A Systematic Review on the Incidence of Injuries to Young Children and Implications for Prevention and Surveillance

by

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Abstract

Introduction: Childhood injuries represent a significant public health problem, with young children being injured in often predictable ways. Injury surveillance – not currently done in Canada – could track the population burden and help identify factors amenable to prevention. **Methods:** A systematic review of the childhood injury incidence literature was conducted using methods adapted from the Cochrane Collaboration. Particular attention was paid to identifying injuries according to developmentally sensitive age groupings to avoid masking the incidence of specific injury types in younger children. **Results:** Eight incidence studies met appraisal criteria. The highest injury rate was 375 per 1,000 one-year-old boys in Alberta. Despite variability in data sources and reporting methods, it was possible to use these findings to suggest new approaches to child injury surveillance that are developmentally sensitive and grounded in ecological approaches to understanding injury etiology. **Discussion:** The implications for child injury research, prevention, and surveillance in Canada are reviewed.

Keywords: childhood injury; surveillance; prevention; child development; systematic review

I dedicate this work to my family.

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List of Acronyms

BC	British Columbia
CHIRPP	Canadian Hospital Injury Reporting and Prevention Program
CIHI	Canadian Institute for Health Information
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CIS	Canadian Incidence Study
DAD	Discharge Abstract Database
E code	External Cause of Injury Code
ER	Emergency Room
HMDB	Hospital Morbidity Database
ICD	International Statistical Classification of Diseases and Health Related Problems
ISS	Injury Severity Scores
MeSH	Medical Subject Heading
N code	Nature of Injury Diagnosis
NACRS	National Ambulatory Care Reporting System
NFP	Nurse Family Partnership
PHAC	Public Health Agency of Canada
RCT	Randomized Controlled Trial
Triple P	Positive Parenting Program
WHO	World Health Organization

Chapter 1.

Introduction

Injuries are a major cause of death and disability for infants and children globally (Peden et al., 2008). Internationally, Canada has ranked poorly regarding fatal injuries to children. Of the world's 26 richest nations, Canada ranked 18th regarding deaths due to unintentional and intentional injuries (UNICEF, 2001). Within Canada, injuries are the leading cause of death to children aged one to 14 years (Safe Kids Canada, 2006). The death of a child has obvious negative consequences for the child and surviving family members. Children who experience the death of a sibling, for example, are more likely to show reductions in positive outcomes, such as total years of schooling, in adulthood (Fletcher, Mailick, Song, & Wolfe, 2013). Non-fatal injuries can also have lasting negative effects. Children who have experienced a traumatic brain injury before the age of three, for example, scored lower on a measure of intelligence than children without such an injury more than three years post-injury (Crowe, Catroppa, Bable, & Anderson, 2012). Non-fatal injuries are also more common. Lee, Fleegler, Olson, and Mooney (2009), for example, found that among individuals less than 20 years of age, for every one unintentional or intentional injury fatality there were 36 injury hospitalizations and 1014 injury-related emergency room (ER) visits.

Injury risk is also closely related to a child's developmental progress. With age, a child's physical abilities, such as grasping and ambulation, progress. Injury risk can then increase if caregiver supervision and the child's environment are not fine-tuned to account for this development (Mercy, Sleet, & Doll, 2003). Generally, examining overall injury rates by single year shows a bimodal pattern – injury rates spike in the first year of life, decline, then rise into the mid-to-late teenage years (e.g., Agran, Winn, Anderson, Trent, & Walton-Haynes, 2001). Tracy and colleagues (2013) presented data to suggest that this pattern is similar for injury severity as well. A comprehensive study in Alberta, Canada, also found the highest incidence of injury for children less than 10 years occurred among one-year-olds (Spady, Saunders, Schopflocher, & Svenson, 2004). More specifically, these authors found that injuries occurred at rates of 300 per 1,000 one-year-old girls and 375 per 1,000 one-year-old boys, with intracranial injuries, dislocations, strains, and sprains, as well as open wounds being most common in these groups. Thus, children are experiencing injuries of varying severity and causes, and that variation is at least in part a function of developmental stage. Childhood injuries represent a significant public health problem, but are often overlooked as a health issue. As such, they have been referred to as Canada's "invisible epidemic", given that they are often overlooked despite their frequent negative impact, that have given rise to calls for increases in research, prevention, and surveillance (SMARTRISK, 2005).

Within the younger child injury literature, many studies categorize child age into two groups – under one year, and between one and four years. Broad age group injury analyses present difficulties for linking age-dependent developmental characteristics with injury risk. One-to-four-year-olds, for example, are developing rapidly regarding their motor skills, cognitive abilities, and social interactions, all of which influence exposure to and risk of injury. Collapsing injury data from ages one to four years masks the larger injury rates seen in one- and two-year-olds (5.0 per 1,000 and 3.9 per 1,000) compared to three- and four- year olds (2.9 per 1,000 and 2.7 per 1,000 [Agran et al., 2001]). Thus, using smaller age intervals more clearly illustrates the age-related variability in injury incidence present in young children.

This paper begins by discussing the definitions, risk indicators, primary prevention interventions, and available Canadian population-level surveillance of childhood injuries. The childhood injury incidence literature is then systematically reviewed using methods adapted from the Cochrane Collaboration (Higgins & Green, 2011). The purpose of this paper is to provide a comprehensive assessment of the incidence of injuries to young children, with a particular emphasis on the importance of accounting for children's development progress. Possible avenues to strengthen the surveillance of childhood injuries in Canada – as well as primary prevention efforts – using an overarching child development framework will also be explored in the thesis.

1.1. Definitions and Risk Indicators

Injuries occur when the body is subjected to a force of energy great enough to exceed the limit of physiological tolerance, or when vital elements (such as oxygen) are lacking (Baker, O'Neill, Ginsburg, & Li, 1992). Injuries can be unintentional or intentional. Unintentional injuries occur in the absence of intent to harm, whereas intentional injuries are the result of deliberate acts. Generally, intentional injuries include harm to self or others. Young children, however, are not able to form the intent to harm themselves (e.g., Agran, Anderson, Winn, Thayer, Trent, & Walton-Haynes, 2003). Intentional injuries to young children therefore consist of the deliberate acts of others resulting in harm (e.g., physical abuse). Identifying intentional injuries may be difficult, however, as young children may be unable to communicate clearly, and the perpetrator may be unlikely to disclose their actions (e.g., Ross & Juarez, 2014). In their systematic review, Bailhache, Leroy, Pillet, and Salmi (2013) found that child maltreatment screening instruments suffered from low sensitivity, and identified victims only well after they had suffered serious effects. Some suggest that practitioners should distinguish between intentional and unintentional injuries by determining if the injury matches the child's developmental stage and abilities (Petska & Sheets, 2014), or by using indicator injuries, such as femur fractures in young children, as a sign of possible abuse (Wood et al., 2014). Yet even the use of objective medical tests can be problematic. Sieswerda-Hoogendoorn, Postema, Verbaan, Majoie, and van Rijn (2014), for example, found that computerized tomography and magnetic resonance imaging tests (which could be used to assess the plausibility of a caregiver's account surrounding an injury to a young child) were not able to precisely determine the date of subdural hematoma injuries. Thus, distinguishing between unintentional and intentional injuries to young children is complex. Regarding age, this paper defines "infants" as those under the age of one year, "young children" as those aged birth to four years, "children" as those aged birth to 12 years, and "youth" as those aged 13-18 years.

