-113	ROP31613	1	4	2	2	1	1
PAED-116	ASF61604	1	0	2	0	0	2
PAED-118	ASF61632	2	0	0	0	0	0
PAED-119	ASF61633	1	UNK	UNK	UNK	UNK	UNK
PAED-121	ASF61644	1	0	0	0	0	2
PAED-121	ASF61644	1	0	0	0	0	2

PAED-122	ASF61650	1	0	0	0	2	0
PAED-124	ASF61665	1	0	0	0	0	0
PAED-125	ASF61666	1	UNK	UNK	UNK	UNK	UNK
PAED-125	ASF61666	1	UNK	UNK	UNK	UNK	UNK
PAED-125	ASF61666	1	UNK	UNK	UNK	UNK	UNK
PAED-131	ROP31624	1	0	1	0	0	0
PAED-137	PROS1612	-	0	0	0	0	1
PAED-149	ASF71616	1	0	0	0	0	0
PAED-149	ASF71616	1	7	7	0	0	0
PAED-154	ROP31625	2	0	0	0	0	0
PAED-182	SID71648	2	3	0	0	2	1
PAED-183	ROP31626	1	0	0	0	0	0
PAED-183	ROP31626	1	1	0	0	0	0
PAED-193	PROS1617	2	0	0	0	1	2
PAED-193	PROS1617	2	0	1	0	0	0
PAED-193	PROS1617	2	3	1	0	0	0
PAED-193	PROS1617	2	0	0	0	2	0
PAED-205	ASF71619	1	0	0	0	0	0
PAED-211	ROP31628	1	0	0	0	0	0
PAED-212	ROP31627	1	0	0	0	0	0

H.Head Injury Severity

Unique description and their assigned severity score based on the probability of death. Table H-1 shows the individual head injury descriptions for the trauma sustained by occupants in this study.

Table H-1 Head Injuries by AIS Score 1-3

AIS 1	AIS 2	AIS 3
- Scalp- laceration- NSF - Scalp- contusion	- Cerebral concussion - Skull fracture-NFS - Vault fracture closed (simple; undisplaced; diastatic; linear) - Vault fracture- NFS (may involve frontal, occipital, parietal, or temporal bones not otherwise specified) lethargic, stuporous, obtunded on admission or initial observation at scene (GCS 9-14)- no prior unconsciousness	- Base (basilar) fracture- NFS (may not involve ethmoid, orbital, roof, sphenoid, temporal- incl. petrous, squamous or mastoid portions - Cerebrum- contusion- multiple, on same side- NFS - Cerebrum- contusion- single- NFS - Cerebrum- NFS - Cerebrum- Edema- infarction (acute due to traumatic vascular occlusion) - Cerebrum- edema- mild (compressed ventricle(s) w/o compressed brain stem cisterns) - Cerebrum- edema- NFS - Cerebrum- edema- subarachnoid hemorrhage - Cerebellum- hematoma/hemorrhage- subarachnoid hemorrhage - Vault fracture- comminuted (compound; depressed <= 2cm; displaced)

Table H-2 Head Injuries by AIS Score 4-6

AIS 4	AIS 5	AIS 6
- Cerebrum- edema- intraventricular hemorrhage - Cerebrum- hematoma/hemorrhage- epidural or extradural- NFS - Cerebrum- hematoma/hemorrhage- intracerebral- small (<=30CC;<= 4cm diameter) subcortical hemorrhage - Cerebrum- hematoma/hemorrhage- NFS - Cerebrum- hematoma/hemorrhage- subdural- NFS - Cerebrum- hematoma/hemorrhage- subdural- small (<=50cc adult; <=25 if <= 10 years old; <=1 cm thick; smear; tiny)	- Brain stem (hypothalamus, medulla, midbrain, pons)- compression (incl. transentorial (uncal) or cerebellar tonsillar herniation) - Brain stem (hypothalamus, medulla, midbrain, pons)- hemorrhage injury - Cerebrum- diffuse axonal injury (white matter shearing) - Cerebrum- hematoma/hemorrhage- epidural/extradural- small- bilateral (<=50cc adult; <= 25 cc if <= 10 years old; <= 1cm thick; smear; tiny) - Cerebrum- hematoma/hemorrhage- subdural- small- bilateral (<=50cc adult; <= 25 cc if <= 10 years old; <= 1cm thick; smear; tiny)	- (crush) massive destruction of both cranium (skull) and brain

I. Example Calculations

Intrusion (see Table J-14)

Intrusion	Total (n=61)	No or Minor Injury (n=48)	Severe Injury (n=13)
No	26 (43%)	23 (48%)	3 (23%)
Yes	35 (57%)	25 (52%)	10 (77%)
OR= 3.067			
95% CI= 0.75-12.55			

$n_A = Total\ number\ of\ cases\ in\ population\ A$

$n_B = Total\ number\ of\ cases\ in\ population\ B$

$n_C = Total\ number\ of\ individuals\ in\ population\ A$ - n_A

$n_D = Total\ number\ of\ individuals\ in\ population\ B$ - n_B

n_A= 23, n_B= 3, n_C= 25, n_D= 10

Odds Ratio Calculation

Equation 2-1

$$\boldsymbol{OR = \frac{n_A/n_C}{n_B/n_D}}$$

$$\boldsymbol{OR = \frac{23/25}{3/10}}$$

$$\boldsymbol{OR = 23/25\ x\ 10/3}$$

$$\boldsymbol{OR = \frac{23(10)}{25(3)}}$$

$$\boldsymbol{OR = \frac{230}{75}}$$

$$\boldsymbol{OR = 3.067}$$

Standard Error of Odds Ratio Calculation

Equation 2-3

$$\boldsymbol{SE(OR) = \sqrt{\frac{1}{n_A} + \frac{1}{n_B} + \frac{1}{n_C} + \frac{1}{n_D}}}$$

$$\boldsymbol{SE(OR) = \sqrt{\frac{1}{23} + \frac{1}{3} + \frac{1}{25} + \frac{1}{10}}}$$

