POPULATING AN INDICATOR OF SERIOUS PAEDIATRIC FALL INJURIES ACROSS AGE AND PUBLIC HEALTH UNITS IN ONTARIO

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A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

GRADUATE PROGRAM IN KINESIOLOGY AND HEALTH SCIENCE

YORK UNIVERSITY

TORONTO, ONTARIO

AUGUST 2022

ABSTRACT

Fall injuries among children and youth represent a significant burden to public health. Currently there is no indicator assessing serious fall injuries in children. The purpose of this study was to populate an indicator of serious fall injuries within the paediatric population (0-19 years) using existing ICD-10 coded hospitalization data. The Discharge Abstract Database was used to examine all fall-related hospitalizations in Ontario from 2010-2019. Rates per 100,000 population and rate ratios were calculated for all fall-related and serious fall injuries; serious falls accounted for 3,652 hospitalizations. The highest rates for all fall-related and serious fall injuries were reported in rural health units. The mechanisms of serious fall injuries were highest among males 10-14 and 15-19 from skis, blades, skates, and boards, whereas rates were highest among females 0-4 from stairs and 5-9 from playgrounds. This indicator can be used to prompt action to reduce serious fall injuries in children.

ACKNOWLEDGEMENTS

I would like to extend a sincere thank you to my wonderful supervisor Dr. Alison Macpherson for believing in me and providing me with the opportunity to become your graduate student. Your patience, guidance, and support has made my journey as a graduate student a truly pleasant, memorable, and learning-enriched experience. You have taught me how to think like a true academic researcher and epidemiologist and that it is fine to make mistakes as long as you are able to learn from them. I will continue to take on your expert teachings and knowledge for my future studies and endeavors. Thank you for everything. I am so grateful for having you as my mentor.

Secondly, I would like to thank you Dr. Sarah Richmond. Your expert guidance, knowledge, and teachings throughout the duration of my Masters has shaped me into a better researcher and academic writer. Thank you for working with me on my research and thesis for the past 2 years.

Thirdly, I would like to thank you Justin Thielman for all his hard work on providing me with my data. I appreciate the wonderful job you did on coding the data and ensuring I received all the information I needed for the analysis of my data.

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CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

The Burden of Injury in Children

Injury is a significant public health issue in Canada as it is the leading cause of death for Canadians aged 1 to 44 years (Morrongiello, 2015). Injury is defined as the physical damage sustained by the human body as a result of being suddenly or briefly exposed to excessive and intolerable amounts of energy (Jiang & Pike, 2015). The injury can be a bodily lesion due to acute energy exposure in levels above the physiological threshold, or it may be a functional deficit of vital elements, such as oxygen (Jullien, 2021; Jiang & Pike, 2015). The energy causing the injury can be mechanical energy such as falls, motor vehicle crashes; thermal energy, such as burns; chemical energy involving poisoning or a corrosive agent; and radiant energy, such as radioactive material or sunlight (Jullien, 2021; Jiang & Pike, 2015). Injuries can be further classified as unintentional or intentional (Yao et al., 2020). Unintentional injuries involve injuries that occur with no purpose or intention of harm, such as falls, motor vehicle crashes, drowning and burns (Yao et al., 2020). Intentional injuries result when there is a deliberate act of harm to oneself or another individual, such as violence or suicide (Yao et al., 2020). The leading causes of death from unintentional injuries in Canada are falls, poisoning, and motor vehicle traffic crashes (Yao et al., 2019).

The leading cause of death for children and youth over the age of one year in Canada is injuries (Fridman et al., 2018). Although, vaccines and immunization programs have significantly reduced the incidence of infectious diseases in children, unintentional injuries still remain a major public health concern (Sleet, 2018). According to a study by Yao et al. (2020), in the year 2018-2019, unintentional injuries were the eighth leading cause of hospitalization among Canadians of all ages (Statistics Canada, 2021). For the same time period, unintentional injuries were the second leading cause of hospitalizations for Canadian children aged 1 to 9 years (Statistics Canada, 2021). Furthermore, according to Parachute Canada (2021), unintentional injuries accounted for 12,796 hospitalizations and 806,705 emergency department visits for children 0-14 years and 4,944 hospitalizations and 365, 252 emergency department

visits for children aged 15-19 years. Unintentional injuries are responsible and comprise the majority of the economic burden in Canada (Jiang & Pike, 2015). Unintentional injuries accounted for 86% of total injury costs in Canada at $25.3 billion. (Parachute, 2021). In 2018, the total cost of hospitalizations for unintentional injuries accounted for 5,960 million dollars and 10,204 million dollars for emergency department visits (Parachute, 2021). The potential years of life lost (PYLL) for Canadians as a result of unintentional injuries was 547 per 100,000 population in 2018 (Parachute, 2021).

Variability of Unintentional Injury by Age in Children

While unintentional injuries can affect individuals of all ages, children tend to be highly susceptible as a result of their bodies rapidly undergoing developmental changes compared to adults (Jiang & Pike, 2015; Gong et al., 2021). Among children and adolescents, the mechanisms of unintentional injuries differ by age as a result of factors, such as the child's development and exposure to hazards (Ishikawa & Brussoni, 2015). Ishikawa and Brussoni (2015), found that falls were the most common cause of injury sustained by children and youth across all age groups. In particular, it was stated that falls occur most frequently for children during the first year of life and between the ages 5 and 9 years (Ishikawa & Brussoni, 2015). Gong et al. (2021) observed that as children become older, the prevalence of fall injury decreases from 85.8% for children ages 0-1 years to 49.7% among children 12-18 years of age. Injuries, such as burns and inhalation injuries are a common cause of hospitalization among infants and toddlers, but are less frequent among older children (Ishikawa & Brussoni, 2015). Dellinger & Gilchrist (2019), reported that unintentional injury from suffocation resulted in 85.4% of deaths in infants, and dropped to 16.8% by age 1 year. Poisoning is most prevalent among children ages 1 to 4 years of age as their physical capabilities often exceeds their ability to perceive and judge danger (Ishikawa & Brussoni, 2015). However, Dellinger & Gilchrist (2019) found that injury from poisoning accounted 16% of deaths among adolescents 18 and 19 years of age. Gong et al. (2021), found that the leading cause of unintentional injuries among adolescents 12-18 years was transport. A study by Dellinger & Gilchrist (2019), supported this when they found transport-related injuries accounting for

70% of all unintentional injury deaths among adolescents 15-19 years of age, they discovered that transport-related injuries gradually increase as children become older. In the literature, it is apparent that children and youth of varying age groups are at risk for injuries.

Variability of Unintentional Injury by Sex in Children

Studies have showed that unintentional injury rates are higher among males compared to females (Gong et al., 2021). This may be attributable to factors, such as a difference in the patterns of behaviors and increasing levels of activity between males and females (Gong et al., 2021). In Canada, the mortality rate for unintentional injuries is slightly higher for males when comparing to females during infancy and early childhood (Pitrowski & Cameranesi, 2015). Yao et al. (2019), supported this when they reported that males had a higher unintentional injury death rate compared to females. Pitrowski & Cameranesi (2015), found that the mortality rate is higher in males than females during middle childhood, specifically 5-9 years of age. Furthermore, males tend to be hospitalized more frequently due to unintentional injuries than females for the age group 5-9 years (Pitrowski & Cameranesi, 2015). During adolescence, males aged 12 to 19 years have higher hospitalization rates for injury compared to females (Pitrowski & Cameranesi, 2015). Bhuvaneswari et al. (2018) found in their study that females experienced more injuries compared to males. In another study, Yao et al. (2020) found that females were more likely to be hospitalized for unintentional fall injuries than males, whereas among males, hospitalizations due to unintentional suffocation, motor vehicle traffic crashes, poisoning, and being struck by an object were higher. Unintentional injuries are more commonly reported among males than females in the majority of existing literature.

Fall Injuries in the Pediatric Population

An understanding of the external cause of injury and its mechanisms is essential for injury prevention (Yao et al., 2020). A notable theme in injury control and prevention is which injuries do we want to prevent? (Johnston & Ebel, 2013). Although sustaining injuries is part of the normal active childhood experience, in many instances, some of these injuries can result in severe outcomes (Parachute, 2017; Johnston & Ebel, 2013). One such injury mechanism that is a leading cause of morbidity during

childhood and a common cause of paediatric hospitalization and emergency department use is falls (Parachute, 2021; Johnston & Ebel, 2013). Falls are the leading cause of unintentional injuries requiring medical attention for Canadian children and youth ages <1 to 19 years (Hyndman, 2019; Gill & Kelly, 2021). Falling is considered a normal aspect of a child's development as they learn to walk, jump, climb, and explore the physical environment around them (Parachute, 2021). Children are particularly susceptible to fall-related injuries due to their innate curiosity to explore and experiment, evolving developmental stages, and increasing levels of mobility (World Health Organization, 2021). The majority of falls bear minor consequences, such as slight cuts or bruises (McDonald & Gielen, 2019). Nevertheless, some injuries due to falls extend beyond the resilience of a child's body and the capacity of the contact surface to absorb the transferred energy (Child Safety Link, 2018). For young children, fall injuries are a major concern as they account for the majority of hospitalizations and can result in serious long-term outcomes, such as skull fracture or intracranial injury (Burrows et al., 2015; Araki et al., 2017). Likewise, in young children, the size of their heads is larger and heavier in relation to the rest of the body making it more susceptible to traumatic injury (Araki et al., 2017). In 2018, falls accounted for 5,861 hospitalizations for children ages 0-14 years and 1,139 hospitalizations among children 15-19 years of age in Canada (Parachute., 2021). Specifically, in Ontario for the year 2014-2015, falls accounted for 4,497 hospital visits and 204,101 emergency department visits for children ages 0-14 years (Parachute, 2018). Similarly, for the year 2014-2015, there were 22 deaths, 771 hospital visits, and 44,915 emergency department visits as a result of fall injuries among children 15-19 years of age (Parachute, 2018). The cost of falls in children ages 0-14 years accounted for 996 million dollars (Parachute, 2021). As well, 40% of the total disability-adjusted life years (DALYs) lost as a result of falls occurs in children (World Health Organization, 2021). These statistics elucidate that fall injury is a significant part of the injury burden and should be examined (McDonald & Gielen, 2019).