Applying concepts from an *ecological model* suggests that childhood injuries are caused by the *interaction* of multiple factors nested within one another – involving the child, family, community, and society (Bronfenbrenner, 1979). Young *children*, for example, whose parents consider them to be active, more likely to take risks, and harder to manage have an increased risk of injury (Dal Santo, Goodman, Glik, & Jackson, 2004). At the *familial* level, insufficient parental supervision is associated with an increased risk of injury among young children (Theodore, Runyan, & Chang, 2007). Saluja and colleagues (2004) suggested that parental supervision consists of three vital elements – the level of parental attention, parental proximity to the child, and continuity of supervision. Petrass, Blitvich, and Finch (2009) systematically reviewed the literature to assess the relationship between injury risk and level of supervision. They found evidence that Saluja and colleagues' (2004) three elements of parental supervision protected children best from injury when used together. Decreased adult supervision has also been found to increase the odds of more severe injury in children younger than five years (Schnitzer, Dowd, Kruse, & Morrongiello, 2015).

At the *community* level, lack of parental social supports is associated with having an 'unsafe' home (e.g., lack of smoke detector, unsecured poisons) for a child (Rhodes & Iwashyna, 2007). Such social support systems may be particularly crucial for young mothers, who report uncertainty regarding child rearing and safety practices (Yuma-Guerrero et al., 2013). Then, at the *societal* level, lower socioeconomic status also increases the risk of childhood injury (Gilbride et al., 2006; Pomerantz, Dowd, & Buncher, 2001). Notably, the elevated risk of injury hospitalization and mortality among children living in low-income neighbourhoods reduces *linearly* when compared to children living in neighbourhoods with progressively higher income levels (Brownell, Friesen, & Mayer, 2002). The slope of the linear relationship of risk between children living in lower to progressively higher socioeconomic areas increased between 1985 and 2006 in Manitoba, Canada (Brownell et al., 2010).

The relationship between relative disadvantage and injury risk is also influenced by the cost of maintaining an adequate standard of living. In 2011, for example, British Columbia (BC) families spent the largest proportion of their income (before taxes) on the necessities of food, clothing, and shelter in Canada (Statistics Canada, 2015). Furthermore, BC families have spent more than the national average on these basic living expenses since 1999 (First Call, 2014). Additionally, the strength of the regional economy may also affect child injury rates. For example, Bruckner (2008) found that an eight percent increase in unintentional injury-related infant deaths coincided with a one percent reduction in the number of employed persons across California. Reading, Jones, Haynes, Daras, & Edmond (2008) argue that broader *societal* change – such as focusing on the collective rather than individual responsibility for child safety (Sethi, Racioppi, Baumgarten, & Bertollini, 2006) – may be necessary to influence factors related to parenting and household social circumstances. Thus, multi-faceted primary prevention efforts addressing social inequities may be needed to prevent childhood injuries (e.g., Atlantic Collaborative on Injury Prevention, 2011).

1.2. Primary Prevention

Preventing injuries *before* they happen, known as primary prevention, avoids the potentially long-term harm associated with serious injuries that can occur early in the lifespan. Agran and colleagues (2001), for example, found that young children were seriously injured (resulting in hospitalization or death) most often from falls, poisoning, burns, foreign body ingestions, and suffocation. The first injury was also often not the last, as approximately 73% of children have been shown to suffer more than one injury event (Spady, Saunders, Schopflocher, & Svenson, 2004), greatly increasing the amount of harm they experience. Multiple injury events also increase the risk for involvement with child protective services (Spivey, Schnitzer, Kruse, Slusher, & Jaffe, 2009). Although unintentional injuries outnumber intentional injuries 92 to one (Lee, Fleegler, Olson, Mooney, 2009), intentional injuries nevertheless can lead to serious harm. In their systematic review and meta-analysis, Norman and colleagues (2012) found physical abuse and neglect resulted in statistically significant higher odds of depressive disorders, drug use, suicide attempts, as well as sexually transmitted infections and risky sexual behaviour in adulthood.

In addition to the diminished health, wellbeing, and life potential that injured individuals and their families may experience, there are also broader societal costs. In 2010, for example, falls, transport-, and violence-related injuries to young children cost $543 million in Canada (Parachute, 2015). Given these high individual and collective costs, the prevention of both unintentional and intentional injuries for young children is crucial (e.g., Pinheiro, 2006; WHO, 2008). Fatal injuries also leave no opportunity for secondary prevention – making primary prevention essential. Thus, *primary prevention* efforts that target *young children* may have the most impact in reducing long-term harm.

Haddon made a significant contribution to our understanding of the importance of injury prevention in 1972. His model, known as Haddon's Matrix (1972), focused on improving highway safety and reducing motor vehicle injuries. He argued the importance of focusing not only on the injured individual's behaviour, as was often done at the time, but also on the agent (e.g., motor vehicle) and the environment (e.g., highway design). This model also considered the 'before, during, and after' of an injury event, allowing for injury events and their harmful impact to be more fully understood. Additionally, his work emphasized the importance of a multidisciplinary approach – involving engineers, physicians, and behavioural scientists – and went on to influence injury epidemiology more broadly (including pediatric injury), by highlighting the importance of modifiable injury risk factors (Grossman, 2000). Childhood injuries were historically considered 'accidents' and children were often labeled as 'accident-prone' (Grossman, 2000). But Langley (1982) argued that this term put too much focus on the child, ignored the family and environment, and was counter-productive in that it removed the emphasis from preventing injuries. These changes in language (and the underlying ideas) highlighted that childhood injuries could be tackled with a public health approach, aimed at preventing injuries and reducing their harmful impact (Grossman, 2000).