$$\boldsymbol{SE(OR) = \sqrt{0.5168116}}$$

$$\boldsymbol{SE(OR) = 0.719}$$

95% Confidence Interval Calculation

Equation 2-2

$$\boldsymbol{95\%\ CI = e^{\ln(OR)\ \pm\ [1.96\ x\ SE(OR)]}}$$

$$\boldsymbol{95\%\ CI = e^{\ln(3.067)\ \pm\ [1.96\ x\ 0.719]}}$$

$$\boldsymbol{95\%\ CI = e^{(1.1207)\ \pm(1.4092)}}$$

$$\boldsymbol{+\ 95\%\ CI = e^{(1.1207)+\ [1.4092]}}$$

$$\boldsymbol{+\ 95\%\ CI = e^{2.5299}}$$

$$\boldsymbol{+\ 95\%\ CI = 12.55}$$

$$\boldsymbol{-\ 95\%\ CI = e^{(1.1207)\ -\ [1.4092]}}$$

$$\boldsymbol{-\ 95\%\ CI = e^{(-0.2885)}}$$

$$\boldsymbol{-\ 95\%\ CI = 0.75}$$

<u>Ejection (see Table J-17)</u>

Ejection	Total (n=62)	No or Minor Head Injury (n=49)	Severe Head Injury (n=13)
No	58 (94%)	48 (98%)	10 (77%)
Complete/Partial	4 (6%)	1 (2%)	3 (23%)
Fischer's exact= 0.026			

n_A= 48, n_B= 10, n_C= 1, n_D= 3

Fisher's Exact Test

Equation 2-4

$$\boldsymbol{Fisher's\ Exact\ Test\ p-value} = \frac{(\boldsymbol{n_A}+\boldsymbol{n_B})!\,(\boldsymbol{n_C}+\boldsymbol{n_D})!\,(\boldsymbol{n_A}+\boldsymbol{n_C})!\,(\boldsymbol{n_B}+\boldsymbol{n_D})!}{\boldsymbol{n_A}!\,\boldsymbol{n_B}!\,\boldsymbol{n_C}!\,\boldsymbol{n_D}!\,(\boldsymbol{n_A}+\boldsymbol{n_B}+\boldsymbol{n_C}+\boldsymbol{n_D})!}$$

$$\boldsymbol{p-value} = \frac{(\mathbf{48}+\mathbf{10})!\,(\mathbf{1}+\mathbf{3})!\,(\mathbf{48}+\mathbf{1})!\,(\mathbf{10}+\mathbf{3})!}{\mathbf{48}!\,\mathbf{10}!\,\mathbf{1}!\,\mathbf{3}!\,(\mathbf{48}+\mathbf{10}+\mathbf{1}+\mathbf{3})!}$$

$$\boldsymbol{p-value} = \frac{(\mathbf{58})!\,(\mathbf{4})!\,(\mathbf{49})!\,(\mathbf{13})!}{\mathbf{48}!\,\mathbf{10}!\,\mathbf{1}!\,\mathbf{3}!\,\mathbf{62}!}$$

$$\boldsymbol{p-value} = \mathbf{0.026}$$

J. Data Tables

Table J-1 Gender of occupant with respect to head injury severity as a result of an MVC

Gender	Total (n=61)	No or Minor Head Injury (n=49)	Severe Head Injury (n=12)
Male	36 (59%)	30 (61%)	6 (50%)
Female	25 (41%)	19 (39%)	6 (50%)
OR= 1.579			
p= 0.479			
Fischer's exact= 0.526			
95% CI= 0.44-5.62			

Table J-1 shows gender distribution for rear seated child occupants with relation to head injury severity. Data were available for 61occupants. Females showed a higher odds of involvement in severe head injury cases (OR=1.579, 95% CI= 0.44 to 5.62). The odds ratio was not statistically significant (p= 0.479).

Table J-2 Age of occupant and head injury severity as a result of an MVC

AGE (YEARS)	Total (n=61)	No or Minor Head Injury (n=50)	Severe Head Injury (n=11)
0	8 (13%)	6 (12%)	2 (18%)
1	6 (10%)	5 (10%)	1 (9%)
2	7 (11%)	7 (14%)	0
3	7 (11%)	4 (8%)	3 (28%)
4	12 (20%)	11 (22%)	1 (9%)
5	7 (11%)	6 (12%)	1 (9%)
6	6 (10%)	5 (5%)	1 (9%)
7	4 (7%)	3 (6%)	1 (9%)
8	4 (7%)	3 (6%)	1 (9%)
Nagelkerke R^2= 0.022			
p= 0.353			
exp(B)= 1.13			
95% CI= 0.87-1.46			

Table J-2 shows age of the occupant with relation to head injury severity. Data were available for 61 occupants. A univariate linear regression was performed to ascertain the effects of age on the likelihood of severe head injury. Age of the occupant showed a higher odds of involvement in severe head injury cases (OR=1.13, 95% CI= 0.87 to 1.46, p=0.35). The regression was not statistically significant (p=0.35) for the relationship between age of the occupant and severe head injury. The model explained 2.2% of the variance in the head injury.

Table J-3 Height of occupant and head injury severity as a result of an MVC

HEIGHT (CM)	Total (n=29)	No or Minor Head Injury (n=23)	Severe Head Injury (n=6)
60-69	4 (14%)	2 (9%)	2 (33%)
70-79	1 (3%)	1 (4%)	0
80-89	3 (10%)	3 (13%)	0
90-99	6 (21%)	5 (22%)	1 (17%)
100-109	3 (10%)	3 (13%)	0
110-119	6 (21%)	4 (17%)	2 (33%)
120-129	4 (14%)	3 (13%)	1 (17%)
130-139	1 (3%)	1 (4%)	0
140-149	1 (3%)	1 (4%)	0
Nagelkerke R^2= 0.015			
p= 0.589			
exp(B)= 0.895 [0.105]			
95% CI= 0.60-1.34			

Table J-3 shows height of the occupant with relation to head injury severity. Data were available for 29 occupants. A univariate linear regression was performed to ascertain the effects of height on the likelihood of severe head injury. Height of the occupant showed a lower odds of involvement in severe head injury cases (OR=0.11, 95% CI= 0.60 to 1.34, p=0.589). The regression was not statistically significant (p=0.59) for the relationship between height and severe head injury. The model explained 1.5% of the variance in the head injury.