Mechanisms of Fall Injury

The nature of fall injuries for children varies with the child's developmental level (Morrongiello, 2015). To understand fall injuries in children, it is important to consider the developmental ages at which

they start to roll over, grasp items, crawl, walk, attend school, and engage in sports (Ali et al., 2019). The majority of fall injuries for young children 0-4 years of age occur in the home (Child Safety Link, 2018). For older children, many of the fall injuries occur outside of the home, such as in playgrounds or when involved in sport-related activities (Child Safety Link, 2018). According to Morrongiello (2015), the primary mechanisms of fall injuries for young children that lead to emergency department visits include falls down stairs, furniture, and same-level trips or slips. In a study by Ali et al. (2019) stairs were the leading cause of fall-related injuries for children ages 1 to 19 years. Falls from stairs generally occur as a result of improper foot placement, tripping on objects, distractions, and missing handrails (Ali et al., 2019). During the first few years, the home is the primary setting where infants and toddlers spend the majority of their time (Lodwick, 2017). As a result, a large proportion of fall injuries in infants, toddlers, and preschoolers are associated with furnishings and fixtures within the home (Ali et al., 2019). In particular, falls from beds are a leading contributor to injuries in young children (Lawrence et al., 2015). Falls from car seats and strollers are predominantly experienced by infants less than 1 year of age (Chaudhary et al., 2018). Chaudhary et al. (2018) reported that same level falls resulting in running, slipping, or tripping were higher for older children 1-4 years due to their increasing levels of mobility. Likewise, young children less than 1 year of age were more likely to experience a multi-level fall from a caregiver's arm due to their dependent mobility (Chaudhary et al., 2018). Falls from playgrounds and sport-related activities are other common mechanisms of fall injury, playground equipment, such as monkey bars, swings, and slides are the leading contributors to severe injuries among children 5 to 9 years (Living, 2010; Chaudhary et al., 2018). Among children 10 to 19 years of age, sport and recreational activities, such as basketball and football account for the largest percentage of fall injuries (Ali et al., 2019).

Falls from high-rise buildings and windows can lead to serious injury in children, mainly those residing in apartments. Falling from high-rise residential buildings can result in serious consequences, such as permanent neurological impairment, and can often be fatal. The use of window screens does not

sufficiently serve as a protective barrier against falls as they are unable to withstand the weight of a child when significant force is applied (Living, 2010; Yusuf et al., 2015; Sarkar et al., 2014).

The Severity of Fall Injury

Although falls are mostly predictable and preventable, when they do happen, they can result in serious injuries, such as bone fractures, soft tissue injuries, and head injuries (Wang et al., 2013). This can contribute to physical disability leading to an overall decreased quality of life (Razik et al., 2020). The height of the fall is a significant predictor of severity in paediatric trauma (Zhen et al., 2021). Generally, a height of 10 meters is indicative of a high-risk factor for increased mortality (Zhen et al., 2021). Hence, falls that occur from a high level can cause multiple and severe injuries (Razik et al., 2020). The Canadian Institute for Health Information (2018) reported that the upper extremities were the most common body region injured as a result of a fall (46%) followed by head injuries (25%) and injuries to the lower extremity accounting for 18%. For injuries of the upper and lower extremity, fractures were the most common. For head injuries, the likelihood of children sustaining a skull fracture or intracranial injury is higher when falling from a height in comparison to falling when standing (Burrows et al., 2015). Traumatic brain injury (TBI) is a severe long-term outcome of fall injures and considered a leading cause of disability and death in children (Riemann et al., 2020). The neurological deficits from a TBI can impose a high burden on children, affecting their cognitive, behavioral, and physical development (Riemann et al., 2020).

Fall injury in the paediatric population continues to remain a leading cause of medical morbidity and cost to the healthcare system characterizing a significant burden on public health. Injury prevention programs and efforts focused on preventing serious falls is paramount (Chaudhary et al., 2018; Pathak et al., 2020). Although it is not recommended to curtail children's activity levels to mitigate non-serious injury, it is, however, necessary to prevent the incidence of serious injuries. The challenge that remains unaddressed is how to prevent serious fall injuries without restricting children's exposure to physical activity, and their ability to explore their environment independently (Johnston & Ebel, 2013). While

serious paediatric injuries represent an important burden but are less common than non-serious injuries, they may not be given priority for prevention. Interventions with a population focus can decrease the risk of serious injury but can also worsen inequities (Johnston & Ebel, 2013). Thus, public health unit programs and services should consider approaches that address various levels of disadvantage within the population, rather than only targeting the least disadvantaged groups (Lu & Tyler, 2015). It is essential for public health programming to implement a proportionate universalism approach to effectively address the severity of injury and reduce health inequities for priority populations (Lu & Tyler, 2015).

Injury Indicators

Injury indicators have a significant role in transforming data into relevant information that can be used for informed decision-making and to shed light on inequities and priority areas for public health intervention (Oakey et al., 2021). Injury indicators are effective for providing data on the burden of severe injury and the impact on health services (Pike et al., 2017). Fall prevention can be complex because the mechanisms by which children fall and sustain an injury varies significantly by age (McDonald & Gielen, 2019). Injury indicators are useful in identifying where injury prevention efforts need to be prioritized and tracking trends in serious injury over time necessary for reducing the burden of injury in a population (Pike et al., 2017; Oakey et al., 2021). Furthermore, injury indicators are useful for public health programming as they can prompt action to raise awareness, inform policy, and decision-makers to develop the most effective interventions to reduce serious injury outcomes (MacKay et al., 2010; Ontario Agency for Health Protection and Promotion, 2022).

Rationale and Objectives

Although there is the existence of an indicator for serious paediatic injury, it has not been assessed in children who experience a fall-related injury (Pike et al., 2017). Existing indicators for reporting the severity of injuries in Canada include data such as emergency department visits, hospital admissions, and mortality (Pike et al., 2017). In our unpublished environmental scan report; "Childhood Fall Prevention Indicators for Public Health Practice in Ontario," it was indicated that while these

indicators are crucial to understanding the burden of fall-related injuries in Ontario, they do not however, determine specific mechanisms of childhood falls for public health units to develop effective fall prevention programs (Ontario Agency for Health Protection and Promotion, 2022).

Injury surveillance systems are one approach to collecting data and calling attention to the burden of injury (Pike et al., 2017). However, because surveillance systems can be complex and costly, it is important to develop public health indicators that are accessible to public health units in their prevention efforts (Johnston & Ebel, 2013; Groseclose & Buckeridge, 2017). Over the years, there has been the development of many scoring systems for measuring the severity of injuries and examining their impact on informing prevention efforts for injury prevention research (Bulut et al., 2006). The most widely recognized injury scoring systems include the Injury Severity Score (ISS), the Abbreviated Injury Scale (AIS), as well as the International Classification of Diseases (ICD) (Brown et al., 2017). The ISS is considered the "gold standard" for measuring and rating anatomical severity associated with injury (Brown et al., 2017). Its scores provide a sum of the severity of injury across the three most serious injuries to the individual; however, it takes into account only one injury per body region (Bulut et al., 2006). Due to the physiologic differences in response to injury between children and adults, the ISS can potentially overestimate mortality risk when applied to the paediatric population (Brown et al., 2017). In addition, both the ISS and AIS are based upon individual patient injuries but differ across their diagnoses (Pike et al., 2017). The utilization of various scoring measures can cause a lack of consistency in defining indicators for the severity of injuries as well as limit the evaluation of trends over time (Pike et al., 2017). Most of the injury severity scoring systems have been developed primarily for the adult population (Pike et al., 2017). Children's physiological and anatomical structures are unique and differ in comparison to adults in their injury patterns (Pike et al., 2017). Likewise, children's airway anatomy, response to blood loss, cardiorespiratory variables, and equipment necessary for their treatment vary considerably (Pike et al., 2017).

Due to the paucity of information concerning serious paediatric fall injuries, there is a need for an indicator to measure the population-based burden of fall injuries and to distinguish those that are serious for public health units to prioritize their prevention efforts.