Linking child development and injury risk is also important as it helps to understand injuries and inform prevention by highlighting risk factors associated with developmental progress (Morrongiello & Schwebel, 2008). Some parents may lack knowledge of child development and perceive some injuries as unavoidable (Simpson, Turnbull, Ardagh, & Richardson, 2009; Abelwhite et al., 2015). Some fathers may even consider engaging in risk to be an *important* part of their child's development, viewing such behaviour to be an opportunity for their child to build character, self-esteem, and confidence, while at the same time offering an opportunity for the father to protect his child (Brussoni, Creighton, Olsen, & Oliffe, 2013). Although eliminating all injury risk may not be possible, or even desirable, it is important to ensure that such risk does not exceed a child's developmental progress (Cordovil, Araujo, Pepping, & Barreiros, 2015) given that as children age, their capabilities advance. With each new developmental stage the injury risk of a young child changes. Grasping may result in burn injuries (e.g., grabbing a cup of hot coffee on a table while sitting on a caregiver's lap) or choking (e.g., putting small objects in their mouth). Walking and climbing may lead to injuries due to falls, making commonplace items such as coffee tables hazardous. Although parents of young children may be perceived as being at fault more than parents of older injured children (e.g., Williams, Kalsher, & Wogalter, 2014), it is important to highlight again that understanding and preventing injuries to young children involves more than focusing *solely* on caregivers. Other factors, such as child development and parental social support, for example, also influence injury risk and the possibilities for prevention.

Injury prevention interventions are often categorized as active (targeting behaviour change), passive (targeting environmental change), or regulatory (targeting policy change). In practice though, these categories are not discrete, with most prevention strategies involving some behavioural change (Gielen & Sleet, 2003). Toblin and colleagues (2011), for example, extracted hospital records for children less than three years old. Based on reported circumstances surrounding the injury events, they assessed whether the injuries could have been prevented. The authors concluded that 77% of injury events could have been prevented using active strategies, 47% using passive strategies, and 24% using regulatory strategies; of note, 46% were preventable using more than one strategy. Generally, injury prevention efforts focusing on the relationship between people and objects (e.g., stair gates) target unintentional injuries, while intentional injury prevention efforts target individuals and behaviour. The prevention of unintentional and intentional injuries are discussed, in turn, below.

1.2.1. Unintentional Injury Prevention

Regarding specific prevention interventions, Kendrick, Barlow, Hampshire, Stewart-Brown, and Polnay (2008) conducted a systematic review and meta-analysis to evaluate the effectiveness of parenting interventions designed to prevent unintentional injuries and increase parental safety practices. The authors found that parenting interventions resulted in a significant (18%) reduction in the risk of self-reported and medically attended unintentional childhood injuries. These findings have since been updated with no changes to the original conclusions (Kendrick et al., 2013). Targeting disadvantaged families exclusively has also been effective. For example, Kendrick, Mulvaney, and Watson (2009) showed that at one-year follow-up, low-income families who were randomized to receive a safety consultation and free or low-cost home safety equipment displayed a significant increase in their use of stair gates. The Early Start program – whereby a nurse or social worker visits families experiencing significant stress and challenges for an average of two years – has also shown positive results. At age three (Fergusson et al., 2005) and nine years (Fergusson, Boden, & Horwood, 2013), children randomized to receive Early Start had significantly fewer hospital attendances for unintentional injuries.

Prevention efforts should also consider contextual factors at the familial, community, and societal levels. Smithson, Garside, and Pearson (2011) reviewed qualitative studies investigating factors related to the success of unintentional injury prevention efforts in the home. They found that ongoing support with safety equipment installation and maintenance, practical limitations for parents, and cultural expectations were all related to successfully preventing unintentional childhood injuries. For example, parents may be unable to improve the safety of their child's home environment if they live in rented or shared housing. Families in this situation may be of lower socioeconomic status, highlighting again the applicability of the ecological model. The socioeconomic makeup of households and communities and the distribution of wealth within a society more broadly are all important.

1.2.2. Intentional Injury Prevention

Regarding preventing intentional injuries to children, universal programs (i.e., programs offered to the entire population) have shown success. The full Triple P (Positive Parenting Program [Sanders 1999; Sanders, Turner, & Markie-Dadds, 2002]) has been evaluated in one *community*-level randomized controlled trial (RCT). After two years of community-level intervention, there were beneficial effects (d=1.14) in Triple P counties regarding reduced hospitalization and ER visits related to child maltreatment (Prinz, Sanders, Shapiro, Whitaker, & Lutzker, 2009). The *Period of PURPLE Crying* program also has a broad population scope, in that it is delivered to all new parents in areas where the program is offered, and focuses on a specific intentional injury (abusive head trauma), although it might also be effective in preventing physically abusive injuries in infants more generally (R. Barr, personal communication, November 3, 2015). The *PURPLE* program helps all new parents understand and cope with infant crying using a video and booklet. Mothers randomized to receive the *PURPLE* program materials displayed higher levels of knowledge about infant crying, the dangers of shaking a child, and “walking away” when frustrated with their child’s crying (Barr et al., 2009; Barr et al., 2009; Fujiwara et al., 2012).

Intentional injury prevention efforts targeting specific populations have also been effective. The Nurse-Family Partnership (NFP), for example, pairs first-time, low-income mothers with a public health nurse who visits the family – starting prenatally until the child’s second birthday. NFP has been evaluated in three separate RCTs in the United States (Olds, Henderson, Chamberlin, & Tatelbaum, 1986; Kitzman et al., 1997; Olds et al., 2002), as well one RCT in both the Netherlands (Mejdoubi et al., 2015) and England (Robling et al., 2015). The American and Dutch trials found positive results. Compared to controls, NFP-visited children had significantly fewer verified cases of physical abuse (Olds et al., 1997) and child protective services reports (Mejdoubi et al., 2015). Interestingly, NFP-visited children also had significantly fewer hazards in their homes, as well as significantly fewer healthcare encounters for unintentional injuries, poisonings, and ingestions (Olds et al., 1986; Kitzman et al., 1997; Olds, Henderson, & Kitzman 1994). Interestingly, the English trial found less positive results (Robling et al., 2015). However, some authors have suggested that study design and the quality of “usual care” received by the control group accounts, at least in part, for the English trial’s findings (Olds, 2016). NFP, then, has been effective in preventing unintentional *and* intentional childhood injuries, lending support to Cohen and colleagues’ (2003) argument that, at least in some cases, unintentional and intentional injuries need not be considered and addressed separately. These findings also lend further support to the ecological model of childhood injuries, as NFP targets many aspects of families’ lives (e.g., child health and development, child and parental education, social supports, parental employment). Thus, injuries are not inevitable. They *can* be prevented.