Table J-4 Mass of occupant and head injury severity as a result of an MVC

MASS (KG)	Total (n=42)	No or Minor Head Injury (n=35)	Severe Head Injury (n=7)
1-5	1 (2%)	1 (3%)	0
6-10	8 (19%)	5 (14%)	3 (42%)
11-15	7 (17%)	7 (20%)	0
16-20	13 (31%)	11 (31%)	2 (29%)
21-25	8 (19%)	6 (17%)	2 (29%)
26-30	2 (5%)	2 (6%)	0
31-35	2 (5%)	2 (6%)	0
36-40	1 (2%)	1 (3%)	0
Nagelkerke R^2= 0			
p= 0.927			
exp(B)= 0.977 [0.023]			
95% CI= 0.60-1.59			

Table J-4 shows mass of the occupant with relation to head injury severity. Data were available for 42 occupants. A univariate linear regression was performed to ascertain the effects of mass on the likelihood of severe head injury. Mass of the occupant showed a lower odds of involvement in severe head injury cases (OR=0.023, 95% CI= 0.60 to 1.59, p=0.927). The regression was not statistically significant (p=0.93) for the relationship between mass and severe head injury. The model explained 0% of the variance in the head injury.

Table J-5 Occupant seating position in the vehicle and head injury severity as a result of an MVC

OCCUPANT SEATING LOCATION	Total (n=61)	No or Minor Head Injury (n=50)	Severe Head Injury (n=11)
210	19 (31%)	14 (28%)	5 (46%)
220	4 (7%)	4 (8%)	0
230	27 (44%)	23 (46%)	4 (35%)
310	3 (5%)	3 (6%)	0
320	4 (7%)	3 (6%)	1 (9%)
330	2 (3%)	2 (4%)	0
290	2 (3%)	1 (2%)	1 (9%)
Nagelkerke R^2= 0			
p= 0.963			
exp(B)= 0.991 [0.009]			
95% CI= 0.66-1.48			

Table J-5 shows the occupant seating location with relation to head injury severity. Data were available for 61 occupants. A univariate linear regression was performed to ascertain the effects of occupant seating location on the likelihood of severe head injury. Occupant seating location showed a lower odds of involvement in severe head injury cases (OR=0.009, 95% CI= 0.66 to 1.48, p=0.963). The regression was not statistically significant (p=0.96) for the relationship between seating location and severe head injury. The model explained 0% of the variance in the head injury.

Table J-6 Number of rear occupants in a vehicle during an MVC and resulting occupant head injury severity

Number of Rear Occupants	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
1	22 (36%)	17 (33%)	5 (46%)
2	21(34%)	16 (31%)	5 (46%)
3	14 (22%)	13 (26%)	1 (8%)
4	2 (3%)	2 (4%)	0
5	3 (5%)	3 (6%)	0
Nagelkerke R^2= 0.142			
p= 0.032			
exp(B)= 0.424 [0.576]			
95% CI= 0.194-0.927			

Table J-6 shows number of rear row occupants with relation to head injury severity sustained by the injured occupant. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of number of rear row occupants on the likelihood of severe head injury. Number of rear row occupants showed a lower odds of involvement in severe head injury cases (OR=0.576, 95% CI= 0.194 to 0.927, p=0.032). The regression was statistically significant (p=0.032) for the relationship between collision configuration and severe head injury. The model explained 14.2% of the variance in the head injury.

Table J-7 Year of vehicle involved in an MVC and resulting occupant head injury severity

VEHICLE YEAR	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
<2000	3 (5%)	2 (4%)	1 (9%)
2000-2002	1 (2%)	1 (2%)	0
2003-2005	7(11%)	3 (6%)	4 (37%)
2006-2008	28 (45%)	26 (51%)	2 (18%)
2009-2011	15 (24%)	13 (25%)	2 (18%)
2012-2014	8 (13%)	6 (12%)	2 (18%)
Nagelkerke R^2= 0.225			
p= 0.130			
exp(B)= n/a			
95% CI= n/a			

Table J-7 shows the relationship between the model year of the case vehicle with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects on model year of the case vehicle on likelihood of severe head injury. The regression was not statistically significant (p=0.13) for relationship between the model year of the vehicle and the presence of severe head injuries. The model explained 22.5% of the variance in the head injury.

Table J-8 Season of MVC and resulting occupant head injury severity

SEASON	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
SPRING	11 (17%)	9 (18%)	2 (18%)
SUMMER	21 (34%)	17 (33%)	4 (37%)
FALL	19 (31%)	16 (31%)	3 (27%)
WINTER	11 (17%)	9 (18%)	2 (18%)
Nagelkerke R^2= 0.005			
p= 0.975			
exp(B)= n/a			
95% CI= n/a			

Table J-8 shows the relationship between the season during which the collision occurred with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of the time of year on the likelihood of severe head injury. Cases showed no significant relationship between season and the presence of severe head injuries (p=0.98). The regression was not statistically significant (p=0.98) for the relationship between season and severe head injury. The model explained 0.5% of the variance in the head injury.

Table J-9 CRS type used by occupants involved in an MVC and head injury severity

CRS Type	Total (n=45)	No or Minor Head Injury (n=36)	Severe Head Injury (n=9)
INFANT CARRIER	5 (11%)	3 (8%)	2 (22%)
CHILD SEAT	0	0	0
BOOSTER	19 (43%)	17 (48%)	2 (22%)
INFANT/CHILD	6 (13%)	4 (11%)	2 (22%)
CHILD/BOOSTER	4 (9%)	3 (8%)	1 (12%)
INFANT/CHILD/BOOSTER	11 (24%)	9 (25%)	2 (22%)
Nagelkerke R^2= 0.006			
p= 0.623			
exp(B)= 1			
95% CI= 0.998-1.001			

Table J-9 shows the child restraint type being used by the occupant with relation to head injury severity sustained. Data were available for 45occupants.A univariate linear regression was performed to ascertain the effects of CRS type on the likelihood of severe head injury. CRS type showed no odds of involvement in severe head injury cases (OR=1.0, 95% CI= 0.998 to 1.001, p=0.623). The regression was not statistically significant (p=0.62) for the relationship between CRS type and severe head injury. The model explained 0.6% of the variance in the head injury.

