

# BMJ Open Firearm injury epidemiology in children and youth in Ontario, Canada: a population-based study

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## ABSTRACT

**Background and objective** Despite firearms contributing to significant morbidity and mortality globally, firearm injury epidemiology is seldom described outside of the USA. We examined firearm injuries among youth in Canada, including weapon type, and intent.

**Design** Population-based, pooled cross-sectional study using linked health administrative and demographic databases.

**Setting** Ontario, Canada.

**Participants** All children and youth from birth to 24 years, residing in Ontario from 1 April 2003 to 31 March 2018.

**Exposure** Firearm injury intent and weapon type using the International Classification of Disease-10 CM codes with Canadian enhancements. Secondary exposures were sociodemographics including age, sex, rurality and income.

**Main outcomes** Any hospital or death record of a firearm injury with counts and rates of firearm injuries described overall and stratified by weapon type and injury intent. Multivariable Poisson regression stratified by injury intent was used to calculate rate ratios of firearm injuries by weapon type.

**Results** Of 5486 children and youth with a firearm injury (annual rate: 8.8/100 000 population), 90.7% survived. Most injuries occurred in males (90.1%, 15.5/100 000 population). 62.3% (3416) of injuries were unintentional (5.5/100 000 population) of which 1.9% were deaths, whereas 26.5% (1452) were assault related (2.3/100 000 population) of which 18.7% were deaths. Self-injury accounted for 3.7% (204) of cases of which 72.0% were deaths. Across all intents, adjusted regression models showed males were at an increased risk of injury. Non-powdered firearms accounted for half (48.6%, 3.9/100 000 population) of all injuries. Compared with handguns, non-powdered firearms had a higher risk of causing unintentional injuries (adjusted rate ratio (aRR) 14.75, 95% CI 12.01 to 18.12) but not assault (aRR 0.84, 95% CI 0.70 to 1.00).

**Conclusions** Firearm injuries are a preventable public health problem among youth in Ontario, Canada. Unintentional injuries and those caused by non-powdered firearms were most common and assault and self-injury contributed to substantial firearm-related deaths and should be a focus of prevention efforts.

## Strengths and limitations of this study

- This is a large population-based study with almost complete provincial coverage of children and youth.
- Beyond measuring injury intent, this study measures the weapon type that caused the firearm injury.
- Both in and out of hospital deaths, all hospitalisations and all emergency department visits for firearm injuries in Ontario were captured in available data.
- This study distinguishes the type and nature of injuries caused by various firearms, demonstrating the severity of injuries by weapon type and intent.
- While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the circumstances surrounding the injury.

## INTRODUCTION

Firearm injuries are an important cause of morbidity and mortality among youth in high-income countries.<sup>1,2</sup> Firearm injuries, in particular from assault and self-injury, can be fatal and, among survivors, leave lasting repercussions.<sup>3-7</sup> Firearms also carry the highest rate of lethal injury in those who attempt suicide. Children and youth are particularly vulnerable to firearm injury. It is a period in their lives where they have increasing independence, immature executive functioning and potential access to firearms.<sup>8</sup>

The USA consistently leads with the highest rates of firearm homicide and suicide deaths among the Organisation for Economic Co-operation and Development countries, with Canada, Portugal and Ireland following next for per capita for firearm homicides and Finland, Austria and France afterwards for per capita firearm suicides.<sup>9</sup> The majority of public health research related to paediatric firearm injuries is from the USA, where one-third of households (and up to 61% in some states) own at least one firearm.<sup>10,11</sup> US

data reveals that only one-third of families who own guns report storing their firearms safely<sup>12</sup> and that unintentional injuries represent one-third of firearm injuries in American children,<sup>13</sup> typically occurring either in or close to home.<sup>14</sup> In contrast, only approximately 17%–34% of Canadian households own at least one firearm<sup>15</sup> and firearms are involved in 30% of homicides and 12% of suicides.<sup>16</sup>

Internationally recognised injury reporting standards categorise firearm injuries into one of five groups by intent: unintentional, intentional (assault), self-inflicted (suicide or attempted suicide), legal intervention (war, police shooting) and intent unknown, using validated diagnostic codes.<sup>17–23</sup> Firearms are also generally grouped into one of three types: handguns, rifles/long guns and non-powdered firearms. Legislation and regulations around possession, acquisition, use and transport of these weapons vary considerably by weapon type, yet all are capable of causing serious bodily harm, including death.<sup>24</sup>