Routine public health monitoring of childhood injuries should help to document how many children experience injury events (as well as the types and causes of injury) in a given population within a given time frame, thereby tracking population burden and informing prevention efforts. Public health surveillance should also include monitoring the incidence of childhood injuries at the national level.

1.3. Surveillance

The effective prevention of injuries in Canada requires a system *of surveillance* – the ongoing systematic collection, analysis, interpretation, and dissemination of health information (Holder et al., 2001) – to monitor the incidence of injuries as well as their causes, treatment, and outcomes (Mackay et al., 2003). Objective, reliable, representative data sources are essential for any surveillance system. Regarding the incidence of childhood injuries, self-reported data are likely not representative of the population burden and experience. White and Macpherson (2012), for example, found that estimates using health care records captured an incidence of injuries for children younger than four years old six times higher than that captured using parental self-reported health surveys. These authors suggested that recall bias and small sample size might have resulted in distorted numerators and therefore differences in incidence rates. While there are population-based injury data *sources* in Canada (e.g., Discharge Abstract Database [DAD], Hospital Morbidity Database [HMDB], National Ambulatory Care Reporting System [NACRS], healthcare billing records), there is currently no population-based national surveillance system for routinely reporting the incidence of unintentional and intentional injuries for young children.

Although Canada lacks population-based injury surveillance, there are two injury-related surveillance efforts involving data derived from "clinical" samples — the Canadian Hospital's Injury Reporting and Prevention Program (CHIRPP), and the Public Health Agency of Canada's (PHAC's) Canadian Incidence Studies (CIS). CHIRPP collects injury data for children presenting to ERs across Canada. CHIRPP is unique in that it captures pre-injury event data, allowing for qualitative analyses not possible with other administrative datasets. However, CHIRPP is not population-based (e.g., Macpherson et al., 2008), and does not routinely report the incidence of childhood injuries. PHAC's CIS, meanwhile, surveys child welfare agencies and produces weighted estimates of the incidence of child maltreatment cases every five years. However, CIS only includes cases that are reported to and investigated by child welfare agencies; thus any injury that goes unnoticed or unreported, or is not considered maltreatment, is excluded (PHAC, 2010). Consequently, the incidence of injuries for young children is not routinely monitored and reported on a population level through this source either. Therefore, we need to rely on individual academic papers to assess the incidence of childhood injury in Canada. This paper now turns to systematically reviewing the childhood injury incidence literature.

Chapter 2. Systematic Review Methods

The childhood injury incidence literature was systematically reviewed using methods adapted from the Cochrane Collaboration (Higgins & Green, 2011). Simon Fraser University's Faculty of Health Sciences Librarian also provided guidance regarding search terms and systematic reviews. The search covered the last 25 years (January 1990 to June 2015) and proceeded in an iterative manner comprising nine waves. Wave one provided an introduction to the literature and insight into appropriate relevant search terms by searching for review articles. The academic literature was searched next in waves two through four beginning with *Medline,* using an overly-inclusive "all child" filter, and then the Cumulative Index to Nursing and Allied Health Literature (*CINAHL),* filtering back to "all infant". In an effort to capture more nuanced forms of physical harm, the search approaches used in waves two and three were adapted in wave four by replacing 'Wounds and Injuries' OR 'Infant Mortality' OR 'Child Mortality' OR 'Mortality, Premature' OR 'Child Abuse' in *Medline,* and 'Child Abuse' OR 'Wounds and Injuries' OR 'Infant Mortality' in *CINAHL,* with the search term 'Failure to Thrive'. Waves five, six, and seven then involved searches for relevant dissertations and government/policy documents. *Web of Science* searches made up the eighth wave, seeking articles citing the most pertinent papers. Reference lists of relevant articles were hand searched throughout (wave nine). The list of databases used and the search details are presented in Table 1 and Table 2.

Table 1: List and Description of Databases Used in Systematic Review

Database	Description
Cochrane Database of Systematic Reviews	Regularly updated systematic reviews prepared by the Cochrane Collaboration.
Medline	Indexes more than 1,370 journals from the worldwide biomedical and health literature.
CINAHL	Indexes more than 1,300 journals from the fields of nursing and allied health.
Canadian Research Index	Publications of research value issued by the federal government, the 10 provinces and 3 territories, government agencies/departments, research institutes, and Statistics Canada.
Canadian Public Policy Collection	Public policy institutes, research institutes, think tanks, advocacy groups, government agencies and university research centers in all areas of Canadian public policy.
Web of Science	Ability to determine who cited a particular journal article.

Table 2: Systematic Literature Review Search Terms

Systematic Literature Review Search Terms			
Wave One: Search for Existing Reviews			
Medline	Searched MeSH Terms	Limiters: Review Articles; Last 25 years; English; All infant	Search Terms: 'Wounds and Injuries/Epidemiology/Mortality/Classification' OR 'Child Abuse /Classification /Mortality/ Statistics and Numerical Data'
Cochrane Database of Systematic Reviews	Searched Keywords in Abstract	Limiters: Last 25 years; English	Search Terms: (child* or infan* or p*ediatric*) AND (wound or injur* or trauma* or abuse)
Wave Two: Biomedical & Health Literature			
Medline	Searched MeSH Terms	Limiters: Last 25 years; English; All child (to be overly inclusive)	Three Search Term Strings: 1. 'Wounds and Injuries' OR 'Infant Mortality' OR 'Child Mortality' OR 'Mortality, Premature' OR 'Child Abuse' 2. 'Epidemiology' OR 'Incidence' OR 'Prevalence' 3. 'Population Surveillance' OR 'Public Health Surveillance' OR 'International Classification of Diseases' Conducted Three Searches: (A) 1 AND 2 AND 3 (B) 1 AND 2 (C) 1 AND 3
Wave Three: Nursing & Applied Health Literature			
CINAHL	Searched CINAHL Headings	Limiters: Last 25 years; English; All infant	Search Terms: 'Child Abuse' OR 'Wounds and Injuries' OR 'Infant Mortality' AND 'Child Safety' OR 'Population Surveillance' OR 'International Classification of Diseases' OR 'Incidence' OR 'Prevalence' OR 'Epidemiology' OR 'Disease Surveillance'
Wave Four: Failure to Thrive			
Medline	Searched MeSH Terms	Limiters: Last 25 years; English	Three Search Strings: 1. 'Failure to Thrive' 2. 'Epidemiology' OR 'Incidence' OR 'Prevalence' 3. 'Population Surveillance' OR 'Public Health Surveillance' OR 'International Classification of Diseases' Three Searches: (A) 1 AND 2 AND 3 (B) 1 AND 2 (C) 1 AND 3
CINAHL	Searched CINAHL Headings	Limiters: Last 25 years; English	Search Terms: 'Failure to Thrive' AND 'Child Safety' OR 'Population Surveillance' OR 'International Classification of Diseases' OR 'Incidence' OR 'Prevalence' OR 'Epidemiology' OR 'Disease Surveillance'
Table 2 continues below			