Table J-10 CRS design used by occupants involved in an MVC and head injury severity

CRS DESIGN	Total (n=42)	No or Minor Head Injury (n=34)	Severe Head Injury (n=8)
REMOVABLE BASE	3 (7%)	1 (3%)	2 (25%)
INTEGRATED BASE	1 (3%)	0	1 (12%)
5 PT HARNESS	18 (43%)	14 (41%)	4 (50%)
LOW BACK	11 (26%)	11 (32%)	0
HIGH BACK	9 (21%)	8 (24%)	1 (13%)
Nagelkerke R^2= 0.001			
p= 0.822			
exp(B)= 1			
95% CI= 0.999-1.001			

Table J-10 shows the child restraint design being used by the occupant with relation to head injury severity sustained. Data were available for 42 occupants. A univariate linear regression was performed to ascertain the effects of CRS design on the likelihood of severe head injury. CRS design showed no odds of involvement in severe head injury cases (OR=1.0, 95% CI= 0.999 to 1.001, p=0.822). The regression was not statistically significant (p=0.82) for the relationship between CRS design and severe head injury. The model explained 0.1% of the variance in the head injury.

Table J-11 Improper installation of CRS and occupant head injury severity as a result of an MVC

Improper Installation	Total (n=33)	No or Minor Head Injury (n=27)	Severe Head Injury (n=6)
No	27 (82%)	22 (81%)	5 (83%)
Yes	6 (18%)	5 (19%)	1 (17%)
OR= 0.88			
p= 0.915			
Fischer's exact= 1.00			
95% CI= 0.084-9.29			

Table J-11 shows presence or absence of errors in child restraint system installation with relation to head injury severity. Data were available for 33 occupants. Cases with errors in child restraint systems installation showed a lower odds of involvement in severe head injury cases (OR=0.88, 95% CI= 0.084 to 9.29). The odds ratio was not statistically significant (Fisher's Exact test= 1.00). Fisher's Exact test was used for the p-value since at least one of the cells in the 2x2 table was less than five.

Table J-12 Improper use of CRS and occupant head injury severity as a result of an MVC

Improper Use	Total (n=33)	No or Minor Head Injury (n=28)	Severe Head Injury (n=5)
No	24 (73%)	20 (71%)	4 (80%)
Yes	9 (27%)	8 (29%)	1 (20%)
OR= 0.625			
p= 0.692			
Fischer's exact= 1.00			
95% CI= 0.06-6.49			

Table J-12 shows presence or absence of errors in child restraint use with relation to head injury severity. Data were available for 33 occupants. Cases with errors in child restraint system use showed a lower odds of involvement in severe head injury cases (OR=0.625, 95% CI= 0.06 to 6.49). The odds ratio was not statistically significant (Fisher's Exact test= 0.1.00). Fisher's Exact test was used for the p-value since at least one of the cells in the 2x2 table was less than five.

Table J-13 MVC collision configuration and resulting occupant head injury severity

CONFIGURATION	Total (n=61)	No or Minor Head Injury (n=50)	Severe Head Injury (n=11)
HEAD ON	20 (33%)	18 (36%)	2 (18%)
SIDE	24 (39%)	17 (34%)	7 (64%)
REAR	6 (10%)	5 (10%)	1 (9%)
FIXED	5 (8%)	5 (10%)	0
ROLL-OVER	5 (8%)	5 (10%)	0
UNDERRIDE	1 (2%)	0	1 (9%)
Nagelkerke R^2= 0.003			
p= 0.733			
exp(B)= 0.918 [0.082]			
95% CI= 0.56-1.5			

Table J-13 shows relationship between the collision configuration with relation to head injury severity. Data were available for 61 occupants. A univariate linear regression was performed to ascertain the effects of collision configuration on the likelihood of severe head injury. Collision configuration showed a lower odds of involvement in severe head injury cases (OR=0.082, 95% CI= 0.56 to 1.50, p=0.733). The regression was not statistically significant (p=0.733) for the relationship between collision configuration and severe head injury. The model explained 0.3% of the variance in the head injury.

Table J-14 Intrusion into occupant compartment on head injury severity as a result of an MVC

Intrusion	Total (n=61)	No or Minor Injury (n=48)	Severe Injury (n=13)
No	26 (43%)	23 (48%)	3 (23%)
Yes	35 (57%)	25 (52%)	10 (77%)
OR= 3.067			
p= 0.108			
Fischer’s exact= 0.128			
95% CI 0.75-12.55			

Table J-14 shows presence or absence of intrusion into the occupant compartment with relation to head injury severity. Data were available for 61 occupants. Vehicles with intrusion showed a higher odds of involvement in severe head injury cases (OR=3.067, 95% CI= 0.75 to 12.55). The odds ratio was not statistically significant (Fisher’s Exact test= 0.128). Fisher’s Exact test was used for the p-value since at least one of the cells in the 2 x 2 table was less than five. The average amount of intrusion into a vehicle compartment was 28.4cm with a range of 5 to 100cm. For the collisions that resulted in an occupant with a severe head injury, the average amount of intrusion was 38.3cm with a range of 20 to 100 cm.