In the USA, there is a strong inverse relationship between states with tighter firearm legislation, especially child access prevention laws, and firearm injury rates.<sup>25 26</sup> The same holds true in international jurisdictions where firearms are strictly regulated. In Australia and Japan, for example, non-powdered firearms (eg, air guns or BB guns) require a licence to own and rifles and handguns are owned by a select few among whom use is tightly controlled.<sup>27–29</sup> In these jurisdictions, firearm injuries are now very low.<sup>1</sup>

The extent to which Canadian youth are affected by firearm injuries is not known and the sociocultural environment, drivers and normative behaviours around firearms and legislation are unique and important to understand for firearm injury prevention globally. Further, firearm injury data are often presented as deaths, rather than the number of people injured. Without accounting for all injuries, including emergency department visits and hospitalisations, firearm injuries and their sequelae on patient, families and communities are grossly underestimated.<sup>5 6 30</sup> Finally, reports seldom describe the weapon type or specify intent. Consequently, the extent of firearm injuries and contributing factors are often inferred or not explored due to a paucity of detailed firearm injury data available.

To inform firearm injury prevention strategies for youth, the full scope of firearm injuries in this population must first be defined. It is also critical that we understand the rate of firearm injuries, the types of firearms are being used on victims of firearm injuries by intent and the resulting types of injuries. Knowledge of the patterns of injury are essential to shape policies and programmes to prevent firearm injury. Our objectives were to describe the epidemiology of firearm-related injuries among youth in Ontario, Canada, using data from emergency departments, hospitals and death records, and to compare the risk of injury by weapon type and intent. We hypothesised that unintentional injuries and those from

non-powdered firearms would account for the majority of injuries.

## METHODS

### Study design

We conducted a population-based cross-sectional study in Ontario, Canada's largest province where hospital and outpatient physician services are funded through provincial health insurance to the province's ~14 million residents. For context, Canada does not currently have a firearms registry, though, older data suggests wide variation in household firearm ownership rates with 67% of households in the Yukon and Northwest Territories, 15% of Ontario and about 30% in Atlantic Canada.<sup>31 32</sup> We used linked health and administrative data sets housed at ICES (formerly The Institute for Clinical Evaluative Sciences), a not-for-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyse health data without individual consent. Data sets are linked through encoded unique health identification numbers for all persons with provincial health insurance. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

### Data sources

To identify individuals with firearm injuries, we used diagnostic codes from provincial portions of hospital discharge (Canadian Institutes for Health Information Discharge Abstract Database), emergency department and same-day surgery (National Ambulatory Care Reporting System) and death (Ontario Registrar General—Vital Statistics, Deaths) databases. We used Ontario's healthcare registry, the Registered Persons Database, to obtain demographic data for all Ontario residents eligible for public health insurance and Immigration, Refugees and Citizenship Canada's Permanent Resident Database for immigration information. We linked individual level postal codes to Canadian census data to obtain neighbourhood level income and to determine rural or urban residence. Administrative data available at ICES are widely used and valid for sociodemographic characteristics, physician billing claims and primary hospital diagnoses.<sup>33</sup> Databases included and linkage rates are in the online supplemental appendix 1.<sup>34</sup>

### Study population

We included children and youth from birth to 24 years old living in Ontario, Canada, from 1 April 2003 to 31 March 2018 and eligible for provincial health insurance. The United Nations uses 24 years as the cut-off for defining youth and the Centers for Disease Control and Prevention (CDC) also uses up to 24 years to measure youth violence, and thus we did the same.<sup>35 36</sup>

### Patient and public involvement

No patient involved.

## Outcomes

The framework for measurement of firearm injury was based on the international framework for injury surveillance developed by the CDC and the WHO, using the International Classification of Diseases-10 with Clinical Modification external cause of injury codes for use in administrative data, with Canadian enhancements (ICD 10-CA).<sup>17 37 38</sup> The primary outcome was a firearm injury event identified through emergency department visit, hospitalisation or death records. Secondary outcomes were (1) the intent of the firearm injury, including: unintentional, assault, self-injury/suicide and undetermined and (2) the weapon type: handgun, rifle, non-powdered firearm and undetermined or unspecified (online supplemental appendix 1, firearm codes). For each injury event, we measured the place of injury, nature of the injury (eg, fracture, contusion) and type (location) of injury (eg, traumatic brain injury, extremity, thorax) using ICD-10-CA codes. Individuals with an emergency department visit resulting in hospitalisation or death were considered a single event. Death by firearm out of hospital was only available until 31 December 2016, so these deaths due to injury were not captured in the last 15 months of the 15-year study period. In Canada, non-powdered firearms are considered firearms under Canada's Firearms Act only if the muzzle velocity exceeds 152.4 metres/second (m/s) and the muzzle energy surpasses 5.7 joules.<sup>39</sup> Nonetheless, firearms with projectile velocities of 75 m/s can penetrate eyes<sup>40</sup> and, depending on the mass of the bullet, can penetrate skin at 53 m/s<sup>41</sup>—thresholds far below those that are regulated. Further, what constitutes the legal definition of a firearm in health data varies by jurisdiction with legal definitions in the USA including only those with chemical combustion for a projectile and in Australia including non-powdered weapons without specification about muzzle velocities.<sup>42 43</sup> We included non-powdered firearms based on their mechanism of generating a projectile, not on the velocity or energy of the projectile.