The purpose of this study was to populate an indicator of serious fall injuries within the paediatric population (0-19 years) using existing ICD-10 coded hospitalization data. The primary aims of this study were to examine the rate of serious injury within all fall injuries, to observe whether it varies across age groups and public health units, as well as, what mechanisms are related to serious fall injury.

CHAPTER 2: MANUSCRIPT

ABSTRACT

Background

Falls are the leading cause of injury hospitalizations for Canadian children ages 0-19 years. Despite the medical morbidity and financial burden, it is not recommended to curtail children's activity levels to mitigate non-serious injury, but necessary to prevent the incidence of serious injuries. An indicator of serious paediatric injury exists, but it has not been assessed in children who experience a fall-related injury. The objective of this study was to populate an indicator of serious fall injuries within the paediatric population aged 0-19 years utilizing existing ICD-10 coded hospitalization data.

Methods

The Discharge Abstract Database (DAD) was used to examine all fall-related hospitalizations in Ontario among children and youth (0-19 years), for the year 2010 to 2019. The International Classification of Diseases (ICD-10) diagnostic codes was used to define serious paediatric fall injury. A rate per 100,000 population was calculated for serious fall injuries for the different mechanisms of falls among males and females. This was done by taking the number of serious injury-related hospitalizations due to falls for children and youth (0-19 years) for the years 2010 to 2019 divided by the total child and youth population for each of the age groups in Ontario ×100,000.

Results

Falls accounted for 26, 345 hospitalizations and 3,652 serious hospitalizations among children and youth (0-19 years) during the study period. The rates associated with skis, blades, skates, and boards were highest among male children ages 10-14 (38.24 per 100,000) and 15-19 (67.19 per 100,000). Among females, serious fall injuries from stairs for the ages 0-4 years (18.23 per 100,000) and playgrounds for the ages 5-9 years (13.83 per 100,000) accounted for the highest rates. Falls inside the home, including stairs and furniture were the most common mechanism of serious injury for both males and females 0-4 years. Outside of the home, the most common mechanism of serious fall injury was in playgrounds for

both males and females ages 5-9 years. Overall, males reported higher rates of serious fall injuries compared to females.

Conclusion

The indicator populated in this study identifies important variability in serious falls by mechanism, age, and sex among children and youth (0-19 years). A serious fall-injury indicator can be used to prioritize prevention efforts and prompt action to reduce the burden and severity of fall injuries in the paediatric population.

BACKGROUND

Injuries are responsible for the majority of deaths among children and youth over the age of 1 in Canada (Fridman et al., 2018). Falls are the leading cause of unintentional injury hospitalizations among children and youth ages <1 to 19 years (Fridman et al., 2018; Hyndman, 2019; Gill & Kelly, 2021). The World Health Organization defines falls as 'an event that results in a person coming to rest inadvertently on the ground or floor or other lower level' (World Health Organization, 2021). Children experience fall injuries frequently as they enter into their developmental stages of crawling, grasping, walking, climbing, and learning to explore and master their environment (Parachute, 2021; McDonald & Gielen, 2019). Children's growing curiosity and increasing levels of independence renders them susceptible to fall injuries (World Health Organization, 2021). While falls are considered a natural part of childhood and are often not serious, some fall injuries can result in serious outcomes, such as disability or death (Jullien, 2021). In 2018, there were approximately 4,500 Canadian children from the ages 0-14 years hospitalized as a result of a fall injury (Parachute, 2021). In the literature, fall injuries are consistently recognized as an important contributing factor to the overall injury burden among children and youth (McDonald & Gielen, 2019).

Fall injuries among children have been examined by previous research (Haarbauer-Krupa et al., 2019). Recent studies identify the home as the primary location for the occurrence of paediatric fall injuries (59.5%) (Bhuvaneswari et al., 2018; McDonald & Gielen, 2019). Common mechanisms of fall injury in the home are related to furniture, stairs, beds, and windows for children 0-14 years (Bhuvaneswari et al., 2018; Gaw et al., 2017). Falls from playgrounds and sports have also been identified as other common mechanisms of fall injury among children and youth aged 5-9 and 10-19 years (Chaudhary et al., 2018; Living, 2010). In one study, it was reported that for children ages 1-9 years, paediatric fall-related injuries accounted for 73% of injuries (Haarbauer-Krupa et al., 2019). This study also reported that paediatric fall-related injuries in infants accounts for only 8%, however, infants have a higher likelihood of sustaining severe injuries (Haarbauer-Krupa et al., 2019). Likewise, young children, particularly 4 years and younger are at an increased risk of sustaining head injuries, being hospitalized, or

dying from falls in comparison to older children (Haarbauer-Krupa et al., 2019). Furthermore, a study by Pomerantz et al. (2012) reported that the rate for children being hospitalized as a result of falls from furniture is twice as high compared to stairs, however, falling from stairs is more likely to result in head injuries for children. Fall injuries in children can lead to long-term serious consequences, such as traumatic brain injury, spinal cord injuries, or skeletal fractures that require advanced surgical care (James et al., 2020). There is no national policy that necessitate window safety mechanisms to be installed in homes, even though window safety devices, such as locks and bars, and stair gates have shown to be effective in preventing fall injuries among the pediatric population (Fridman et al., 2018). There is the existence of prevention policies to reduce fall-related injuries in children, however they have not been widely implemented (McDonald & Gielen, 2019).

Despite the high burden of falls, serious injuries due to falls is considered a low priority for prevention as they occur less frequently than non-serious injuries (Pathak et al., 2020). Injury prevention research is challenged to not just describe the burden of fall injury, but instead translate the findings into effective strategies to reduce paediatric injuries (Rothman et al., 2019). As children grow older and their perceptual and cognitive abilities start to develop, they will engage in activities, such as sports or play that increases their susceptibility to fall injuries. It is not recommended to eliminate all fall-related injuries and not desirable developmentally to impose restrictions on children's activity levels to mitigate non-serious injury. It is necessary; however, to identify and prevent those fall injuries that result in more serious outcomes (Sleet, 2018; Dellinger & Gilchrist, 2019). The rate of severe injury-related hospitalizations is an important indicator and critical for understanding the burden of severe injury (Pike et al., 2017; Yao et al., 2020). Injury indicators are useful for providing insight into the burden of serious injuries and to identify priority strategies. Although an indicator of serious paediatic injury exists in the scientific literature, it has not been applied to children who experience a fall-related injury (Pike et al., 2017). There is a paucity of data examining serious paediatric fall injuries. The purpose of this study was to populate an indicator of serious fall injuries within the paediatric population aged 0-19 years utilizing existing ICD-10

coded hospitalization data. The primary aims of this study were to examine the proportion of serious injuries among children hospitalized for a fall-related injury and the mechanism of serious injury by age group and sex.

METHODS

We populated an indicator of serious fall injuries within the paediatric population using existing ICD-10 coded hospitalization data from the Discharge Abstract Database (DAD). The DAD is managed by the Canadian Institute for Health Information and includes data on all patients admitted to a hospital in Canada (Canadian Institute for Health Information, 2021). The DAD was deemed most appropriate for the utilization of this study as it captures a comprehensive range of diagnostic codes to define serious paediatric fall injuries. The DAD contains clinical, administrative, and demographic information on hospital discharges from acute inpatient facilities in Canada (Canadian Institute for Health Information, 2021). Using the DAD, all fall-related hospitalizations in Ontario were examined among children and youth (0-19 years), from the year 2010 to 2019. We obtained and analyzed aggregate data on all hospitalized injuries from the DAD and used it to identify serious injuries.

The International Classification of Diseases (ICD-10) includes a range of diagnostic codes used to define an injury. To assess the rate of serious injuries, ICD-10 diagnostic codes identified by Pike et al. (2017) were used to define serious paediatric injury (The full specification for the serious fall injury indicator is outlined in the appendix). Hospitalization for a serious injury was defined as the number of inpatients who have spent at least one night in the hospital following visit and who leave the hospital through discharge following treatment for a severe injury. The number of serious injury-related fall hospitalizations for children and youth aged 0–19 years was stratified by age group (0-4, 5-9, 10-14, 15-19), mechanism of fall, and sex. The total population of children and youth in Ontario was stratified by age group (0-4, 5-9, 10-14, 15-19 years) and sex (male, female). The relevant population of children and youth (0-19 years) in Ontario was retrieved from the 2016 Statistics Canada census of population (Statistics Canada, 2017). To analyze the varying severity and mechanism of the fall over time among the different

age groups and sexes, a rate per 100,000 population was calculated for serious fall injuries for the different mechanisms of falls among males and females. This was done by taking the number of serious injury-related hospitalizations due to falls for children and youth (0-19 years) for the years 2010 to 2019 divided by the total child and youth population for each of the age groups in Ontario ×100,000. Rate ratios were also computed for serious fall injuries by dividing the number of serious fall injuries over the number of all fall-related injuries

RESULTS

Summary of The Number and Rate of Serious & Non-Serious Fall Injury by Age and Sex

In total, there were 26,345 fall-related hospitalizations and 3,652 serious fall hospitalizations in Ontario between 2010 to 2019 among children and youth ages (0-19 years). The main findings for the number and rate of serious and non-serious fall injuries by age and sex is highlighted in Table 1. In general, males had a higher rate of hospitalization for non-serious fall injuries compared to females. Particularly, males in the age groups 5-9 and 10-14 years were hospitalized frequently for a non-serious fall injury. For females, the most common age groups hospitalized for a non-serious fall injury were 0-4 and 5-9 years. For serious fall injuries, males also had a higher rate of hospitalization than female children. Hospitalization for serious fall injuries were common in males ages 10-14 and 15-19 years, as for females, 0-4 and 5-9 year old's were hospitalized frequently for a serious fall injury.