Table J-15 Equivalent barrier speed experienced by vehicle involved in an MVC and resulting occupant head injury severity

Equivalent Barrier Speed (KM/HR)	Total (n=50)	No or Minor Head Injury (n=41)	Severe Head Injury (n=9)
10-19	2 (4%)	2 (5%)	0
20-29	16 (32%)	12 (29%)	4 (44%)
30-39	5 (10%)	5 (12%)	0
40-49	14 (28%)	14 (34%)	0
50-59	10 (20%)	6 (15%)	4 (44%)
60-69	2 (4%)	2 (5%)	0
70-79	0	0	0
80-89	0	0	0
90-99	1 (2%)	0	1 (12%)
Nagelkerke R^2= 0.040			
p= 0.253			
exp(B)= 1.283			
95% CI= 0.84-1.97			

Table J-15 shows the equivalent barrier speed with relation to head injury severity. Data were available for 50 occupants. A univariate linear regression was performed to ascertain the effects of equivalent barrier speed on the likelihood of severe head injury. Equivalent barrier speed showed an increased odds of involvement in severe head injury cases (OR=1.283, 95% CI= 0.84 to 1.97, p=0.25). The regression was not statistically significant (p=0.25) for the relationship EBS and severe head injury. The model explained 4% of the variance in the head injury. There were 50 occupants with information about EBS. Nine (18%) sustained severe head injuries. The 9 occupants were involved in collisions ranging from 20+ km/hr up to 90+km/hr, (average EBS 45.8 km/hr).

Table J-16 Delta-v experienced by the vehicle in an MVC and resulting occupant head injury severity

DELTA-V (KM/HR)	Total (n=54)	No or Minor Head Injury (n=44)	Severe Head Injury (n=10)
10-19	2 (4%)	2 (5%)	0
20-29	8 (15%)	8 (18%)	0
30-39	12 (22%)	9 (21%)	3 (30%)
40-49	15 (27%)	12 (27%)	3 (30%)
50-59	7 (13%)	5 (11%)	2 (20%
60-69	7 (13%)	7 (16%)	0
70-79	1 (2%)	0	1 (10%)
80-89	0	0	0
90-99	0	0	0
100-109	0	0	0
110-119	0	0	0
120-129	0	0	0
130-139	2 (4%)	1 (2%)	1 (10%)
Nagelkerke R^2= 0.044			
p= 0.207			
exp(B)= 1.187			
95% CI= 0.91-1.55			

Table J-16 shows the delta-v with relation to head injury severity. Data were available for 54 occupants. A univariate linear regression was performed to ascertain the effects of the change in velocity during the collision on the likelihood of severe head injury. Delta-v showed a higher odds of involvement in severe head injury cases (OR=1.187, 95% CI= 0.91 to 1.55, p=0.21). The regression was not statistically significant (p=0.21) for the relationship between delta-v and severe head injury. The model explained 4.4% of the variance in the head injury. Of the 54 pediatric occupants involved in collisions that had information about delta-v, 10 (18.5%) sustained severe head injuries. These 10 occupants were involved in collisions ranging from 30+ km/hr up to 30+km/hr, (average delta-v 54.7 km/hr).

Table J-17 Ejection of occupant during MVC and occupant head injury severity as a result of an MVC

Ejection	Total (n=62)	No or Minor Head Injury (n=49)	Severe Head Injury (n=13)
No	58 (94%)	48 (98%)	10 (77%)
Complete/Partial	4 (6%)	1 (2%)	3 (23%)
OR= 14.4			
p= 0.006			
Fischer's exact= 0.026			
95% CI= 1.34-143.04			

Table J-17 shows distribution of child occupant ejection from the vehicle with relation to head injury severity. Data were available for 62 occupants. Cases with complete or partial ejection showed a higher odds of involvement in severe head injury cases (OR=14.4, 95% CI= 1.34 to 143.04). The odds ratio was statistically significant (Fisher's Exact test= 0.026). Fisher's Exact test was used for the p-value since at least one of the cells in the 2x2 table was less than five.

Table J-18 Overall MAIS score for occupants involved in an MVC and head injury severity

MAIS OVERALL	Total (n=58)	No or Minor Head Injury (n=47)	Severe Head Injury (n=11)
0	16 (28%)	16 (34%)	0
1	19 (33%)	18 (38%)	1 (9%)
2	8 (14%)	8 (17%)	0
3	5 (8%)	3 (7%)	2 (18%)
4	4 (7%)	2 (4%)	2 (18%)
5	5 (8%)	0	5 (46%)
6	1 (2%)	0	1 (9%)
Nagelkerke R^2= 0.244			
p= 0.003			
exp(B)= 1.524			
95% CI= 1.15-2.01			

Table J-18 shows relationship of the overall MAIS of the occupant to head injury severity. Data were available for 58 occupants. A univariate linear regression was performed to ascertain the effects of Overall-MAIS value on the likelihood of severe head injury Overall-MAIS of the occupant showed a higher odds of involvement in severe head injury cases (OR=1.524, 95% CI= 1.15 to 2.01, p=0.003).

The regression was statistically significant (p=0.003) for the relationship between collision configuration and severe head injury. The model explained 24.4% of the variance in the head injury.

Table J-19 MAIS of the face for occupants involved in an MVC and head injury severity

MAIS-FACE	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
0	35 (57%)	27 (53%)	8 (73%)
1	22 (35%)	20 (39%)	2 (18%)
2	4 (6%)	4 (8%)	0
3	1 (2%)	0	1 (9%)
Nagelkerke R^2= 0.005			
p= 0.646			
exp(B)= 0.801 [0.199]			
95% CI= 0.31-2.06			

Table J-19 shows maximum injury score to the face with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of injury to the face on the likelihood of severe head injury. Facial injury showed a lower odds of involvement in severe head injury cases (OR=0.199, 95% CI= 0.31 to 2.06, p=0.646). The regression was not statistically significant (p=0.65) for the relationship between facial injury and severe head injury. The model explained 0.5% of the variance in the head injury.

