Trends in unintentional injury mortality in Canadian children 1950–2009 and association with selected population-level interventions

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ABSTRACT

OBJECTIVES: To examine unintentional injury mortality rates in children (0–19 years) in Canada from 1950 to 2009 against national population-level injury prevention interventions.

METHODS: Injury mortality rates were age and sex adjusted. Changes in trend and level of mortality rates were assessed at pre-specified intervention periods using segmented linear regression analyses for interrupted time series. Maximum likelihood estimation was used with a second order autoregressive error process.

RESULTS: From 1950 to 2009, the overall unintentional injury mortality rate decreased by 86%. Males had consistently higher mortality rates compared to females; however, the standardized rate ratio decreased from 2.37:1 in 1950 to 1.97:1 in 2009. Substantial declines in choking/suffocation deaths were noted in children less than 1 year of age, predominantly during the period 1970–1988 when the Hazardous Products Act and Crib Regulations were implemented. For burns, significant changes in slope were noted comparing 1972–1994 to pre-1971 (introduction of the Hazardous Products Act – Flammability Regulations), where the greatest decline was noted in children ages 1–4 years (Est. = −0.03, 95% CI = −0.02, −0.04). For 15–19 year olds, there was a 408% increase in motor vehicle collision-related mortality rates between 1950 and 1971; however a significant change in slope was noted during the period 1978–1985, compared to 1972–1977 (Est. = −0.10, 95% CI = −0.20, −0.007) across all age groups.

CONCLUSION: While this study is not a cause and effect analysis, there is a strong association with implementation of safety campaigns and legislative changes related to child safety and a dramatic decline in childhood fatalities related to injury.

KEY WORDS: Adolescent; Canada/epidemiology; cause of death; mortality/trends; wounds and injuries/mortality; wounds and injuries/prevention & control; child; preschool; infant

La traduction du résumé se trouve à la fin de l'article.

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Unintentional injury accounts for 10% of all deaths worldwide.[1] In Canada, unintentional injury is the leading cause of death among children 1–19 years of age.[2] Implementing effective injury prevention interventions is key, given that up to 90% of childhood unintentional injuries are considered preventable.[3] Effective strategies to reduce injury fall into the three Es of injury prevention: *education* (e.g., awareness campaigns), *enforcement* (e.g., implementation of legislation), *engineering/environmental* (e.g., child resistant packaging), or a combination of all three.[4] There are many examples of prevention strategies that have reduced the burden of injury, for example, graduated driver licensing laws have been associated with a 30% reduction in fatal car crashes among 15–17 year olds, and the mandatory use of child safety seats has been estimated to reduce the risk of death for infant occupants by up to 71%.[5] The objective of this study was to examine the unintentional injury mortality rates by age and sex in Canadian children over a 60-year period and to examine changes in mortality rates against selected national-/population-level injury prevention strategies.

METHODS

Childhood injury mortality data from 1950 to 2009 were obtained from the Canadian Vital Statistics Death Database from Statistics Canada and the Public Health Agency of Canada.[6,7] Unintentional injury mortality data were categorized by age group (<1, 1–4, 5–9, 10–14, 15–19 years) and by sex. Deaths by injury type were coded using the World Health Organization International Classification of Diseases, tenth version (ICD-10). Code equivalency across five ICD versions was based on work by injury epidemiologists in the Health Surveillance and Epidemiology Division of the Public

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Health Agency of Canada. Unintentional injuries because of firearms were not analyzed given the lack of clear coding equivalents from ICD-6 (1950). Unintentional injury deaths by major injury types: motor vehicle collisions (MVCs, particularly occupants), choking/suffocation, and burns, were specifically analyzed. Major national-/population-level injury prevention strategies for motor vehicle collisions, choking/suffocation, and burns were identified from in-print Federal Statutes and Regulations of Canada, Canadian Justice Law Website, published literature, and grey literature reports (Public Health Agency of Canada and Safe Kids Canada).