## Covariates

Covariates included age, sex, neighbourhood material deprivation quintile measured using the Ontario Marginalization Index,<sup>44</sup> neighbourhood level income quintile, immigration status, rurality using the Rurality Index of Ontario<sup>45</sup> and hospital type at initial presentation (ie, paediatric teaching, non-paediatric teaching, community hospitals).

## Statistical analyses

Baseline characteristics of individuals injured versus killed by firearm were compared and reported as numbers and proportions. Crude and strata-specific rates of injury by weapon type, intent and sociodemographic characteristics were calculated using the corresponding Ontario population as the denominator. Multivariable Poisson regression models were used to estimate rate ratios with 95% CIs with weapon type as the primary exposure and

age and sex as covariates. Separate regression models were then used for each injury intent.

All analyses were conducted using SAS V.9.4 for Unix (SAS Institute). Cell sizes less than six were not reportable because of ICES institutional policy on data privacy.

## RESULTS

Over the 15-year study period, there were 5486 children and youth in Ontario injured or killed by firearms, with most (90.7%) of those injured surviving (table 1). Most injuries and deaths occurred in males (90.1%) and in those between 18 and 24 years (61.5%). Individuals living in low-income neighbourhoods (ie, quintile of 2 and below) accounted for over half (56.3%) of all firearm injuries and deaths. Similarly, individuals from neighbourhoods with high material deprivation (ie, quintile 4 and above) accounted for over half (55.6%) of all firearm injuries and deaths. Most firearm-related injuries and deaths occurred in those living in major urban centres (65.1%). Most injuries were unintentional (n=3416, 62.3%), and a quarter (n=1452, 26.5%) were from assault. Self-injury accounted for 204 (3.7%) cases, and legal intervention accounted for 61 (1.1%) cases. There were 353 (6.4%) injuries from an undetermined intent. Non-powdered firearms accounted for almost half (48.6%) of all firearm injuries and 41.7% of firearms were from an unspecified weapon type. Just over half of the total injuries presented at community hospitals (58.6%), followed by non-paediatric teaching hospitals (31.2%).

Characteristics of firearm injuries and deaths are presented in table 2. Most injury events occurred in non-specified locations (76.4%); however, 9.2% occurred at home and 5.4% occurred on the street. Two-thirds (66.3%) of firearm injuries among survivors were open wounds, with a small proportion (12.7%) only causing superficial injuries yet still requiring emergency room care. One-third (33.6%) were either traumatic brain or head injuries and approximately half (44.9%) were to areas of the body with vital organs including the trunk, thorax and head (ie, non-extremity injuries).

Males disproportionately experience firearm injuries from non-powdered firearms (6.76 per 100 000 population) and unspecified firearms (6.49 per 100 000 population) (table 3). Adolescents between the ages of 13 and 17 years had the highest rate of firearm injury from non-powdered firearms (6.91 per 100 000 population) and emerging adults, 18–24 years, had the highest rate of handgun injuries (1.63 per 100 000 population). Across all weapon types, those in the lowest income quintile had the highest injury rates. Handgun and unspecified firearm type injuries occurred most in major urban areas with rifle and non-powdered firearm injury rates highest among those living in rural areas.

For unintentional firearm injuries, highest rates were observed for non-powdered firearms and unspecified firearms, especially among adolescents 13–17 years (5.72 per 100 000 population). Males disproportionately

**Table 1** Baseline characteristics of children and emerging adults (0–24 years) who experienced a firearm injury in Ontario, Canada, 2003–2017. All numbers n (%) unless otherwise specified