Table 1: Number and Rate Distribution of Serious & Non-Serious Fall Injuries by Age and Sex Among Children and Youth 0-19 Years, Ontario 2010-2019

	Female 0-4	Male 0-4	Female 5-9	Male 5-9	Female 10-14	Male 10-14	Female 15-19	Male 15-19	Total
Number of Non-Serious Injuries	554	564	1736	1842	384	946	229	931	7186
Rate of Non-Serious Injuries	162.91	157.85	470.76	475.58	104.48	244.44	57.98	223.41	1897.41
Number of Serious Injuries	62	68	51	51	39	148	41	280	740
Rate of Serious Injuries	18.23	19.03	13.83	13.17	10.61	38.24	10.38	67.19	190.68

Rate of Serious Fall Injuries by Age and Mechanism Among Males and Females

Table 2 outlines the total rate of serious fall injuries by the different mechanisms of falls among males and females. For falls on the same level and due to collision, males ages 10-14 years had the highest rate (16.54 per 100,000). Females ages 15-19 years had the lowest rate (5.32 per 100,000). Falls from skis, blades, skates, and boards, males 15-19 years had the highest rate (67.19 per 100,000), the lowest rate for this type of fall was reported in females ages 0-4 years (0.00 per 100,000). Falls from furniture accounted for the highest rate of serious injuries for males ages 0-4 years (11.75 per 100,000). The lowest rate for falls from furniture was reported among male children ages 10-14 years (0.00 per 100,000). For serious falls in playgrounds, females ages 5-9 years sustained the highest rate (13.83 per 100,000) and females ages 15-19 years had the lowest rate (3.04 per 100,000). The highest rate of falls from stairs was among males 0-4 years (19.03 per 100,000). Females in the age group 10-14 years had the lowest rate of falls from stairs (1.63 per 100,000).

Falls From ladders/scaffolding and from, out of or through building or structure accounted for the highest rate of serious injury among males 15-19 years (6.96 per 100,000) and the lowest rate for males 10-14 years (0.00 per 100,000). Falls while being carried or supported by other persons and involving

wheelchair and other types of walking devices had the highest rate for males 0-4 years (8.12 per 100,000). Similarly, males ages 10-14 years had the lowest rate (0.00 per 100,000). For falls in the natural environment, the highest rate was in males 15-19 years (4.56 per 100,000) and lowest rate was in males 10-14 years (0.00 per 100,000). Other and unspecified falls accounted for the highest rate in males 15-19 years (13.68 per 100,000), and the lowest rate for males 5-9 years (2.07 per 100,000).

In summary, males reported the highest rate of serious fall injuries from skis, blades, skates, and boards among the age groups 15-19 (67.19 per 100,000) and 10-14 years (38.24 per 100,000), respectively. For females, the highest rate of serious fall injuries was from falls on stairs for children in the age group 0-4 years (18.23 per 100,000) and falls in playgrounds for the ages 5-9 years (13.83 per 100,000). Falls inside the home was the most common mechanism of injury for both males and females in the age group 0-4 years. The highest rate of serious injury inside the home were falls from stairs for males in the age group 0-4 years (19.03 per 100,000) and females in the age group 0-4 years (18.23 per 100,000). This was subsequently followed by falls from furniture for males ages 0-4 years (11.75 per 100,000) and females ages 0-4 years (7.35 per 100,000). Outside of the home, the most common mechanism of serious fall injury for both males and females were in playgrounds. For both males and females, the age group 5-9 years had the highest rate of serious fall injury from playgrounds (13.17 per 100,000) and (13.83 per 100,000). Males in the age groups 10-14 (16.54 per 100,000) and 15-19 (15.60 per 100,000) years had the highest rate of serious injury from falls on the same level and due to collision with, or pushing by, another person. Overall, the rates of serious fall injuries were higher for males compared to females.

Table 2: Rate of Serious Fall Injuries by Mechanism, Sex, and Age Ranked from Highest to Lowest Among Children and Youth 0-19 Years, Ontario 2010-2019

Type of Fall	Sex	Age Group	Rate per 100,000
On the same level and due to collision with, or pushing by, another person	Male	10-14	16.54
	Male	15-19	15.60
	Female	10-14	8.43
	Male	0-4	7.56
	Female	5-9	6.78
	Male	5-9	6.45
	Female	0-4	6.18
	Female	15-19	5.32
From skis, blades, skates, boards	Male	15-19	67.19
	Male	10-14	38.24
	Female	15-19	10.38
	Female	10-14	8.43
	Male	5-9	4.39
	Female	5-9	4.34
	Male	0-4	2.24
	Female	0-4	0.00
From Furniture	Male	0-4	11.75
	Female	0-4	7.35
	Female	5-9	2.44
	Male	5-9	1.81
	Male	15-19	1.68
	Female	10-14	1.36
	Female	15-19	1.27
	Male	10-14	0.00
In Playgrounds	Female	5-9	13.83
	Male	5-9	13.17
	Female	10-14	10.61
	Male	10-14	10.08
	Female	0-4	7.35
	Male	15-19	4.80
	Male	0-4	4.48
	Female	15-19	3.04

Type of Fall	Sex	Age Group	Rate per 100,000
On stairs	Male	0-4	19.03
	Female	0-4	18.23
	Male	5-9	11.62
	Male	15-19	11.04
	Female	15-19	9.12
	Male	10-14	7.75
	Female	5-9	7.32
	Female	10-14	1.63

From ladders/scaffolding and from, out of or through building or structure	Male	15-19	6.96
	Female	0-4	4.41
	Female	15-19	3.80
	Male	0-4	3.64
	Male	5-9	2.84
	Female	5-9	1.90
	Female	10-14	1.63
	Male	10-14	0.00
While being carried or supported by other persons and involving wheelchair and other types of walking devices	Male	0-4	8.12
	Female	0-4	6.47
	Male	5-9	2.32
	Female	5-9	1.90
	Male	15-19	1.68
	Female	10-14	0.00
	Female	15-19	0.00
	Male	10-14	0.00
Falls in the natural environment including from tree, cliff, and diving or jumping into water (injury other than drowning)	Male	15-19	4.56
	Female	15-19	2.79
	Male	5-9	1.29
	Female	0-4	0.00
	Female	5-9	0.00
	Female	10-14	0.00
	Male	0-4	0.00
	Male	10-14	0.00
Other and unspecified falls	Male	15-19	13.68
	Male	10-14	7.49
	Male	0-4	6.16
	Female	10-14	5.17
	Female	5-9	4.88
	Female	15-19	3.80
	Female	0-4	3.23
	Male	5-9	2.07

DISCUSSION

This population-based study is the first to populate an indicator of serious fall injuries within the paediatric population ages 0-19 years. We sought to examine the number of fall injuries that are serious, what mechanisms are related to serious injury, and if it varies across age groups and sexes. The findings

of this study add to the existing literature on falls in children and youth, prioritizing serious injury related to falls in prevention efforts. Our findings; however, indicate variability and differing patterns of injury when observing the rates of serious fall injuries among children and youth. Our study reported the highest rate of serious fall injuries from skis, blades, skates, and boards among children in the age groups 15-19 and 10-14 years. This finding is consistent with a study by Cassell and Clapperton (2014) who found that among older children (10-14 years), falls from skates, skis, rollerskates, and skateboards are the leading mechanism of serious fall injury hospitalizations. Similarly, a study by Unni et al. (2012), reported that for children 10 to 14 years, falls from skateboards were the leading mechanism of injury. Our findings indicated that serious fall injuries from skis, blades, skates, and boards were highest among male children. Likewise, Unni et al. (2012) found that falls from skateboards occurred most frequently among older males.

Furthermore, the current study reveals that falls from playgrounds had the highest rate of serious injury among children in the age group 5-9 years. Our finding is consistent with prior literature in that for children in the age group 5-9 years, falls from playground equipment is the most common mechanism of injury hospitalizations (Ali et al., 2019; Bierbaum et al., 2018; Blanchard et al., 2020; Cassell & Clapperton, 2014; Unni et al., 2014). In these studies, it was documented that children ages 5-9 years most commonly experienced fall injuries from climbing apparatuses, such as monkey bars (Ali et al., 2019; Bierbaum et al., 2018; Unni et al., 2014; Tuckel et al., 2018). Likewise, in the study by Cassell and Clapperton, 2014, it was found that most of the serious fall injury hospitalizations from playgrounds occurred on monkey bars in children aged 5-9 years.