Table J-20 MAIS of the neck for occupants involved in an MVC and head injury severity

MAIS	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
0	59 (95%)	48 (94%)	11 (100%)
1	3 (5%)	3 (6%)	0
Nagelkerke R^2= 0.035			
p= 0.999			
exp(B)= 0			
95% CI= 0			

Table J-20 shows relationship between maximum injury score to the neck with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of neck injury on the likelihood of severe head injury. Neck injury showed indeterminates odds of involvement in severe head injury cases (OR=0, 95% CI= 0, p=0.999). The regression was not statistically significant (p=0.999) for the relationship between MAIS for the neck and severe head injury. The model explained 3.5% of the variance in the head injury. The observed MAIS 1 injuries of the neck were described in three cases as skin abrasions.

Table J-21 MAIS of the thorax for occupants involved in an MVC and head injury severity

MAIS	Total (n=61)	No or Minor Head Injury (n=50)	Severe Head Injury (n=11)
0	51 (83%)	46 (92%)	5 (46%)
1	3 (5%)	3 (6%)	0
2	0	0	0
3	4 (7%)	1 (2%)	3 (27%)
4	3 (5%)	0	3 (27%)
Nagelkerke R^2= 0.262			
p= 0.003			
exp(B)= 2.009			
95% CI= 1.28-3.16			

Table J-21 shows maximum injury score to the thorax with relation to head injury severity. Data were available for 61 occupants. A univariate linear regression was performed to ascertain the effects thoracic injury on the likelihood of severe head injury. Thorax injury showed an increased odds of involvement in severe head injury cases (OR=2.009, 95% CI= 1.28 to 3.16, p=0.003). The regression was statistically significant (p=0.003) for the relationship between collision configuration and severe head injury. The model explained 26.2% of the variance in the head injury. The more severe thoracic injuries resulted from contacting extra-CRS structures such as the interior walls of the vehicle, the floor, seat/back support, and the exterior of another vehicle. When contacting the CRS, occupants tended to have lower severity injuries to their thoracic region.

Table J-22 MAIS for the abdomen for occupants involved in an MVC and head injury severity

MAIS	Total (n=61)	No or Minor Head Injury (n=50)	Severe Head Injury (n=11)
0	50 (82%)	43 (86%)	7 (64%)
1	4 (7%)	4 (8%)	0
2	3 (4%)	1 (2%)	2 (18%)
3	4 (7%)	2 (4%)	2 (18%)
Nagelkerke R^2= 0.024			
p= 0.314			
exp(B)= 1.259			
95% CI= 0.81-1.97			

Table J-22 shows maximum injury score to the abdomen with relation to head injury severity. Data were available for 61 occupants. A univariate linear regression was performed to ascertain the effects of abdominal injury on the likelihood of severe head injury. Abdominal injury showed a higher odds of involvement in severe head injury cases (OR=1.259, 95% CI= 0.81 to 1.97, p=0.314). The regression was not statistically significant (p=0.31) for the relationship between abdominal injury and severe head injury. The model explained 2.4% of the variance in the head injury. The abdominal injuries sustained in this study for occupants with severe head injuries were from contacting the right-side armrest or hardware, webbing/buckle belt restraint, and left side interior surfaces.

Table J-23 MAIS of the spine for occupants involved in an MVC and head injury severity

MAIS	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
0	57 (92%)	51 (100%)	6 (55%)
1	1 (2%)	0	1 (9%)
2	4 (6%)	0	4 (36%)
Nagelkerke R^2= 0.382			
p= 0.999			
exp(B)= 770524608.2			
95% CI= 0			

Table J-23 shows maximum injury score to the spine with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects spinal injury on the likelihood of severe head injury. Spinal injury showed a higher odds of involvement in severe head injury cases (OR=770524608.2, 95% CI= 0, p=0.999). The regression was not statistically significant (p=0.999) for the relationship between spinal injury and severe head injury. The model explained 38.2% of the variance in the head injury. The spinal injuries sustained by occupants with severe head injuries were: strains; fractures without cord contusions or lacerations; dislocations without fractures, cord contusions or lacerations.

Table J-24 MAIS of the upper extremities for occupants involved in an MVC and head injury severity

MAIS	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
0	50 (81%)	41 (80%)	9 (82%)
1	7 (11%)	6 (12%)	1 (9%)
2	5 (8%)	4 (8%)	1 (9%)
Nagelkerke R^2= 0.014			
p= 0.442			
exp(B)= 1.438			
95% CI= 0.57-3.62			

Table J-24 shows maximum injury score to the upper extremities with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of upper extremity injury on the likelihood of severe head injury. Upper extremity injury showed a higher odds of involvement in severe head injury cases (OR=1.438, 95% CI= 0.57 to 3.62, p=0.442). The regression was not statistically significant (p=0.44) for the relationship between upper extremity injury and severe head injury. The model explained 1.4% of the variance in the head injury. The upper extremity injuries sustained in this study were to the humerus and clavicle. These injuries came from contacting the left interior surface of the vehicle and buckle belt restraint/webbing, respectively.

Table J-25 MAIS of the lower extremities for occupants involved in an MVC and head injury severity

MAIS	Total (n=62)	No or Minor Head Injury (n=51)	Severe Head Injury (n=11)
0	45 (72%)	43 (84%)	2 (18%)
1	8 (13%)	2 (4%)	6 (55%)
2	7 (11%)	5 (10%)	2 (18%)
3	1 (2%)	0	1 (9%)
4	1 (2%)	1 (2%)	0
Nagelkerke R^2= 0.183			
p= 0.008			
exp(B)= 2.475			
95% CI= 1.26-4.85			

Table J-25 shows maximum injury score to the lower extremities with relation to head injury severity. Data were available for 62 occupants. A univariate linear regression was performed to ascertain the effects of lower extremity injury on the likelihood of severe head injury. Lower extremity injury showed a higher odds of involvement in severe head injury cases (OR=2.475, 95% CI= 1.26 to 4.85, p=0.008). The regression was statistically significant (p=0.008) for the relationship between lower extremity injury and severe head injury. The model explained 18.3% of the variance in the head injury. Lower extremities included the pelvic region. The injuries sustained to the lower extremities were: hip contusion; femur fracture; pelvis fracture with/without dislocation of any or one combination acetabulum, ilium, ischium, coccyx, sacrum, pubis and/or pubic ramus; tibia fracture; fibula fracture; skin abrasions and contusions. These injuries were due to contacting: webbing/ buckle belt restraint; seat, back support; sight side interior surface; child safety seat.