Analysis

Annual mortality rates by category of unintentional injury death (series) were calculated from 1950 to 2009, and age and sex adjusted. It was deemed necessary to apply a square-root transformation to each series to stabilize the standard errors. The square-root transformed series were then assessed for changes in slope at pre-specified intervention periods using segmented linear regression analyses for interrupted time series.[8] Each regression model (by age group) assessed multiple interventions. This was done by examining the linear trends before and after each intervention period, removing the relevant years from the series upon which a segmented regression model was applied. Separate analyses on MVC mortality rates were conducted for age categories 0–19 years and 15–19 years, to examine the effect of MVC-specific policy interventions across all ages and of graduated driver licencing in the age group 15–19 years. Maximum likelihood estimation was used with a second order autoregressive error process. All statistical analyses were performed using the SAS software version 9.3 (SAS Institute Inc., Cary, NC), with statistical significance evaluated using two-sided *p*-values at the 5% testing level.

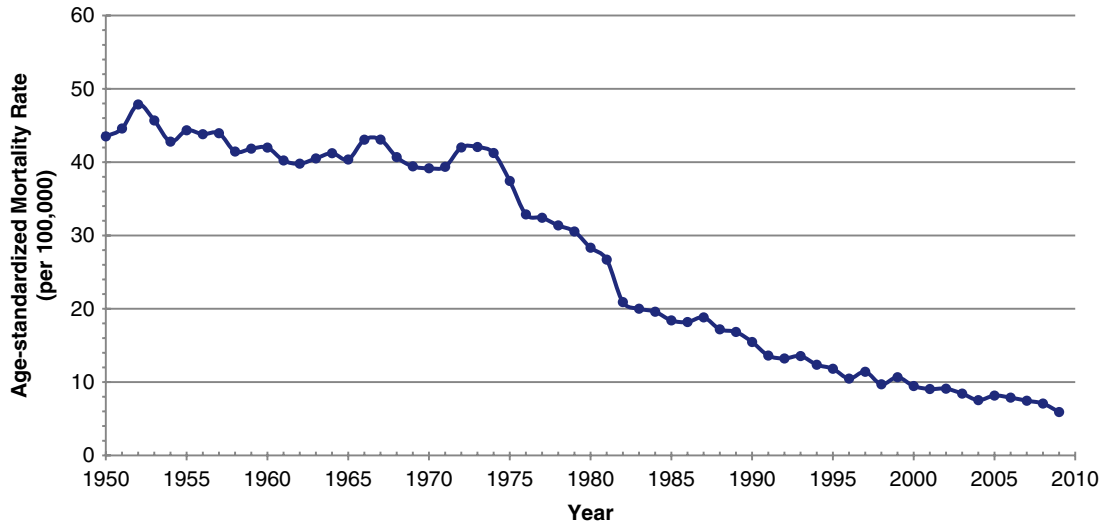

Figure 1. Mortality rates for all unintentional injuries in children 0–19 years (1950–2009)

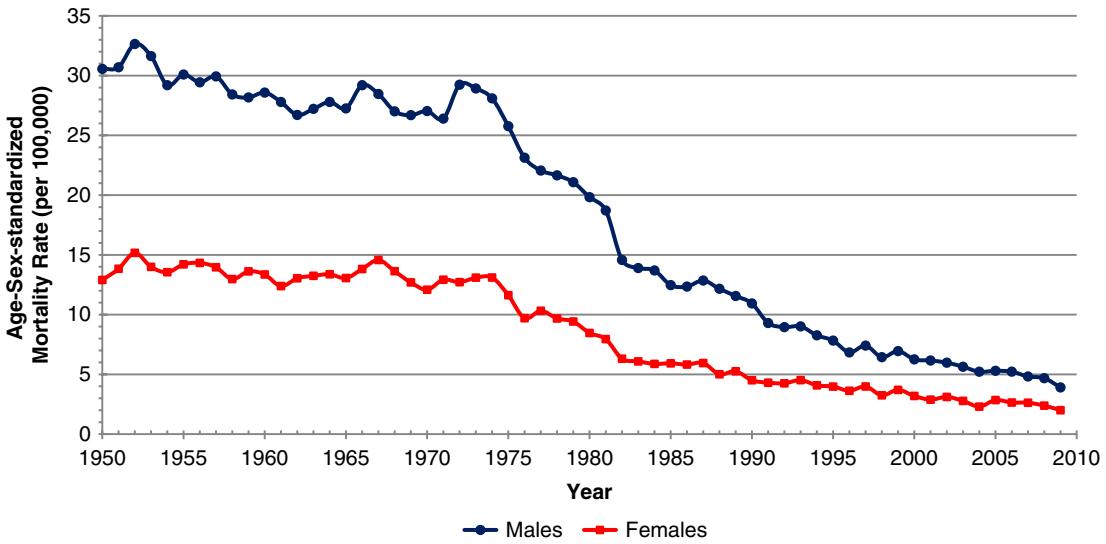

Figure 2. Mortality rates for all unintentional injuries by sex, ages 0–19 years (1950–2009)