Studies have reported that fall-related injuries involving playground equipment are predominantly associated with fractures of the upper extremities (Bierbaum et al., 2018; Blanchard et al., 2020; Tuckel et al., 2018). This may be explained by young children lacking the dexterity and musculature to safely play on playground equipment that involves climbing of increased height (Migneault et al., 2018). The risk of falling and sustaining injuries to the head and arms is strongly correlated with the height of playground

equipment (Al-Hajj et al., 2020). Studies in Canada have indicated that falls from playground equipment with a height exceeding 1.5 m are twice as likely to result in serious injuries (Macarthur et al., 2000; Laforest et al., 2001; Canadian Public Health Association, 2019). It is recommended that playground structures and equipment should adhere to the CSA standards in order to decrease the incidence of serious injuries (Migneault et al., 2018).

Our novel findings showed that falls from playgrounds were associated with a higher rate of serious injury among females than males ages 5-9 years. Multiple studies have reported that the rate of hospitalization as a result of falls from playgrounds was higher in males compared to females (Bierbaum et al., 2018; Blanchard et al., 2020; Tuckel et al., 2018). Tuckel et al. (2018) examined the incidence of falls from playground equipment, their findings indicated that compared to females, males were more prone to sustain a serious injury, such as fractures of the upper and lower extremities, open wounds of the head or neck, as well as intracranial injury. Morrongiello and McArthur, (2018) examined parental supervision and injuries in young children in their research. In one of the studies, they found that when considering differences in sex, males tend to be less closely supervised compared to females which may account for the higher rate of injury in males (Morrongiello & Rennie, 1998). Previous research has also depicted that risk taking and impulsivity behaviors are higher for males than females as they tend to underestimate the potential dangers when engaging in activities (Morrongiello & Dawber, 1998; Morrongiello et al., 2016). It is suggested that parental supervision is necessary for the safety of young children as they have a limited capacity to assess potential dangers and risks (Morrongiello & McArthur, 2018). There is a lack of consensus; however, between Morrongiello and McArthur and Brussoni. Brussoni's research on child development and play indicates that imposing restrictions on the activities that children engage in can impede their development (Brussoni et al., 2012). In her research, Brussoni does not advocate for parental supervision, rather, suggests that children can learn to avoid unsafe activities and develop their perceptual-motor skills by taking risks in play (Brussoni et al., 2012).

Our study aligns with previous research in younger children where falls in the home was the primary location for injury (Krishnamurthy et al., 2021; Pathak et al., 2020; Ali et al., 2019; Cassell & Clapperton, 2014). Falls from stairs in the home is reported to be a are common mechanism of injury for children across age groups (Lawrence et al., 2015). Our study found that the highest rate of serious fall injury from stairs occurred in children ages 0-4 years. In contrast to our finding, a study by Ali et al. (2019) reported that the leading cause of fall injuries due to stairs were among children in the age groups 10-14 and 15-19 years. Younger children ages 0-4 years are more likely to fall from stairs and sustain a serious injury when safety gates are not used in the home, are left open, or when stairs are not lined with carpeting (Kendrick et al., 2016). The utilization of safety equipment in homes, including guard rails and safety gates are suggested as preventative measures to reduce fall injuries from stairs for younger children (Ali et al., 2019).

Our findings suggest that children ages 0-4 years had the highest rate of serious injury due to falls from furniture. Similarly, previous studies have also reported that the majority of fall injuries for young children ages 0-4 years occurred from furniture (Haarbauer-Krupa et al., 2019; Chaudhary et al., 2018; Ali et al., 2019). A study by Unni et al. (2012) found that falls due to furniture was the leading cause of injury among children ages 1-4 years. Additionally, Haarbauer-Krupa et al. (2019) found that young children ages 1-2 years have a higher rate of falls. This finding is intuitive with young children entering their developmental stages of independent mobility and exploratory behavior to learn new skills (Haarbauer-Krupa et al., 2019; Krishnamurthy et al., 2021). Previous studies have reported that infants have a higher likelihood of sustaining serious injuries, such as traumatic brain injury due to falls from furniture in the home (Haarbauer-Krupa et al., 2019; Kamboj et al., 2017). This finding is likely caused by the exposure of time young children spend at home and due to their increased head size in relation to their overall body size (Lodwick, 2017; Wang et al., 2013). A study by Pomerantz et al. (2012) found that more children were hospitalized as a result of falls from furniture in comparison to stairs. Conversely, our findings revealed that children who fell from stairs had higher rates of serious injury hospitalizations than

those who fell from furniture. Moreover, the current study found that for falls on the same level, males in the age groups 10-14 and 15-19 years had the highest rate of serious injury. Our finding contradicts other research studies that have documented same-level falls as most common in younger children under the age of 5 years (Chaudhary et al., 2018; Krishnamurthy et al., 2021).

The findings from this current study provides an enhanced understanding of the rates of serious fall injury among the different age groups and sexes. This data can be used by public health units to increase their capacity in developing public health interventions targeted at preventing paediatric fall injuries.

CHAPTER THREE: EXPANDED METHODS

Rates of Falls, Serious Falls, and the Rate Ratio Across Public Health Units in Ontario

The ICD-10 coding contains two important fields, one is the diagnosis which consists of the primary reason the patient was hospitalized or required medical attention. These ICD-10 codes range from *S00-T88* and was used to define all injuries (Table 3). Secondly, the external cause of injury code includes the causes of fall injury, which ranges from *W00-W19* and was used to define falls (Table 4). To examine the rate of serious injuries, we utilized the ICD-10 diagnostic codes *S01.9- T79.4* identified by Pike et al. (2017) to define serious paediatric injury (Table 5). The number of all fall-related hospitalizations and severe injury-related fall hospitalizations for children and youth ages 0–19 years was stratified by age group (0-4, 5-9, 10-14, 15-19) and public health unit. The total population of children and youth in Ontario was also stratified by age group (0-4, 5-9, 10-14, 15-19) and public health unit.

To draw comparisons across public health units, we calculated a rate per 100,000 population of all fall-related injuries and serious fall injuries for the 34 public health units across Ontario. This was done by taking the number of all injury-related hospitalizations and serious injury-related hospitalizations due to falls for children and youth (0-19 years) for the years 2010 to 2019 divided by the total child and youth population for each of the age groups in Ontario ×100,000. Data for the number of all fall injuries and the number of serious fall injuries for children 0-19 years of age was provided by Public Health Ontario using the DAD. The relevant population of children and youth (0-19 years) was retrieved from the 2016 Statistics Canada census of population (Statistics Canada, 2017). A rate ratio was computed for serious fall injuries by dividing the number of serious fall injuries over the number of all fall-related injuries. A table was configured to display the rate per 100,000 child population and rate ratio distribution of non-serious fall injury hospitalizations and serious fall injury hospitalizations by age and public health unit for children and youth (0-19 years) in Ontario. For some of the public health units, the number of serious injury-related fall hospitalizations had to be suppressed for certain age groups as the numbers were too small to report (i.e., less than 5 hospitalizations). For these particular public health units, we were unable to report the true rates

and rate ratios. A median value of 2.5 was assigned as the number of hospitalizations to calculate the rates and rate ratio of serious falls, these values were marked with a * as shown in the tables.

Table 3: ICD-10 code classification for injury, poisoning and certain other consequences of external causes

ICD-10	Diagnosis
S00-S09	Injuries to the head
S10-S19	Injuries to the neck
S20-S29	Injuries to the thorax
S30-S39	Injuries to the abdomen, lower back, lumbar spine, pelvis and external genitals
S40-S49	Injuries to the shoulder and upper arm
S50-S59	Injuries to the elbow and forearm
S60-S69	Injuries to the wrist, hand and fingers
S70-S79	Injuries to the hip and thigh
S80-S89	Injuries to the knee and lower leg
S90-S99	Injuries to the ankle and foot
T07-T07	Injuries involving multiple body regions
T14-T14	Injury of unspecified body region
T15-T19	Effects of foreign body entering through natural orifice
T20-T25	Burns and corrosions of external body surface, specified by site
T26-T28	Burns and corrosions confined to eye and internal organs
T30-T32	Burns and corrosions of multiple and unspecified body regions
T33-T34	Frostbite
T36-T50	Poisoning by, adverse effect of and underdosing of drugs, medicaments and biological substances
T51-T65	Toxic effects of substances chiefly nonmedicinal as to source
T66-T78	Other and unspecified effects of external causes
T79-T79	Certain early complications of trauma
T80-T88	Complications of surgical and medical care

Table 4: ICD-10 code classification for fall injuries

ICD-10	Type of Fall
W00-W01, W03, W18	On the same level and due to collision with, or pushing by, another person
W02	From skis, blades, skates, boards
W06-W08	From furniture
W09	In playgrounds
W10	On stairs
W11-W13	From ladders/scaffolding and from, out of or through building or structure
W04-W05	While being carried or supported by other persons and involving wheelchair and other types of walking devices
W14-W17	Falls in the natural environment including from tree, cliff and diving or jumping into water (injury other than drowning)
W19	Other and unspecified falls

Table 5: ICD-10 codes constituting severe injury-related hospitalizations among children and youth 0–19 years of age