Systematic Literature Review Search Terms			
Wave Five: Dissertations & Theses			
Digital Dissertations	Keywords in Titles	Limiters: Last 25 Years; English	Search Terms: (inj* OR traum* OR mortality OR death) AND (child* OR infan* OR p*ediatric)
Wave Six: Government Reports/Research			
Canadian Research Index	Searched Keywords in Abstracts	Limiters: Last 25 years; English	Search Terms: (inj* OR traum* OR mortality OR death) AND (child* OR infan* OR p*ediatric)
Wave Seven: Canadian Policy Documents			
Canadian Public Policy Collection	Searched Subject and Text in Key Fields	No limiters due to small number of results	Search Terms: *subject* "Wounds And Injuries" OR "Child Abuse" AND *text and key fields* "child* OR infan* OR p*ediatric*"
Wave Eight: Web of Science			
(1) Found the articles that met all inclusion criteria in the current search in *Web of Science.* (2) Searched for all articles that cited the articles in step one above.			
Wave Nine: Hand Searches			
Reference lists of pertinent articles were searched by hand throughout.			

Note: Search strings used in wave two and four to manage large search results in *Medline.* Search A gives results that were indexed using all three strings, search B gives results indexed with strings one and two, and search C gives results indexed using strings one and three.

Article quality was assessed in three appraisal areas – measurement, data comprehensiveness, and developmentally-sensitive age groupings (Table 3). Regarding *measurement*, self-report health survey data underestimates the incidence of childhood injuries by at least 50 percent (White & Macpherson, 2012). Thus, to be included, studies must have used objective healthcare records classifying injuries with the International Statistical Classification of Diseases and Related Health Problems (ICD) tenth version or earlier (World Health Organization [WHO], 1992), and included *nature of injury diagnosis* (N) or *external cause* (E) codes. Regarding *comprehensiveness*, studies must have also used (at least) one large *population-based* dataset covering hospital admissions, or primary care and ER visits, or have used more than one data source to increase reliability (Potter et al., 2005). Furthermore, studies must have covered a range of injury types and severities, given the importance of both fatal and non-fatal injuries (Potter et al., 2005; Powell & Tanz, 2002).

Then regarding *developmentally-sensitive age grouping*s, studies must have used age groupings that revealed distinct child developmental features (Christoffel, 1993). Collapsing injury data from ages one to four years masks the elevated injury risk seen in one- and two-year-olds (Agran et al., 2001), for example. Furthermore, three- and four-year-olds display injury rates more similar to five-to-eight-year-olds than to one-to-two-year-olds (Agran et al., 2001). Thus, for this systematic review, studies must have presented their injury data for children aged younger than 24 months using one-year intervals (or shorter). Studies must have also expressed their data as a *rate* accounting for the size of the population from which the injuries occurred. All three appraisal criteria are summarized in Table 3.

Table 3: Systematic Literature Review Appraisal Criteria

Measurement	Objective healthcare record injury data (ICD N or E injury codes).
Data Comprehensiveness	Population-based data set covering range of injury types and severities from inpatient, or outpatient and ER.
Developmentally-Sensitive Age Groupings	Findings presented using one-year intervals (or shorter) for children aged younger than 24 months, expressed as a rate (accounting for population size).

Chapter 3. Systematic Review Results

Eight articles met all three appraisal criteria from Table 3 (see Figure 1). All eight are summarized in Table 4 and Table 5. There was one report (Safe Kids Canada, 2006) that presented rates of unintentional injury hospitalizations by single year (sourced from the Canadian Institute for Health Information [CIHI]); however, these results were *only* presented graphically and the exact details of the data and analyses were not clear. Therefore this report was excluded.