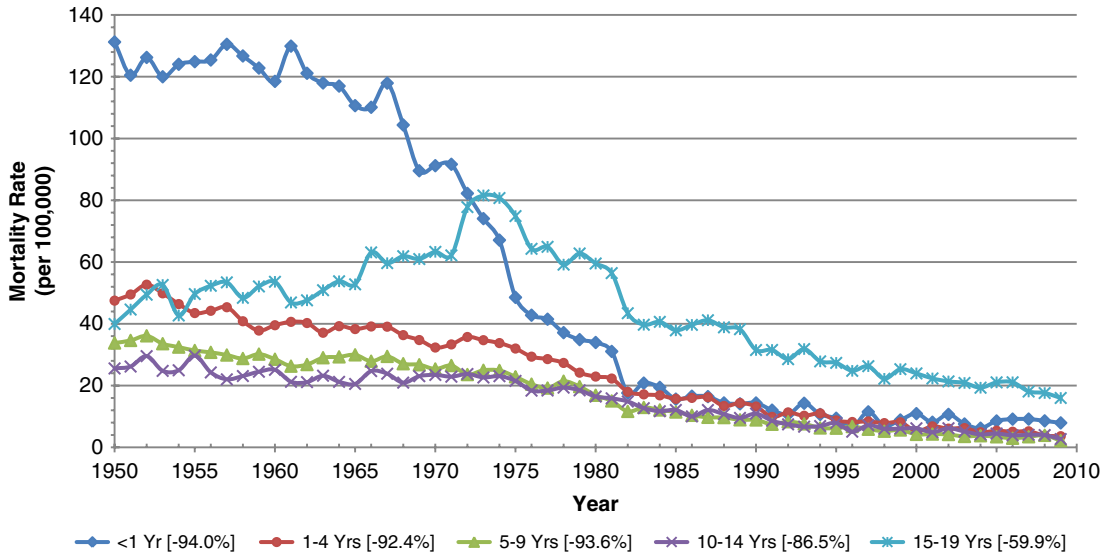

Figure 3. Mortality rates for all unintentional injuries by age group (1950–2009)

Table 1. Intervention by injury type and year of implementation

Cause of death	Intervention	Year implemented
Choking, choking other*/suffocation	Hazardous Products Act – Juvenile Product Safety	1969
	Heart Saver Program	1980
	Consumer Product Packaging & Labeling	1985
	Crib Regulations	1986
Fire/flame/scalds	Hazardous Products Act – Flammability Requirements for Children's Sleepwear and Bedding	1971
	Child Resistant Lighters Regulation & Labelling Requirements	1994
Motor vehicle collision	Criminal Law Amendment Act (Introduced Drinking & Driving Offences)	1969
	Motor Vehicle Safety Act – Seat Belts Required in All New Vehicles	1971
	Mandatory Seat Belt Laws in Ontario, Quebec, Saskatchewan and British Columbia	1976–1977
	Amendments to Criminal Code – Tougher Penalties for Impaired Drivers	1985
	National Occupant Restraint Program – Campaign to Increase Seatbelt Usage	1989
	Graduated Licensing Programs Introduced in Most Canadian Jurisdictions	1994

* Choking: food and gastric, choking other: other objects.

RESULTS

Mortality data

During the study period, the most common cause of unintentional injury death among children 0–19 years was MVCs (49%), followed by drowning (15%), burns (7%), choking (6%), suffocation (3%), falls (3%) and poisoning (1%). Between 1950 and 2009, the absolute age-sex adjusted mortality rate (ASMR) decreased from 43.5/100,000 to 5.9/100,000; a relative decrease of 86% (Figure 1). Males had consistently higher unintentional injury mortality rates compared to females; however, the male:female rate ratio declined from 2.37:1 in 1950 to 1.97:1 in 2009 (Figure 2). From 1950 to 1973, there was a steady decrease in male and female mortality rates; however, a sharp decline in mortality rates was observed post-1974. Figure 3 illustrates the change in injury-related deaths between 1950 and 2009 by age group.