Number	ICD-10	Diagnosis
1	**S01.9**	Open wound of head, part unspecified
2	**S02.1**	Fracture of base of skull
3	**S02.7**	Multiple fractures involving skull and facial bone
4	**S02.9**	Fracture of other facial bones
5	**S04**	Injury of cranial nerves
6	**S05.7**	Avulsion of eye
7	**S06.1**	Traumatic cerebral oedema
8	**S06.2**	Diffuse brain injury
9	**S06.3**	Focal brain injury
10	**S06.4**	Epidural haemorrhage
11	**S06.5**	Traumatic subdural haemorrhage
12	**S06.6**	Traumatic subarachnoid haemorrhage
13	**S06.8**	Other intracranial injuries

14	**S06.9**	Intracranial injury, unspecified
15	**S07.0**	Crushing injury of face
16	**S11**	Open wound of neck
17	**S12**	Fracture of neck
18	**S13**	Dislocation, sprain and strain of joints and ligaments at neck level
19	**S14.1**	Complete lesion of cervical spinal cord
20	**S14.6**	Other and unspecified injuries of neck
21	**S15**	Injury of blood vessels at neck level
22	**S21**	Open wound of thorax
23	**S22**	Fracture of rib(s), sternum and thoracic spine
24	**S24**	Injury of nerves and spinal cord at thorax level
25	**S25.0**	Injury of thoracic aorta
26	**S25.3**	Injury of innominate or subclavian vein
27	**S25.4**	Injury of pulmonary blood vessels
28	**S26.0**	Injury of heart with haemopericardium
29	**S26.8**	Other injuries of heart (contusion, laceration, puncture)
30	**S27**	Injury of other and unspecified intrathoracic organs
31	**S28**	Crushing injury of thorax and traumatic amputation of part of thorax
32	**S31**	Open wound of abdomen, lower back and pelvis
33	**S32**	Fracture of lumbar spine and pelvis
34	**S35.0**	Injury of abdominal aorta
35	**S35.1**	Injury of inferior vena cava
36	**S36**	Injury of intra-abdominal organs
37	**S37**	Injury of urinary and pelvic organs
38	**S38.1**	Crushing injury of other and unspecified parts of abdomen, lower back and pelvis

39	**S42.0**	Fracture of clavicle
40	**S42.1**	Fracture of scapula
41	**S72.0**	Fracture of neck of femur
42	**S75.0**	Injury of femoral artery
43	**S77**	Crushing injury of hip and thigh
44	**S78**	Traumatic amputation of hip and thigh

Table 5: Continued

Number	ICD-10	Diagnosis
45	**S86**	Injury of muscle and tendon at lower leg level
46	**S88.0**	Traumatic amputation at knee level
47	**T01.9**	Multiple open wounds, unspecified
48	**T06.8**	Other specified injuries involving multiple body regions
49	**T20.3**	Burn of third degree of head and neck
50	**T21**	Burn and corrosion of trunk
51	**T22.3**	Burn of third degree of shoulder and upper limb, except wrist and hand
52	**T24**	Burn and corrosion of hip and lower limb, except ankle and foot
53	**T27**	Burn and corrosion of respiratory tract
54	**T29.3**	Burns of multiple regions, at least one burn of third degree mentioned
55	**T30.3**	Burn of third degree, body region unspecified
56	**T58**	Toxic effects of carbon monoxide
57	**T68**	Hypothermia
58	**T71**	Asphyxiation
59	**T75.1**	Drowning and non-fatal submersion
60	**T79.4**	Traumatic shock (immediate/delayed following injury)

CHAPTER FOUR: EXPANDED RESULTS

Rates of Falls, Serious Falls, and the Rate Ratio Across Public Health Units in Ontario

Table 6 displays the rate per 100,000 child population and the rate ratio distribution of non-serious fall hospitalizations and serious fall hospitalizations by age and public health unit in Ontario. The highest rate of all fall-related injuries was in Thunder Bay District Health Unit for the age group 0-4 years (2,202.19 per 100,000). Among all children (0-19 years), children ages 0-4 and 5-9 years had the highest rates of all fall-related injuries. Overall, higher rates of all fall-related injuries were reported in the rural regions compared to urban regions. The public health unit that had the lowest rate of all fall-related injuries was Peterborough County-City Health unit for the age group 15-19 years (285.13 per 100,000). In contrast to the public health units with the highest rates of all fall-related injuries, lower rates were majorly reported in urban regions than rural regions. Overall, ages 0-4 and 5-9 years accounted for the highest rates of all fall-related injuries, whereas the age groups 10-14 and 15-19 years accounted for the lowest rates of all fall-related injuries among the public health units.

Timiskaming Health Unit accounted for the highest rate of serious fall injuries for the age group 15-19 years (369.39 per 100,000). Children and youth in the age groups 0-4 and 15-19 years had the highest rates of serious fall injuries. Similar to the highest rates of all fall-related injuries, the highest rates for serious fall injuries were also commonly reported in rural regions. Kingston, Frontenac and Lennox and Addington Health Unit reported the lowest rate of serious fall injuries for children ages 5-9 years (*25.44 per 100,000). Among all public health units, children in the age group 5-9 years reported the lowest rates of serious fall injuries. There was variability observed among the age groups when comparing rates between the public health units. The age groups 0-4 and 15-19 years accounted for the highest rates of serious fall injuries, whereas the age group 5-9 and 10-14 years accounted for the lowest rates of serious fall injuries.

The rate ratio of serious to non-serious falls was highest in the public health unit of Huron Perth for the age group 15-19 years (RR: 0.40). Following Huron-Perth the highest rate ratios of serious to non-

serious injuries was found in Timiskaming (RR: 0.37), Simcoe Muskoka District (RR: 0.35), Durham Regional (RR: 0.32), Renfrew County and District (RR: 0.32), Oxford - Elgin - St. Thomas (RR: 0.32), Haldimand-Norfolk (RR: 0.31), Niagara Regional Area (RR: 0.29), Waterloo (RR: 0.29), and Peterborough County-City (RR: 0.29) among children ages 15-19 years. The lowest rate ratios of serious to non-serious falls was reported in the rural regions for the age group 5-9 years. The highest rate ratios of serious to non-serious falls was also reported in the rural regions for the age group 15-19 years, indicating variability in the rate of serious injuries by public health unit. A trend that was observed among the public health units was that the health units that had high rates of all fall-related injuries reported lower rate ratios of serious to non-serious falls. Similarly, the health units that had low rates of all fall-related injuries reported higher rate ratios of serious to non-serious falls.

Huron Perth Health Unit had the highest rate ratio (RR: 0.40) but a low rate of all fall-related injuries for children ages 15-19 years (571.77 per 100,000). The District of Algoma Health Unit showed the lowest rate ratio for children aged 5-9 years (RR: *0.02). For the age group 10-14 years, Peterborough County City Health Unit had the highest rate ratio (RR: 0.28). For the age group 0-4 years, Ottawa Health Unit had the highest rate ratio (RR: 0.21). The District of Algoma had the lowest rate ratio of serious to non-serious falls for children ages 5-9 years but a high rate of all fall-related injuries for the same age group (1,917.29 per 100,000). Peterborough County-City Health Unit had a high-rate ratio (RR: 0.29) but the lowest rate of all fall-related injuries (285.13 per 100,000) for the age group 15-19 years. Likewise, Thunder Bay District Health Unit had a low-rate ratio of serious to non-serious falls (RR: 0.12) but the highest rate of all fall-related injuries (2,202.19 per 100,000) for the age group 0-4 years. The public health units of Chatham-Kent and Porcupine both had a high rate of all fall-related injuries (1515. 42 per 100,000), (1678.05 per 100,000) but a low-rate ratio of serious to non-serious falls for children in age group 5-9 (RR: *0.03). Timiskaming public health unit reported a low rate of all fall-related injuries for children aged 15-19 years (1002.64 per 100,000) but had a high-rate ratio of serious to non-serious falls (RR: 0.37).

Table 6: Rate & Rate Ratio Distribution of Serious & Non-Serious Fall Injury Hospitalizations by Age and Public Health Unit per 100,000 Child Population, Ontario 2010-2019

Region	Rate per 100,00 0-4		Rate per 100,000 5-9		Rate per 100,000 10-14		Rate per 100,000 15-19	
Algoma Health Unit	Serious	171.10	Serious	*46.99	Serious	132.20	Serious	158.45
	Non- Serious	1520.91	Non- Serious	1917.29	Non- Serious	1227.57	Non- Serious	1161.97
Rate Ratio	0.11		*0.02		0.11		0.14	
Brant County Health Unit	Serious	224.57	Serious	97.50	Serious	112.36	Serious	145.81
	Non- Serious	1770.15	Non-Serious	1230.96	Non- Serious	799.00	Non- Serious	546.78
Rate Ratio	0.13		0.08		0.14		0.27	
Chatham-Kent Health Unit	Serious	208.53	Serious	*44.05	Serious	*43.21	Serious	163.67
	Non- Serious	1194.31	Non-Serious	1515.42	Non- Serious	847.02	Non- Serious	621.93
Rate Ratio	0.17		*0.03		*0.05		0.26	
Durham Regional Health Unit	Serious	117.66	Serious	65.11	Serious	103.55	Serious	141.96
	Non- Serious	952.51	Non-Serious	1011.77	Non- Serious	675.54	Non- Serious	446.82
Rate Ratio	0.12		0.06		0.15		0.32	
Eastern Ontario Health Unit	Serious	179.58	Serious	97.30	Serious	73.53	Serious	177.38
	Non- Serious	1162.57	Non-Serious	787.26	Non- Serious	634.19	Non- Serious	647.45
Rate Ratio	0.15		0.12		0.12		0.27	
Grey Bruce Health Unit	Serious	144.40	Serious	84.29	Serious	186.45	Serious	209.79
	Non- Serious	1311.67	Non-Serious	1180.01	Non- Serious	994.41	Non- Serious	780.89
Rate Ratio	0.11		0.07		0.19		0.27	