Figure 1: Flowchart Depicting Systematic Literature Review

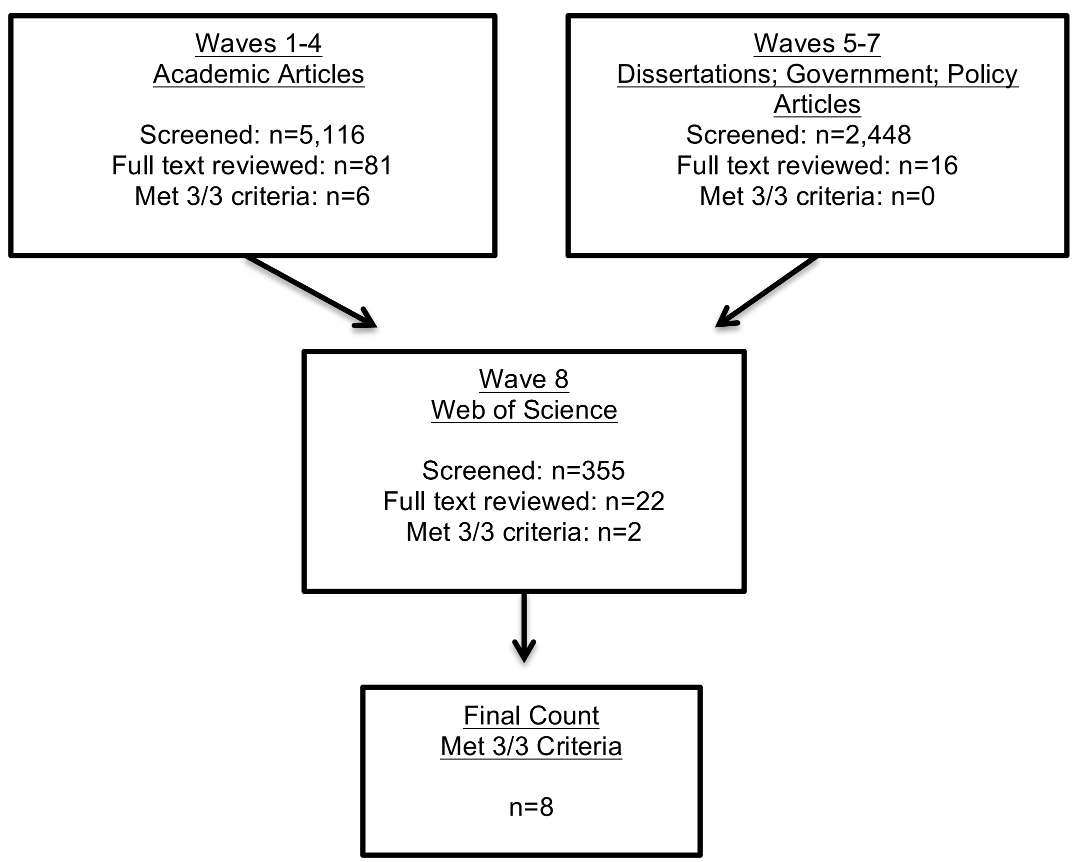

Table 4: Overview of Study Designs Included in Systematic Review

Author (Year)	Location & Year	Sample Size	Data Source	Classification	ICD Injury Codes
Spady, Saunders, Schopflocher, & Svenson, (2004)	Alberta, Canada; 1985-1998	96,559 Children (0-9yrs)	Universal Health Insurance. Hospital, Outpatient, & ER	ICD-9 Clinical Modification (CM) N Codes	800-904; 910-957; 960-994
Toblin et al., (2011)	Washington DC, USA; Oct/1/1995-Sept/30/1996	3,041 Injuries (0-3yrs)	ER and Inpatient from all 10 DC hospitals, plus death certificate	ICD-9 CM E Codes	E800-E999
Agran, Winn, Anderson, Trent, & Walton-Haynes, (2001)	California, US; 1997	37,211 Children (0-19yrs)	All Californians hospital discharges and death certificates	ICD-9 CM E Codes	E800-E69; E880-E929; E950-E999
Schmertmann, Williamson, & Black, (2012)	New South Wales, Australia; 1999-2009	64, 495 Injuries (0-4yrs)	Hospitalization (NSW Health Dept. Records)	ICD-10 Australian Modification (AM) E & N codes	V01-Y09; S00-T79
Agran, Anderson, Winn, Thayer, Trent, & Walton-Haynes, (2003)	California, USA; 1996-1998	23,173 Injuries (0-4yrs)	All Californians hospital discharges and death certificates	ICD-9 CM E Codes	E800-E69; E880-E929; E950-E999
Leventhal, Martin, & Gaither, (2012)	USA (38 States); 2006	4,569 Injuries (0-18yrs)	Discharge from 3739 non – rehabilitation community hospitals	ICD-9 CM E & N codes	800-959 with E960-E968 or E995.55
Gilbride, Wild, Wilson, Svenson, & Spady, (2006)	Alberta, Canada; April 1st, 1995 to March 31st, 1996	182,759 Children (0-17yrs)	Universal health insurance. Outpatient, Inpatient, ER	ICD-9 CM N Codes	800-999
Guice, Cassidy, & Oldham, (2007)	USA (36 States); 2003	146,358 Injuries (0-18yrs)	Discharge from non – rehabilitation community hospitals	ICD-9 CM E & N codes	800-904; 925-929; 940-959

Table 5: Summary of Findings of Studies Included in Systematic Review

<table>
<tr><th rowspan="2">Author</th><th rowspan="2">Injury Data</th><th rowspan="2">Intent</th><th colspan="8">Age and Injury Rate Per 1,000</th></tr>
<tr><th colspan="4">< 1 Year Old</th><th colspan="4">1 year old</th></tr>
<tr><td rowspan="2">Spady, Saunders, Schopflocher, & Svenson, (2004)</td><td rowspan="2">ER, Inpatient, Outpatient</td><td rowspan="2">Not Studied</td><td colspan="4">158.0 (male)</td><td colspan="4">374.3 (male)</td></tr>
<tr><td colspan="4">143.2 (female)</td><td colspan="4">300.4 (female)</td></tr>
<tr><td>Toblin et al., (2011)</td><td>ER, Inpatient, Death</td><td>Unintentional & Intentional</td><td colspan="4">159</td><td colspan="4">193</td></tr>
<tr><td>Agran, Winn, Anderson, Trent, & Walton-Haynes, (2001)</td><td>Inpatient, Death</td><td>Unintentional & Intentional</td><td colspan="4">3.4</td><td colspan="4">5.0</td></tr>
<tr><td>Schmertmann, Williamson, & Black, (2012)</td><td>Inpatient</td><td>Unintentional and Intentional (But only reported leading causes of injury)</td><td colspan="4">0.8 (Fall while carried)
0.5 (Bed Fall)
0.4 (Fall from 1 level) 0.4 (Furniture fall)
0.4 (IPV)</td><td colspan="4">1.4 (Burn drinks, oils)
1.0 (Between 2 objects)
1.0 (Struck by/against)
0.8 (Chair fall)
0.8 (Fall same level)</td></tr>
<tr><td rowspan="3">Agran, Anderson, Winn, Thayer, Trent, & Walton-Haynes, (2003)</td><td rowspan="3">Inpatient, Death</td><td rowspan="3">Unintentional & Intentional</td><th colspan="8">Age in Months</th></tr>
<tr><th>0-2</th><th>3-5</th><th>6-8</th><th>9-11</th><th>12-14</th><th>15-17</th><th>18-20</th><th>21-23</th></tr>
<tr><td>3.4</td><td>2.6</td><td>3.3</td><td>4.2</td><td>4.7</td><td>5.1</td><td>4.8</td><td>4.6</td></tr>
<tr><th colspan="11">Studies with unclear rates by single year graphically only</th></tr>
<tr><td rowspan="2">Leventhal, Martin, & Gaither, (2012)</td><td rowspan="2">Inpatient coded for physical abuse</td><td rowspan="2">Intentional Injuries (Physical abuse)</td><th colspan="4">< 1yr Old</th><th colspan="4">0-3 years</th></tr>
<tr><td colspan="4">0.6</td><td colspan="4">0.3</td></tr>
<tr><td rowspan="2">Gilbride, Wild, Wilson, Svenson, & Spady, (2006)</td><td rowspan="2">ER, Inpatient, Outpatient</td><td rowspan="2">Not Studied</td><td colspan="4" rowspan="2">57.9</td><th colspan="4">1-4 years</th></tr>
<tr><td colspan="4">238.3</td></tr>
<tr><td>Guice, Cassidy, & Oldham, (2007)</td><td>Inpatient</td><td>Unintentional & Intentional (Excluded late effects, superficial injuries, and foreign bodies)</td><td colspan="4">2.1 (Northeast)
1.8 (Midwest)
1.6 (South)
1.6 (West)</td><td colspan="4">1.8 (Northeast)
1.5 (Midwest)
1.5 (South)
1.8 (West)</td></tr>
</table>