National-/population-level injury prevention interventions

In total, 12 national-/population-level injury prevention strategies related to motor vehicle collisions, burns, and choking/suffocation were identified from in-print copies of Federal Statutes and Regulations of Canada, from the Canadian Justice Law Website, published literature, and grey literature reports. Table 1 describes four identified strategies for the prevention of choking/suffocation, two identified strategies for the prevention of injuries from fire/flames, and six strategies for the prevention of MVCs (specific to occupants and drivers) and the year of implementation of the strategy. Table 2 describes all statistically significant changes in slope by injury type and comparison years.

Choking/suffocation mortality in infants (<1 year)

Trends in mortality rates among infants (<1 year) from choking/suffocation were compared in four segments: 1950–1969 (start of dataset to implementation of the Hazardous Product Act – Juvenile Product Safety), 1970–1980 (to implementation of the Heart Saver Program), 1981–1986 (to implementation of the Consumer Product Packaging & Labelling and Crib Legislation), and post-1986. Across all intervention time periods, the segmented regression model showed estimated slopes to be significantly steeper, post compared to pre intervention (Figure 4). Table 2 quantifies the changes in slope in injury

Table 2. Statistically significant changes in slope in injury mortality rates before and after specific interventions for choking/suffocation, burns and MVCs in children 0–19 years, 1950–2009

Age group	Injury type	Comparison years	Change in slope	95% CI*
<1 year	Choking†	1970–1980, pre-1970	−0.36	−0.44, −0.28
	Choking‡	1970–1980, pre-1970	−0.10	−0.18, −0.03
	Suffocation	1970–1980, pre-1970	−0.24	−0.31, −0.17
	Suffocation	1981–1986, 1970–1980	0.25	0.05, 0.46
1–4 years	Burns (fire/flames/scalds)	1972–1994, pre-1971	−0.03	−0.04, −0.02
		Post-1994, 1972–1994	0.03	0.02, 0.05
5–9 years		1972–1994, pre-1971	−0.02	−0.04, −0.01
10–14 years		Post-1994, 1972–1994	0.02	0.003, 0.03
0–19 years	Motor vehicle collisions	1972–1977, 1978–1985	−0.10	−0.20, −0.007

* Confidence interval.
† Choking: food and gastric.
‡ Choking: other objects.