Haldimand-Norfolk Health Unit	Serious	230.91	Serious	103.90	Serious	149.38	Serious	289.63
	Non- Serious	1367.67	Non- Serious	1541.13	Non- Serious	1410.79	Non- Serious	945.12
Rate Ratio	0.17		0.07		0.11		0.31	
Haliburton, Kawartha, Pine Ridge District Health Unit	Serious	101.01	Serious	*32.36	Serious	156.63	Serious	153.34
	Non- Serious	1111.11	Non- Serious	1009.71	Non- Serious	819.28	Non- Serious	569.55
Rate Ratio	0.09		*0.03		0.19		0.27	
Halton Regional Health Unit	Serious	127.45	Serious	86.90	Serious	90.57	Serious	137.21
	Non- Serious	993.46	Non- Serious	1137.59	Non- Serious	721.96	Non- Serious	573.55
Rate Ratio	0.13		0.08		0.13		0.24	
Hamilton Health Unit	Serious	123.78	Serious	68.13	Serious	149.23	Serious	186.74
	Non- Serious	1075.15	Non- Serious	1536.37	Non- Serious	1187.04	Non- Serious	790.54
Rate Ratio	0.12		0.04		0.13		0.24	
Hastings and Prince Edward Counties Health Unit	Serious	183.01	Serious	96.74	Serious	87.01	Serious	115.27
	Non- Serious	1411.76	Non- Serious	1039.90	Non- Serious	596.64	Non- Serious	507.20
Rate Ratio	0.13		0.09		0.15		0.23	

Region	**Rate per 100,00 0-4**		**Rate per 100,000 5-9**		**Rate per 100,000 10-14**		**Rate per 100,000 15-19**	
Huron Perth Health Unit	Serious	217.25	Serious	112.43	Serious	87.94	Serious	226.33
	Non- Serious	1776.36	Non- Serious	1511.56	Non- Serious	678.39	Non- Serious	571.77
Rate Ratio	0.12		0.07		0.13		0.40	

Kingston, Frontenac, Lennox & Addington Health Unit	Serious	177.38	Serious	*25.44	Serious	103.90	Serious	113.26
	Non- Serious	1274.94	Non-Serious	936.39	Non- Serious	654.55	Non- Serious	471.92
Rate Ratio	0.14		*0.03		0.16		0.24	
Lambton Health Unit	Serious	146.94	Serious	130.62	Serious	91.05	Serious	230.55
	Non-Serious	1714.29	Non-Serious	1436.87	Non- Serious	1183.61	Non- Serious	951.01
Rate Ratio	0.09		0.09		0.08		0.24	
Leeds, Grenville and Lanark District Health Unit	Serious	216.07	Serious	72.25	Serious	80.69	Serious	149.02
	Non- Serious	1147.87	Non-Serious	939.19	Non- Serious	530.26	Non- Serious	574.77
Rate Ratio	0.19		0.08		0.15		0.26	
Middlesex-London Health Unit	Serious	248.14	Serious	112.64	Serious	104.38	Serious	172.19
	Non- Serious	1261.37	Non-Serious	1553.70	Non- Serious	1071.86	Non- Serious	648.47
Rate Ratio	0.20		0.07		0.10		0.27	
Niagara Regional Area Health Unit	Serious	173.29	Serious	79.59	Serious	136.93	Serious	225.55
	Non- Serious	1641.40	Non-Serious	1463.63	Non- Serious	1086.86	Non- Serious	773.87
Rate Ratio	0.11		0.05		0.13		0.29	
North Bay Parry Sound District Health Unit	Serious	236.58	Serious	*41.49	Serious	99.59	Serious	216.38
	Non- Serious	1346.68	Non- Serious	1261.41	Non- Serious	1178.42	Non- Serious	880.99
Rate Ratio	0.18		*0.03		0.08		0.25	
Northwestern Health Unit	Serious	104.71	Serious	*48.44	Serious	*51.70	Serious	258.45
	Non- Serious	1298.43	Non- Serious	1182.17	Non- Serious	1034.13	Non- Serious	1013.92

Rate Ratio	0.08		*0.04		*0.05		0.25	
Ottawa Health Unit	Serious	202.58	Serious	68.88	Serious	80.99	Serious	118.90
	Non- Serious	986.29	Non- Serious	996.00	Non- Serious	593.28	Non- Serious	536.81
Rate Ratio	0.21		0.07		0.14		0.22	
Oxford-Elgin-St.Thomas Health Unit	Serious	207.16	Serious	72.03	Serious	121.56	Serious	186.76
	Non- Serious	1476.05	Non- Serious	1504.60	Non- Serious	964.34	Non- Serious	592.77
Rate Ratio	0.14		0.05		0.13		0.32	
Peel Regional Health Unit	Serious	159.86	Serious	68.76	Serious	67.82	Serious	92.64
	Non- Serious	1053.53	Non- Serious	870.91	Non- Serious	505.86	Non- Serious	355.10
Rate Ratio	0.15		0.08		0.13		0.26	
Peterborough Health Unit	Serious	120.12	Serious	*36.81	Serious	201.55	Serious	81.47
	Non- Serious	1276.28	Non- Serious	942.56	Non- Serious	713.18	Non- Serious	285.13
Rate Ratio	0.09		*0.04		0.28		0.29	

Region	**Rate per 100,00 0-4**		**Rate per 100,000 5-9**		**Rate per 100,000 10-14**		**Rate per 100,000 15-19**	
Porcupine Health Unit	Serious	284.55	Serious	*48.78	Serious	*52.08	Serious	174.93
	Non- Serious	1707.32	Non- Serious	1678.05	Non- Serious	1000.00	Non- Serious	855.20
Rate Ratio	0.17		*0.03		*0.05		0.20	
Renfrew County and District Health Unit	Serious	193.66	Serious	142.73	Serious	*47.25	Serious	222.63
	Non- Serious	968.31	Non-Serious	909.90	Non- Serious	472.59	Non- Serious	705.01

Rate Ratio	0.20		0.16		*0.10		0.32	
Simcoe Muskoka District Health Unit	Serious	160.81	Serious	87.67	Serious	158.26	Serious	184.00
	Non- Serious	916.23	Non-Serious	910.47	Non- Serious	675.90	Non- Serious	520.82
Rate Ratio	0.18		0.10		0.23		0.35	
Sudbury and District Health Unit	Serious	133.26	Serious	96.81	Serious	109.34	Serious	134.17
	Non- Serious	1055.87	Non-Serious	1055.18	Non- Serious	984.10	Non- Serious	706.62
Rate Ratio	0.13		0.09		0.11		0.19	
Thunder Bay District Health Unit	Serious	257.57	Serious	134.89	Serious	137.93	Serious	243.76
	Non- Serious	2202.19	Non-Serious	1549.11	Non- Serious	1291.54	Non- Serious	975.04
Rate Ratio	0.12		0.08		0.11		0.25	
Timiskaming Health Unit	Serious	*148.80	Serious	*147.05	Serious	*154.79	Serious	369.39
	Non- Serious	1369.05	Non-Serious	1117.65	Non- Serious	990.71	Non- Serious	1002.64
Rate Ratio	*0.11		*0.13		*0.16		0.37	
Toronto Health Unit	Serious	206.62	Serious	83.69	Serious	96.77	Serious	114.07
	Non- Serious	1052.21	Non- Serious	1204.96	Non- Serious	702.54	Non- Serious	454.92
Rate Ratio	0.20		0.07		0.14		0.25	
Waterloo Health Unit	Serious	111.86	Serious	82.49	Serious	80.60	Serious	127.94
	Non- Serious	1036.35	Non- Serious	1060.19	Non- Serious	567.27	Non- Serious	443.32
Rate Ratio	0.11		0.08		0.14		0.29	
	Serious	209.75	Serious	58.38	Serious	81.25	Serious	173.21

Wellington-Dufferin-Guelph Health Unit	Non- Serious	1110.43	Non- Serious	1185.06	Non- Serious	853.16	Non- Serious	714.48
Rate Ratio	0.19		0.05		0.10		0.24	
Windsor-Essex County Health Unit	Serious	138.82	Serious	61.86	Serious	79.28	Serious	118.95
	Non- Serious	1036.19	Non- Serious	1073.80	Non- Serious	721.89	Non- Serious	483.74
Rate Ratio	0.13		0.06		0.11		0.25	
York Regional Health Unit	Serious	113.57	Serious	78.70	Serious	74.65	Serious	112.13
	Non- Serious	939.98	Non- Serious	954.79	Non- Serious	629.58	Non- Serious	428.51
Rate Ratio	0.12		0.08		0.12		0.26	