K.Intrusion Injury Pattern

Table K-1 shows the injury patterns for occupants with severe head injuries with respect to intrusion. The most common regions to be injured when an MVC involved intrusion into the vehicle compartment were the head, thorax, abdomen, and upper and lower extremities.

Table K-1 Injury patterns with respect to occupant compartment intrusion in an MVC.

(n= number of total occupants in that category, % of occupants sustaining an injury in the particular body region)

INTRUSION	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS - THORAX	MAIS - ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
YES n= 9 (%)	9 (100)	1 (11.1)	0	3 (33.3)	3 (33.3)	1 (11.1)	3 (33.3)	6 (66.7)
NO n= 4 (%)	4 (100)	3 (75)	0	2 (50)	0	2 (50)	1 (25)	2 (50)

L. CRS Type Injury Patterns

The patterns of injury to each body region for the different CRS types observed in this study can be found in Table L-1.

Table L-1 Child Restraint System Type used by occupant in MVC and resulting injury patterns.

(n= number of occupants using the type of restraint, % of occupants with an injury to the body region)

CRS Type	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS - THORAX	MAIS-ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
INFANT CARRIER n=6 (%)	3 (50)	2 (33.3)	1 (16.7)	1 (16.7)	1 (16.7)	0	1 (16.7)	2 (33.3)
INFANT CARRIER/ CHILD SEAT n=6 (%)	2 (33.3)	1 (16.7)	0	1 (16.7)	1 (16.7)	1 (16.7)	1 (16.7)	1 (16.7)
CHILD SEAT/ BOOSTER SEAT n= 4 (%)	1 (25)	0	0	0	0	0	1 (25)	1 (25)
BOOSTER SEAT n=19 (%)	5 (26.3)	9 (47.4)	0	2 (10.5)	2 (10.5)	1 (5.3)	3 (15.8)	3 (15.8)
INFANT CARRIER/ CHILD	2 (18.2)	6 (54.5)	2 (18.2)	2 (18.2)	2 (18.2)	0	3 (27.3)	2 (18.2)

SEAT/ BOOSTER SEAT n=11 (%)								

The most common injured body regions when an infant carrier CRS was used were the head, face, and lower extremities. The body region most injured for children while using a combination seat of an infant carrier and child seat was the head. For child and booster seat combination seats, the most frequently injured regions were the head and the upper and lower extremities. Booster seats, which had the largest number of users in this study, had the head, face, and upper and lower extremities as the most frequently injured regions. However, for the infant, child, and booster seat combination seat, the most frequently injured body regions were the face and the upper extremities, with injuries also occurring in almost all other body regions. The average MAIS value for each body region and type of CRS used can be found in Table L-2.

Table L-2 Average MAIS value for injuries to the eight body regions sustained during an MVC based on CRS type used, including the occupants that sustained no injury to the region.

CRS Type	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS -THORAX	MAIS-ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
INFANT CARRIER	2.5	0.3	0.2	0.5	0.3	0	0.3	0.5
INFANT CARRIER/ CHILD SEAT	1.8	0.2	0	0.7	0.5	0.3	0.2	0.2
CHILD SEAT/ BOOSTER SEAT	1.8	0	0	0	0	0	0.3	0.3

BOOSTER SEAT	0.7	0.5	0	0.6	0.5	0.1	0.2	0.2
INFANT CARRIER/ CHILD SEAT/ BOOSTER SEAT	0.8	0.6	0.2	0.2	0.3	0	0.3	0.5

M. Seasonal Injury Patterns

The observed seasonal injury patterns from this study can be found in Table M-1. The most common seasons for collisions to occur were the summer and fall. The summer and fall MVCs included injuries to 41 occupants. The children in the summer MVCs had injuries of the head, face, thorax, and lower extremities most frequently. The summer cases also had less frequent injuries to the other body regions (neck, abdomen, spine, and upper extremities). The children in the fall MVCs had injuries most frequently of the head, face, thorax, abdomen, and upper and lower extremities.

Table M-1 Season of MVC and resulting injury patterns.

(n= number of occupants involved in a collision during that season, % of occupants with an injury to the body region)

SEASON	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS - THORAX	MAIS - ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
SPRING n=10 (%)	2 (20)	5 (50)	1 (10)	1 (10)	2 (20)	1 (10)	3 (30)	1 (10)
SUMMER n= 21 (%)	6 (28.6)	9 (42.9)	2 (9.5)	4 (19)	3 (14.3)	1 (4.8)	1 (4.8)	5 (23.8)
FALL n=20 (%)	5 (25)	7 (35)	0	4 (20)	3 (15)	1 (5)	5 (25)	6 (30)
WINTER n=13 (%)	5 (38.5)	7 (53.8)	0	2 (15.4)	3 (23.1)	1 (7.7)	3 (23.1)	4 (30.8)

The average MAIS value severity for each body region during each season can be found in Table M-2. When head injuries are excluded, the summer cases tended to have higher AIS values for injuries of the thorax and abdomen; the fall cases had higher AIS values for the face and upper extremities, and those children injured in the winter, tended to have more severe face, thorax, abdomen, and upper and lower extremity injuries. The highest average MAIS-Head injuries happened in winter.

Table M-2 Average MAIS value for seasonal injuries to the eight body regions sustained during an MVC, including the occupants that sustained no injury to the region.

SEASON	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS -THORAX	MAIS -ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
SPRING	0.7	0.6	0.1	0.4	0.3	0.2	0.3	0.1
SUMMER	1.1	0.5	0.1	0.6	0.6	0.1	0.1	0.4
FALL	1.1	0.6	0	0.5	0.2	0.1	0.4	0.5
WINTER	1.6	0.5	0	0.5	0.5	0.2	0.4	0.8

N.Improper Use and Installation of CRS Injury Patterns

Table N-1 shows the injury patterns for occupants involved in MVCs with improper installation of a CRS. There were more frequent injuries of the head and face than any other body region when restraints were installed incorrectly; however, when there were no installation errors, injuries involving the head, face, and thorax were the most frequent.