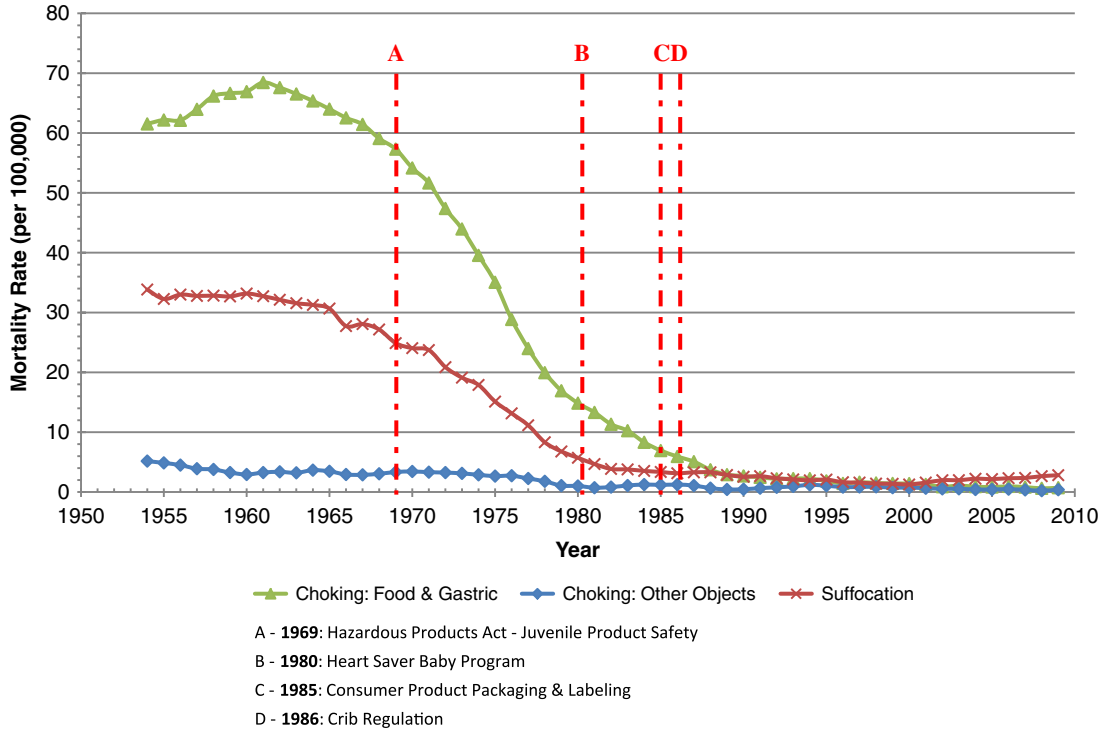

Figure 4. Injury prevention interventions and choking/suffocation mortality rate among infants <1 year of age (1950–2009)

mortality rates before and after specific interventions for choking/suffocation, burns and MVCs in children 0–19 years, over the time period 1950–2009.

Burns (fire/flame/scalds) mortality in children 1–14 years

Trends in mortality rates among children 1–14 years resulting from burns (fire/flame/scalds) were compared in three segments: 1950–1971, 1972–1994 and post-1994 (based on implementation of interventions), across three age groups (1–4 years, 5–9 years and 10–14 years). The segmented regression model detected significantly steeper slopes, post compared to pre intervention across all interventions (Table 2), with the greatest decline in burn injuries occurring during the period 1972–1994 (compared to pre-1971) for children ages 1–4 years (Figure 5).

Motor vehicle collision mortality in children 1–19 years

Trends in MVC occupant mortality rates among children age 0–19 years and 15–19 years were compared in seven segments: 1950–1969, 1970–1971, 1972–1977, 1978–1985, 1986–1989, 1990–1994 and post-1994, based on implementation of interventions. The segmented regression model showed that the estimated slope for 1978–1985 was significantly steeper compared to 1972–1977 (Est. = −0.10, 95% CI = −0.20, −0.01). Adolescents between the ages of 15–19 years were the only age group to experience an increase in MVC mortality rates over the study period (Figure 6).

DISCUSSION

The decline in the unintentional injury mortality rate in children 0–19 years over the 60-year period is dramatic. Of note, males had consistently higher mortality rates compared to females. The age

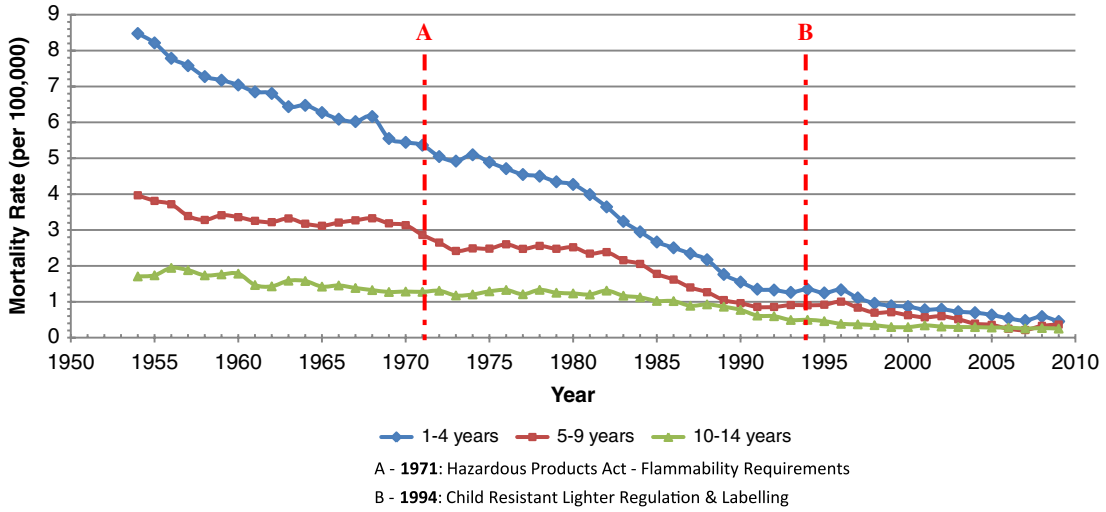

Figure 5. Injury prevention interventions and burn mortality rate, by age group (1950–2009)