*Note: * represents median Value of 2.5 substituted to calculate rate/rate ratio*

CHAPTER FIVE: EXPANDED DISCUSSION

Rates of Falls, Serious Falls, and the Rate Ratio Across Public Health Units in Ontario

Overall, our findings showed that across the 34 public health units in Ontario, the highest rates of all fall-related and serious fall injuries for children and youth (0-19 years) occurred in rural health units over largely urban health units. Our finding is consistent with previous studies that have examined urban and rural disparities in childhood injury (Kim et al., 2012; Leonhard et al., 2015; Bang et al., 2019; Owoaje et al., 2015; Pathak et al., 2020). Leonhard et al. (2015), examined the mortality of paediatric patients with traumatic brain injury in rural/urban settings. Their findings showed that the rate of traumatic brain injury was higher among children in rural settings in comparison to urban metropolitan settings. They also found that compared to children in urban areas**,** rural children had a higher rate of mortality from traumatic brain injury. Studies have suggested that a contributing factor to the increased mortality due to traumatic brain injury in rural children may be associated with longer transport times (Leonhard et al., 2015; Ficker, 2021; Li et al., 2020). The chances of survival have shown to be reduced with transportation times exceeding 30 minutes from the time of injury to receiving medical care (Leonhard et al., 2015). In their study, Leonhard et al. (2015), found that for the majority of children injured in rural settings, transportation times experienced to a hospital was more than 30 minutes. In the study by Amram et al. (2016), it was found that access to paediatric trauma centers was limited in rural locations leading to increased mortality and morbidity rates. Thus, this disparity between rural and urban areas may be attributed to the longer travel distances to hospitals and limited access to health care services (Bang et al., 2019; Ficker, 2021; Kim et al., 2012). Providing timely access to medical treatment and trauma care is crucial for improved health outcomes in children with serious injuries (Amram et al., 2016).

Our study found that the highest rate of all fall-related injury was in children ages 0-4 years, residing in rural public health units. Our finding was supported by Loftus et al. (2018), who reported that children under the age of 4 were more likely to sustain a traumatic injury from falls. In addition, it was found that sustaining a serious injury such as skull fracture or traumatic brain injury was higher for rural

children in comparison to children in urban areas. A study by Owoaje et al. (2015), examining fall injuries in the home also reported that the majority of fall injuries in children occurred in the age group 0-4 years and in rural settings. Conversely, Pathak et al. (2020) found that children aged 5-10 years in rural settings were more prone to suffer fall injuries. There was some variability between our findings and prior studies concerning the age of children and serious fall injuries. Our results indicated that the highest rate of serious fall injuries was reported in adolescents aged 15-19 years in rural health units. However, most of the previous research has suggested higher rates of fall injury in younger children aged 0-4 years from rural areas (Loftus et al., 2018; Owoaje et al., 2015).

There is a dearth of literature examining the differences of serious fall injury between rural and urban areas. Injury prevention efforts should be specific to the geographic location of children and youth to reduce serious fall injuries (Kim et al., 2012).

The results from this current study indicate that the mechanisms of serious and non-serious fall injuries vary according to age and sex among children and youth ages 0-19 years. There is also a disparity in the number of serious and non-serious fall injuries when considering urban vs rural public health units. There is a growing body of evidence signifying that fall injuries in the paediatric population should be a focus of injury prevention. There is limited data available; however, to understand where prevention efforts need to be prioritized for serious fall injuries. The data from this study identifies priority populations for targeted intervention to reduce serious fall injuries.

STRENGHTS AND LIMITATIONS

This population-based study is the first to populate an indicator of serious fall injuries within the paediatric population aged 0-19 years. The primary strengths of this study included use of an indicator of serious injury, from the scientific literature, defined for the paediatric population (Pike et al., 2017). Another strength includes the ability to provide this information to public health units in Ontario to help build a targeted program of public health to reduce the number of serious falls across the province. One of the biggest limitations of this study included the need to suppress results for certain public health units

due to, cell counts less than 5. The rate and rate ratio calculations for these specific public health units were based on a median value of 2.5 which does not reflect the actual number of hospitalizations and rates of serious falls. Another limitation of this study was that although we were able to provide an enhanced understanding of what mechanisms were related to serious fall injury, most of the injuries were due to "other causes." We were unable to identify these other types of injuries as there were no specific ICD-10 codes for them. There is data needed to better understand the context in which these serious fall injuries are happening in order to prevent them. In addition, another major limitation of this study was the lack of exposure data. We were able to identify the mechanisms of serious fall injury in children, however we were not able to sufficiently determine the risk factors as there was no measure of exposure. Our results may have differed if we were able to report on the number of falls over the exposure to risk. The exposure to risk may vary for children depending on their age and environment. Younger children may have greater exposure to risk in the home from furniture and stairs, while older children may have more exposure to risk outside the home, such as in playgrounds or during sports. Similarly, children in rural settings are at a higher risk of falling and sustaining serious injuries from haylofts and operating machinery compared to urban children (Pickett et al., 2007). Finally, out results were all based on data from Ontario and may not be generalizable to paediatric populations in other provinces across Canada.

Implications for Public Health Units

The indicator populated in this study aims to prompt action on serious childhood falls. The role of public health units is to provide prevention programs and information focused on addressing major public health issues in their community (Public Health Ontario, 2020). Using the public health approach, this study was able to define the problem of serious fall injuries in children and youth, as well as identify a few of the risk factors (Satcher & Higginbotham, 2008). The next steps for this research are to provide these findings to public health units to expand their understanding of the risk factors associated with serious falls in children, and to collaborate with their communities to develop interventions that mitigate the risk of serious fall injuries. Our results showed that children and youth in rural public health units have higher rates of serious fall injury in comparison to children in urban public health units. This may be

attributed to the fact that children in rural public health units are exposed to more hazardous conditions (Pickett et al., 2007; Pickett et al., 2005). The exposure to risks may vary depending on the environment in which children and youth reside. Pickett et al. (2007) looked at paediatric injuries in agricultural settings, it was conveyed that falls are common among children residing on farms, and this may be attributable to the greater exposure to unsafe environments which renders them particularly vulnerable to serious injuries. Hence, an understanding of the conditions and environments, as well as the exposure to risks they pose for children is crucial for developing prevention strategies to reduce serious fall injuries.

CONCLUSION

The indicator populated in this study provides insight into the burden of serious fall injury among children and youth (0-19 years). Fall-related injuries in the paediatric population are a major public health concern and represent a significant cost to the healthcare system (World Health Organization, 2021). It is imperative for fall injury prevention efforts to be implemented based on the evidence available and after understanding the scope of the issue (Ameratunga et al., 2008). Children are an important population of focus for injury prevention due to their vulnerability to a fall injury and the life-long impact of a serious fall injury. Our findings identify important variability in serious falls by public health unit, age, and sex. As well, the results of this study provide an enhanced understanding on the mechanisms of falls that contribute to serious injuries among children and youth. Fall injuries are preventable and by translating the findings from this research into practice, this indicator aims to contribute to the identification of strategies to support the goal of reducing the burden and severity of fall injury in the paediatric population.

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APPENDIX

Serious injury-related hospitalizations due to a fall

The number/rate per 100,000 of serious injury-related hospitalizations due to a fall

Importance and Use	The rate of serious injury-related hospitalizations due to a fall is an important indicator for understanding the burden of serious falls on the public health system. Reporting on these data, will allow public health units to identify priority strategies in the population.
Key terms	**Serious injury-related Hospitalization:** Hospitalization for a serious injury is defined as the number of inpatients who have spent at least one night in the hospital following visit and who leave the hospital through discharge.
How is it calculated?	**Numerator**: Number of serious injury-related hospitalizations due to falls for children and youth (0-19 years) for the years 2010-2019 **Denominator**: The total child and youth population of Ontario ages 0-19 years **Method of Calculation**: (Numerator/Denominator) x 100,000
What data is needed?	• Total number of serious injury-related hospitalizations due to a fall for children and youth ages 0-4, 5-9, 10-14 and 15-19 years ○ ICD-10 code for injury, poisoning and certain other consequences of external causes (S00-T88) ○ ICD-10 code for fall injuries (External Cause Codes: W00-W19) ○ ICD-10 code for serious injury-related hospitalizations as defined by Pike et al. 2017 (S01.9-T79.4) • Population of children and youth 0-19 years (stratified by age group (0-4, 5-9, 10-14, 15-19) and sex
Where can it be found?	**Numerator:** The original source can be found on the Canadian institute for Health Information (CIHI) Discharge Abstract Database (DAD). It is distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. **Denominator:** Population of children and youth 0-19 years (2016 to 2017) ● Original source: Statistics Canada, 2016 census of population ● Distributed by: Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO
Potential Stratifications* *Note: These are suggestions of potential stratification categories, and not an exhaustive list.	To inform a more comprehensive understanding of the burden of falls among children and youth, serious injury-related hospitalizations due to falls can be analyzed by other variables such as: • **Socio-economic status** • **Geographic location** • **Demographic characteristics such as race and ethnicity**
Limitations	For some of the public health units, the number of serious injury-related fall hospitalizations had to be suppressed for certain age groups as the cell counts were under 5. Population of children and youth were not available for 2010 or 2019.