As seen in Table 4 and Table 5, of the eight studies that met inclusion criteria, five were conducted in the US, one in Australia, and two in Canada (both in Alberta). The two Albertan studies were the most comprehensive in that they included outpatient, ER, and inpatient visits (Spady, Saunders, Schopflocher, & Svenson, 2004; Gilbride, Wild, Wilson, Svenson, & Spady, 2006). Of the remaining six articles, one used ER, inpatient, and death records (Toblin et al., 2001), and five used either inpatient records alone, or inpatient records paired with death certificate records. The comprehensiveness of the data source used is important since including less serious (and more common) injuries increases injury rates. For example, using ER, inpatient, and *outpatien*t data (Spady et al., 2004) results in higher injury rates compared to ER, inpatient, and *mortality* data (Toblin et al., 2011; see Table 5). Injuries were most commonly classified using the ICD-9, with only one study (Schmertmann, Williamson, & Black, 2012) using the ICD-10 (WHO, 1992). There was also variability regarding whether studies calculated rates of injury types (e.g., fractures) or causes (e.g., falls). For example, the two studies from Alberta used only N codes, and as such did not study cause or intent. One study reported both types *and* causes of injuries (Guice, Cassidy, & Oldham, 2007), but did so using age groupings of less than one year and one to four years. The remaining five studies reported only causes of injuries. Although all eight studies presented injury rates using age groupings of no more than one year, variability was again present. Agran and colleagues (2003) presented injury rates using three-month intervals, and was the only study to use age groupings of less than one year. The seven other studies used age intervals of precisely one year – with three presenting results by single year *graphically* only, which made their exact findings unclear and difficult to interpret.

Regarding injury incidence, and as seen in Table 5, injuries occurred at rates of 159 per 1,000 in children under one, and 193 per 1,000 in one-year-olds (Toblin et al., 2011). Split by gender, Spady et al., (2004) found that annual child injury episodes occurred at rates ranging from 143 per 1,000 girls under one to 374 per 1,000 in one-year-old boys. Consistent with past research, Spady et al., (2004) found higher injury rates among boys. Explanations for this pattern vary, but some authors suggest that differential socialization and socially constructed gender norms account for the higher rates seen among boys (e.g., Morrongiello & Dawber, 1999). Using intervals shorter than one year, Agran et al. (2003) found unintentional and intentional injury-related hospitalizations and deaths occurred at rates ranging from three per 1,000 in three-to-five-month-old children to six per 1,000 in 15-to-17-month-old children. Severity of injury may also be directly related to a child's age. Tracy and colleagues (2013) found that injury severity scores (ISS) were bi-modal – ISS were high among children under one, decreased at one year of age, then generally increased into the teen years with a peak around ages 16–17 years. This pattern was generally seen for injury rates to children as well (using one year age groupings).

3.1. Injury Causes and Developmentally-Sensitive Age Groupings

Regarding injury *causes*, the age groupings used to present injury rates is again important. In particular, different rates are seen in one- and four-year-olds. Comparing unintentional poisonings between these age groups, for example, shows a sixfold increased risk for one-year-old children (Agran et al., 2001). Furthermore, presenting injury rates by clustering ages one through four masks the fact the following events are all more common in one-year-olds: injuries due to hot objects or substances; unintentional poisoning; pool and spa submersion or drowning; and falls from furniture (Agran et al., 2001). Table 6 presents the variability that is masked by aggregate analyses (e.g., largest and smallest rates by single year versus aggregate rates of injury causes). Similarly, Schmertmann, Williamson, & Black, (2012) found that aggregate analyses (i.e., 0-4 years) highlighted falls involving playground equipment as the leading cause of injury, while analyzing injury rates by single year resulted in four *different* leading causes of injury over the same age range (i.e., <1 year: fall while being carried or supported by other persons; 1 year: burn by hot drinks, food, fats and cooking oils; 2 years: poisoning by other and unspecified pharmaceuticals; 3 years: fall involving playground equipment). Agran and colleagues (2003) suggest that even single year age groupings are too large to reveal important differences in injury risk to young children. For children zero to 12 months of age, for example, she found there was a different leading cause of injury for children aged birth to two months (other falls from height), three to five months (battering), six to eight months (falls from furniture), and nine to eleven months (non-airway foreign body). They also found that for children aged 12 to 17 months, hot liquid and vapor injuries was the most common specific injury, and that children aged 15 to 17 months had the highest injury rate overall.

Table 6: Variability Of Injury Rates Missed Using Aggregate Analyses

	Rate per 100,000		
Injury Cause	**1 year olds**	**4 year olds**	**1-4 year olds**
Hot objects/substances	60	7	23
Foreign body, except eye and respiratory	10	40	19
Unintentional poisoning	83	14	46
Falls from playground equipment	4	19	12
Pool and spa submersion/drowning	21	6	14
Falls from furniture	44	15	28
Falls from buildings	7	16	12

Note: Adapted from Agran et al. (2001)

Chapter 4. Discussion

There were eight studies that met all three appraisal criteria (i.e., comprehensive, ICD-coded, population-based injury data reported as a rate by single year or less), although variability was present. Generally, reporting injury rates by single year shows a bimodal pattern – all-cause injury rates are highest by the first year of life, decline, and then rise into the mid-to-late teenage years. Tracy and colleagues (2013) presented data to suggest that this pattern is similar for injury severity as well. Spady and colleagues (2004) presented the best Canadian estimates, finding annual child injury episodes of 158 per 1,000 boys under one, 375 per 1,000 one-year old boys, 143 per 1,000 girls under one, and 301 per 1,000 one-year-old girls in Alberta.

Yet reporting the data by three-month intervals reveals additional detail. Agran et al. (2003) – the only study to report injury rates using intervals of less than one year – found that the highest rate of injury-related hospitalization and death for children younger than three years was between months 15 to 17 of life. She also found a different leading cause of injury during the first 12 months of life for *each* of four age intervals reported (i.e., 0-2; 3-5; 6-8; 9-11 months). Thus reporting injury rates using intervals of less than one year helps to better understand injuries to young children. This idea is not new, however. Reporting injuries to children younger than 24 months by *single* month of life has been recommended in the past (Christoffel et al., 1992; Christoffel 1993). Similar recommendations are still being made (e.g., Siskind & Scott, 2013). Some authors continue to report injuries to young children using large age groupings, however (e.g., White & Macpherson, 2012; Scime et al., 2010). Such large age groupings may be appropriate when presenting injury rates covering larger age ranges (i.e., birth to 18 years), for example, but more intricate details would be lost. Aggregate age group analyses mask injury risks related to a child's developmental progress, such as falls from furniture (Agran et al., 2001; Table 6), seen among very young children, who are most vulnerable. Thus, more precise injury rate presentations help to better understand injuries and protect young children by highlighting the types and causes of injuries that are associated with a child's developmental stage.