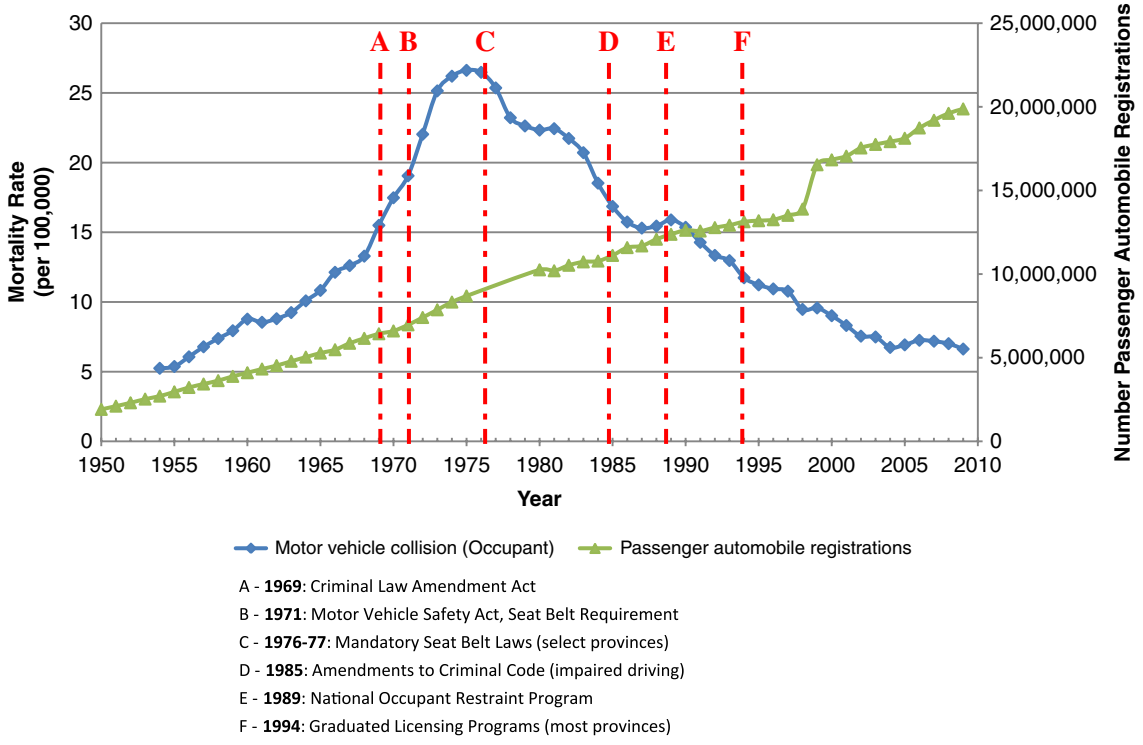

Figure 6. Injury prevention interventions and motor vehicle collision mortality rates in adolescents 15–19 years and passenger automobile registrations (1950–2009)

group <1 year experienced the largest decline in mortality rates and represented 11% of all deaths in this cohort. Adolescents (15–19 years) were the only paediatric age group to experience an increase in unintentional injury mortality rates over the time period of study; this occurred between 1950 and 1975 and was related to MVCs.