Table N-1 Improper installation of restraints on occupant injury patterns.

(n= the number of total occupants in that category, % is occupants sustaining an injury in the particular body region)

IMPROPER INSTALLATION	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS - THORAX	MAIS - ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
YES n=7 (%)	2 (28.6)	2 (28.6)	0	0	1 (14.3)	0	0	1 (14.3)
NO n=33 (%)	5 (15.2)	11 (33.3)	2 (6.1)	5 (15.2)	4 (12.1)	2 (6.1)	4 (12.1)	4 (12.1)

Table N-2 shows the injury patterns for occupants involved in MVCs with restraint misuse. There were more frequent injuries of the head, face and abdomen when a restraint system was misused. When the restraint system used properly, then there tended to be more injuries of the face, head, and upper extremities.

Table N-2 Improper restraint use on occupant injury patterns.

(n= the number of total occupants in that category, % is occupants sustaining an injury in the particular body region)

IMPROPER USE	MAIS-HEAD	MAIS-FACE	MAIS-NECK	MAIS - THORAX	MAIS - ABDO-MEN	MAIS-SPINE	MAIS-UPPER EXTREM-ITIES	MAIS-LOWER EXTREM-ITIES
YES n=11 (%)	2 (18.2)	3 (27.3)	0	1 (9.1)	3 (27.3)	0	0	2 (18.2)
NO n= 28 (%)	4 (14.3)	8 (28.6)	2 (7.1)	3 (10.7)	2 (7.1)	1 (3.6)	4 (14.3)	1 (3.6)

O.Probable Injury Contact Points

In this study, there were 13 occupants that sustained MAIS 2+ head injuries. For many of the analyses conducted, not all 13 occupants had complete information.

Table O-1 Contact points for head, thorax, and lower extremity injuries for occupants with MAIS 2+ head injuries.

<table>
<tr><th>PAED Number</th><th>Transport Canada Case Number</th><th>Occupant Number</th><th>Region (AIS)</th><th>Probable Contact Point</th></tr>
<tr><td rowspan="3">PAED-001</td><td rowspan="3">ROP31608</td><td rowspan="3">230</td><td>Head (3)</td><td>Interior-seat, back support</td></tr>
<tr><td>Thorax (3)</td><td>Floor- floor or console mount, shifter</td></tr>
<tr><td>Lower Extremities (1)</td><td>Interior- webbing/buckle belt restraint</td></tr>
<tr><td rowspan="2">PAED-057</td><td rowspan="2">ROP31604</td><td rowspan="2">210</td><td>Head (4, 1)</td><td>Interior- seat, back support</td></tr>
<tr><td>Lower Extremities (3)</td><td>Interior- seat, back support</td></tr>
<tr><td rowspan="2">PAED-075</td><td rowspan="2">PROS1610</td><td rowspan="2">230</td><td>Head (3, 2, 1)</td><td>Left side- interior surface</td></tr>
<tr><td>Lower Extremities (1)</td><td>Interior- webbing/ buckle belt restraint</td></tr>
<tr><td rowspan="8">PAED-087</td><td rowspan="8">ASF71611</td><td rowspan="5">220</td><td>Head (5)</td><td>Other front of vehicle- exterior/other vehicle</td></tr>
<tr><td>Head (4, 1)</td><td>Right side- interior surface</td></tr>
<tr><td>Head (3)</td><td>Ground- other exterior</td></tr>
<tr><td>Thorax (4)</td><td>Right side- interior surface</td></tr>
<tr><td>Lower Extremities (2)</td><td>Right side- interior surface</td></tr>
<tr><td rowspan="3">230</td><td>Head (5,4)</td><td>Other front of vehicle- exterior/other vehicle</td></tr>
<tr><td>Head (3)</td><td>Right side- interior surface</td></tr>
<tr><td>Thorax (3)</td><td>Other front of vehicle- exterior/other vehicle</td></tr>
</table>

			Lower Extremities (2)	Right side- interior surface
PAED-105	SID71629	230	Head (5,4,3,2)	Right side- frame or side window glass
			Thorax (4)	Right side- interior surface
			Lower Extremities (1)	Interior- child safety seat
PAED-113	ROP31613	210	Head (5,3)	Interior- seat, back support
			Thorax (4,3)	Interior-seat, back support
			Thorax (1)	Interior- child safety seat
PAED-116	ASF61604	290	Head (4,3)	Left side- interior surface
			Lower Extremities (2)	Left side- interior
PAED-149	ASF71616	210	Head (6)	Front bumper- exterior/other vehicle
PAED-118	ASF61632	230	Head (5,4,3,2,1)	Interior- interior loose objects
PAED-011	ROP31616	210	Head (3,2,1)	Left side- interior surface
			Thorax (3,1)	Interior- child safety seat
			Lower Extremities (1)	Interior- child safety seat
PAED-182	SID71648	310	Head (3)	Interior- child safety seat
PAED-193	PROS1617	210	Head (2)	Interior- seat, back support

Curriculum Vitae

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May 10, 2018	London Health Research Day, London, Canada- Real World Motor Vehicle Collision Head Injury Risk and Car Seat Use for Children under 8 Years Old. (Abstract and Poster)
April 13, 2018	Annual Pathology Research Day, London, Canada- Real World Motor Vehicle Collision Head Injury Risk and Car Seat Use for Children under 8 Years Old. (Abstract and Poster)
March 16, 2018	Western Research Forum, London, Canada- Head injury risk and car seat use for children in collisions. (Abstract and Poster)
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March 30, 2017	Annual Pathology Research Day, London, Canada- The Relation of Injury Severity for Child Occupants under the Age of Six and the Time of Day of Motor Vehicle Collisions. (Abstract and Poster)
April 17, 2015	Schroeder P. Measuring Risk in Peterborough. Trent University Undergraduate Community-Based Thesis. 2015.
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