It is possible that some authors are using population estimates provided by government agencies to find appropriate denominators, and are therefore using aggregate age groupings. For example, Vandenbroucke and Pearce (2012) suggest that since dynamic populations (i.e., populations without fixed membership) are never completely in steady state, the estimated average population per year must be multiplied by the observation period and then used to approximate the total number of person-years for all rate calculations. Currently, large age groupings (i.e., 0-4; <1, 1-4 years) are readily available, but smaller population estimates are more rare. Statistics Canada (2015) provides mid-point population estimates by single year (by manipulating Table 051-0001) and the annual estimated number of births (Table 051-0013), but does not provide population estimates by single *month* for young children. To construct such population estimates, additional analyses (such as linear interpolation) are required in order to make "estimates from estimates" (e.g., Agran et al., 2003; Fujiwara, Barr, Brant, Rajabali, & Pike, 2012). If single-month-of-life estimates were provided by Statistics Canada, this could increase the number of studies reporting injury rates by single month, thereby allowing for more uniform reporting and comparison of findings. Such estimates may be helpful within child health research more broadly as well, potentially allowing for more detailed analyses. Using smaller age groupings to present injury rates leads to a better understanding of injuries to young children and their causes. This information could be used to inform prevention as well by highlighting factors amenable to prevention.

Any childhood injury prevention campaign should be accompanied by routine monitoring and reporting of injuries to assess if injury rates are decreasing. Although injury data is currently being collected in Canada, there is no surveillance system routinely reporting childhood injury rates. To be truly comprehensive, injury data ideally needs to be collected from outpatient, ER, inpatient, and mortality sources and needs to include both severe and minor injuries (e.g., Ferguson, Shields, Cookson, & Gielen, 2013; Lang et al., 2014; Hambidge, Davidson, Gonzales, & Steiner, 2002). An objective standardized classification scheme, such as the ICD-10 (WHO, 1992), is also essential.

Including both ICD E and N codes may be ideal, as in some cases E codes may be inaccurate or unavailable due to insufficient detail regarding the injury event (e.g., McKenzie, Enraght-Moony, Walker, McClure, & Harrison, 2009). Such a system could be used to monitor the burden of injuries to young children *and* inform prevention efforts by highlighting specific injuries (or their causes) that occur more frequently for certain populations. Such a national surveillance approach could entail collating current injury sources (i.e., DAD, HMDB, NACRS). Alternatively, injury surveillance could be tackled at the provincial level. Injury-related billing records would be comprehensive, in that they would capture all physician fee-for-service injury-related visits in outpatient, ER, and inpatient facilities; however, such records may lack cause of injury data (e.g., Spady et al., 2004; Gilbride et al., 2006). These sources may also need to be linked with mortality records.

Ensuring consistent use of the same *version* of the ICD may also present a challenge as the ICD is updated. For example, when the DAD began using the tenth version of the ICD, it took two years for the change to be taken up uniformly by all provinces (CIHI, 2012). Capturing other demographic information may also be important. For example, lower socio-economic status is associated with increased injury risk (e.g., Gilbride et al., 2006; Brownell, Friesen, & Mayer, 2002). Additionally, Aboriginal communities (Alaghehbandan, Sikdar, MacDonald, Collins, & Rossignol, 2010), and areas with high Aboriginal populations (Oliver & Kohen, 2012), have also been shown to have elevated child injury rates. Some authors suggest that social disadvantage may explain these findings as well (e.g., Alaghehbandan, Sikdar, MacDonald, Collins, & Rossignol, 2010). Additional considerations may be needed to accommodate more northern communities, as health records can be fragmented and only partially reported in these areas (e.g., CIHI, 2012; Pike et al., 2012). Any such additional considerations are important, however, in order for a surveillance system to be truly national and capture *all* Canadian children.

In conclusion, the childhood injury incidence literature often relies on age groupings that are too large and too variable. As such, findings from the studies meeting all three appraisal criteria were difficult to compare. Despite the variability in study design and injury rates, it is clear that children were experiencing injuries serious enough to warrant seeking medical care too often – many children died as a result of their injuries. If vital statistics (from bodies such as Statistics Canada) were presented by single month of life for children younger than two years of age, this would allow researchers to report child injury rates in a more uniform and informative manner. Such calculations might also uncover additional age-related injury risks, as the smallest age groupings used to date is three months (Agran et al., 2003). More precise analyses could also inform new prevention efforts by uncovering populations with higher injury incidence, as well as factors amenable to prevention. A national injury surveillance program that included the aforementioned elements would allow for *routine reporting* of injuries to young children in a developmentally-sensitive way. Thus, relying solely on individual academic papers would be unnecessary because the incidence of injuries to young children would be routinely reported through an ongoing surveillance system.

This reporting could also be an efficient way to attract a larger audience. The profile of pediatric injury could be raised if surveillance reports were made available online, and thereby reaching people who may not regularly read peer reviewed academic journal articles, and by implementing public health advocacy principles (e.g., Pless, 2007; Chapman, 2004). Such a surveillance program also need not be overly expensive. Routinely collected administrative data (e.g., DAD, HMDB, NACRS) could be re-purposed to serve as the injury surveillance data source. Ultimately, childhood injuries can be understood and often prevented, and a national injury surveillance system would certainly contribute to this end. A unified national public health approach is needed to monitor, understand the rates and causes, and therefore inform prevention efforts regarding injuries to young children. But simply informing prevention efforts by highlighting factors amenable to prevention is not enough (e.g., Pless, 2008). Despite evidence suggesting that unintentional and intentional injuries to children *can* be prevented (e.g., Kendrick et al., 2013; MacMillan et al., 2009), calls for injury prevention in Canada are still relevant, as comprehensive national injury prevention efforts are lacking (e.g., Atlantic Network on Injury Prevention, 2003; SMARTRISK, 2005; Parachute, 2015). Young children are still being injured in predictable ways, with serious consequences. Spending the time and money to better understand injuries to young children is important and necessary, but the knowledge gained must also be put into action in order to reduce harm and increase the wellbeing of young children and their families.

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