The sharp decline in mortality rates related to infant choking was predominant between 1970 and 1980, compared to pre-1971 and may be associated with implementation of the *Hazardous Product Act* (or Juvenile Product Act) in 1969.[9] Predominant causes of choking in infants are food items such as nuts, carrots, hot dogs and grapes, and small items found in the home.[9] The purpose of the *Hazardous Product Act* was to "control the advertisement, sale and importation of potentially hazardous products (including toys) in Canada".[9] It is also likely that improved medical care and emergency responsiveness played a significant role. For example,

Nathens et al. (2000) showed that implementation of regional trauma systems reduced the risk of death from injury.[10] In the 1970s, lay rescuers were advised to utilize any one or a combination of three lifesaving manoeuvres for conscious choking adults. These included the back-blow and chest thrust manoeuvre, the Heimlich manoeuvre, and shoulder blows.[11] At that time, however, there were no Canadian guidelines for effective management of choking in infants. In 1980, the first "heart-saver baby" program began, specifically designed to train parents, babysitters and day-care personnel in basic cardio-pulmonary techniques for unconscious infants.[12] In 1986, the *Crib Regulations Act* required all cribs to adhere to government safety standards to reduce the number of entrapments (side rails) and suffocation deaths.[13]

Several interventions may have contributed to the decline in burn injuries. The 1971 *Flammability Requirements for Children's Sleepwear and Bedding Act* outlined flammability standards.[14] In addition, there were stricter regulations imposed later; for example, in 1987, the *Flammability Requirements for Children's Sleepwear and Bedding Act* was amended based on published research. This amendment required loose garments to be made of pure synthetic fabrics (e.g., polyester, nylon), i.e., materials that will not burn at temperatures associated with ignition devices found in the home.[15] The first National Building Code of Canada published in 1941 described: 1) reducing scald burns in homes by regulating water temperatures; and 2) reducing the spread of fires and improving construction design to allow for easy exit routes in case of fire.[16] In 1980, the Canadian Standards Association made recommendations on factory requirements for residential hot water tanks, including thermostat regulations set at 49° C, and for external heater controls for temperature adjustment; hot water educational programs for consumers; manufacturer-issued manuals for the operation of hot water heaters; and improvements in the accuracy of thermostats.[17] Moreover, awareness campaigns on the importance of fire prevention began as early as 1923 during the annual National Fire Prevention Week.[18] In 1994, *Child Resistant Lighters and Labelling Requirements* further increased the requirement for safety features to prevent burn injuries.[19]

From 1950 to 1971, there was a fourfold increase in MVC mortality rates in 15–19 year olds. Passenger automobile registrations also quadrupled during this time frame;[20] however, passenger automobile registrations continued to increase post-1971, while mortality rates declined. The early 1970s was a period associated with an increased focus on safety features in vehicles, and the implementation and enforcement of legislation. For example, in 1971, all new vehicles required a National Safety Mark that certified automobile manufacturing as per the safety requirements of the *Motor Vehicle Safety Act*.[21] In addition, seat belts were required in all new vehicles beginning in 1971, and mandatory seat belt legislation came into effect in 1976–1977 across the provinces of Ontario, Quebec, Saskatchewan and British Columbia.[21] Concomitantly, these years demonstrated significant declines in MVC fatalities in children 0–19 years, compared to the period 1972–1977. The most recent survey (2009–2010) by Transport Canada reports that seat belt use is approximately 95%.[22] In addition, the 1969 *Criminal Law Amendment Act* made it illegal to drive with a blood alcohol concentration of more than 80 mg/100 ml.[23] Of note, blood alcohol levels under the legal limit (50%–60% range) may be sufficient to impair an inexperienced driver.[24] By 1989, MVC mortality rates in adolescents declined significantly. In 1985, amendments to the Criminal Code resulted in stricter penalties (higher fines, jail time, licence suspension) for impaired driving.[25] Currently across most provinces, there is a zero blood alcohol tolerance in young drivers under 21 years of age.[26] By 1994, most provinces also required new drivers to undergo a graduated drivers licensing (GDL) program.

Strengths and limitations

This study examined long-term temporal trends of childhood injury mortality in Canada. Data were obtained from Statistics Canada – a national mortality database; therefore, the data are population-based and representative. Considering the timeline of the study, however, it is important to acknowledge the five ICD manual revisions made in the past 60 years. While efforts have been taken to ensure consistency in coding between revised ICD manuals, some coding differences may have existed. For example, beginning in 1969, ICD-8 specified MVC deaths by road user type (pedestrian, occupant, driver, etc.) and type of collision (motor vehicle collision with a bicycle, motor bus, street car, etc.), based on a fourth digit code. In earlier versions, the fourth digit subgrouped collision type without specification of the road user.

The Statistics Canada dataset is limited in content; therefore, the potential for confounding by variables unavailable for consideration is possible. While the national-/population-level interventions described in this paper are likely associated with the decline in unintentional injury mortality rates, other social and demographic factors are also likely to have contributed to the findings. There is some evidence that education and safety campaigns may be effective; for example, road safety campaigns have reported effectiveness in reducing collisions,[27] and alcohol-impaired driving and collisions.[28,29] However, the literature would generally suggest that safety campaigns are less effective than environmental and legislative change.[30] In a 2004 report, the World Health Organization concluded that road safety campaigns are best able to influence driving behaviour when used in conjunction with enactment and enforcement of policy.[1] Such a multidisciplinary approach, that would include parents, practitioners, researchers, policy-makers, public health and media, has long been advocated for in injury prevention.[31] Last, it was beyond the scope of this paper to examine injury mortality rates in other high-income countries for comparison. Such a comparison would be a valuable contribution to the literature.

CONCLUSIONS

This study highlights the remarkable decline in unintentional injury mortality rates in children over the past six decades. The paper demonstrates the decline in childhood mortality associated with choking, suffocation, burns and MVCs in the context of national-/population-level injury prevention strategies. Despite the obvious success of legislation and enforcement in the reduction of childhood injuries in Canada, injuries remain the leading cause of death in children 1–19 years of age. Given the substantial evidence that childhood injuries are both predictable and preventable, current efforts should be focused on a national, systematic approach to injury prevention that includes adequate funding, legislative support, and enforcement.[31]

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RÉSUMÉ

OBJECTIFS : Examiner les taux de mortalité liés aux blessures non intentionnelles chez les enfants (0–19 ans) au Canada de 1950 à 2009 par rapport aux interventions nationales de prévention des blessures à l'échelle de la population.

MÉTHODE : Les taux de mortalité liés aux blessures ont été rajustés selon l'âge et le sexe. Nous avons estimé les changements dans les tendances et le niveau des taux de mortalité durant des périodes d'intervention préétablies à l'aide d'analyses en régression linéaire segmentée pour des séries chronologiques interrompues. Nous avons procédé par estimation du maximum de vraisemblance avec un processus d'erreur autorégressif d'ordre 2.

RÉSULTATS : De 1950 à 2009, le taux global de mortalité lié aux blessures non intentionnelles a diminué de 86 %. Les taux de mortalité des garçons étaient systématiquement plus élevés que ceux des filles, mais le rapport de taux standardisés a baissé, passant de 2,37:1 en 1950 à 1,97:1 en 2009. Nous avons remarqué des baisses importantes des décès par étouffement ou suffocation chez les enfants de moins d'1 an, principalement pour la période de 1970 à 1988, quand la *Loi sur les produits dangereux* et le *Règlement sur les lits d'enfant* ont été mis en œuvre. Pour les brûlures, nous avons remarqué des changements importants dans la pente de la courbe entre la période de 1972 à 1994 et celle d'avant 1971 (introduction du *Règlement sur l'inflammabilité* de la *Loi sur les produits dangereux*); la plus forte baisse a été remarquée chez les enfants de 1 à 4 ans (est. = −0,03, IC de 95 % = −0,02, −0,04). Chez les 15 à 19 ans, il y a eu une hausse de 408 % des taux de mortalité liés aux collisions entre véhicules automobiles entre 1950 et 1971; cependant, nous avons remarqué un changement significatif dans la pente de la courbe pour la période de 1978 à 1985 comparativement à celle de 1972 à 1977 (est. = −0,10, IC de 95 % = −0,20, −0,007) dans tous les groupes d'âge.

CONCLUSION : Notre étude n'est pas une analyse causale, mais il existe une forte association entre la mise en œuvre des campagnes de sécurité et des modifications législatives liées à la sécurité des enfants et la baisse spectaculaire des blessures mortelles durant l'enfance.

MOTS CLÉS : adolescent; Canada/épidémiologie; cause de décès; mortalité/tendances; plaies et lésions traumatiques/mortalité; plaies et lésions traumatiques/prévention et contrôle; enfant d'âge préscolaire; nourrisson