Variable	Firearm injury survivor	Firearm deaths	Total injuries and deaths
Overall firearm injuries	4976 (90.7)	510 (9.3)	5486
Age, years			
0–12	548 (11.0)	7 (1.4)	555 (10.1)
13–17	1464 (29.4)	92 (18.0)	1556 (28.4)
18–24	2964 (59.6)	411 (80.6)	3375 (61.5)
Mean±SD	17.9±4.3	20.0±3.0	18.1±4.2
Median (IQR)	19 (15–21)	20 (18–22)	19 (16–21)
Sex			
Female	509 (10.2)	36 (7.1)	545 (9.9)
Male	4467 (89.8)	474 (92.9)	4941 (90.1)
Neighbourhood income quintile			
1 (low)	1689 (33.9)	217 (42.5)	1906 (34.7)
2	1069 (21.5)	114 (22.4)	1183 (21.6)
3	887 (17.8)	86 (16.9)	973 (17.7)
4	774 (15.6)	57 (11.2)	831 (15.1)
5 (high)	520–524*	31–35*	555 (10.1)
Missing	33–37*	1–5*	38 (0.7)
Neighbourhood material deprivation quintile			
1 (low)	546 (11.0)	33 (6.5)	579 (10.6)
2	683 (13.7)	64 (12.5)	747 (13.6)
3	863 (17.3)	71 (13.9)	934 (17.0)
4	968 (19.5)	93 (18.2)	1061 (19.3)
5 (high)	1755 (35.3)	236 (46.3)	1991 (36.3)
Missing	161 (3.2)	13 (2.5)	174 (3.2)
Rurality			
Major urban centre	3174 (63.8)	395 (77.5)	3569 (65.1)
Urban	1141 (22.9)	54 (10.6)	1195 (21.8)
Rural	505 (10.1)	45 (8.8)	550 (10.0)
Missing	156 (3.1)	16 (3.1)	172 (3.1)
Immigrant status			
Non-refugee immigrants	387 (7.8)	64 (12.5)	451 (8.2)
Non-immigrants	4380 (88.0)	418 (82.0)	4798 (87.5)
Refugee immigrants	209 (4.2)	28 (5.5)	237 (4.3)
Hospital type at presentation			
Community	3162 (63.5)	55 (10.8)	3217 (58.6)
Paediatric	232–236*	1–5*	237 (4.3)
Teaching	1578–1582*	130–134*	1712 (31.2)
None	0 (0.0)	320 (62.7)	320 (5.8)
Firearm type			
Handgun	341–345	39–43*	383 (7.0)
Rifle	269 (5.4)	69 (13.5)	338 (6.2)
BB guns/non-powdered firearm	2412–2416*	1–5*	2417 (44.1)
Unspecified firearm	1907 (38.3)	380 (74.5)	2287 (41.7)

Continued



Table 1 Continued

Variable	Firearm injury survivor	Firearm deaths	Total injuries and deaths
Injury intent			
Unintentional	3351 (67.3)	65 (12.7)	3416 (62.3)
Assault	1180 (23.7)	272 (53.3)	1452 (26.5)
Self-injury	57 (1.1)	147 (28.8)	204 (3.7)
Undetermined	347 (7.0)	6 (1.2)	353 (6.4)
Legal intervention	41 (0.8)	20 (3.9)	61 (1.1)

\*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

experienced the greatest risk of unintentional-related firearm injuries from non-powdered firearms (5.39 per 100, 000 population) compared with females (0.63 per 100 000 population). Assault rates were highest from handguns (0.43 per 100 000 population) and non-powdered firearms (0.39 per 100 000 population). While assaults from handguns were most common among men and those living in urban and low-income neighbourhoods, non-powdered firearm injuries were also greatest in these groups.

Firearm injuries from self-injury occurred most often in adolescent and emerging adult males with few differences by sociodemographic characteristics. While rare relative to other intents, self-inflicted firearm injuries had the highest case-fatality rate (72%).

In the adjusted regression models (table 4), individuals under 12 years of age and those aged 13–17 years were significantly less likely to be injured by a firearm than individuals aged 18–24 years, regardless of the injury intent. Similarly, across all models, females were less likely to be injured by a firearm compared with males. The risk of unintentional and unspecified firearm injury was higher for non-powdered firearm injury (adjusted rate ratio 1.53 (95% CI 1.42 to 1.64) and 2.20 (95% CI 1.73 to 2.80), respectively). The risk of unintentional firearm injury was 8.34 times higher for non-powdered firearms compared with handguns in the unadjusted model and 14.75 times higher in the adjusted model. Similar, but not as strong, results were found for unspecified firearm injury. In the adjusted model, only small differences were observed in assaults by non-powdered firearms compared with handguns.

## DISCUSSION

In this population-based study, we found that 5486 children and youth up to 24 years of age between 2003 and 2017 were injured or killed by a firearm in Ontario, Canada. This is equivalent to a mean of 366 firearm injuries annually and a rate of firearm injuries of 8.7 per 100 000 population. Non-powdered firearms made up the largest proportion of firearm injuries overall, whereas rifles were responsible for almost twice the number of deaths as handguns when the weapon type was identified. Almost two-thirds of all injuries were unintentional

and almost one-quarter were from an assault. Most injuries were to boys or young men and those living in either low income or urban neighbourhoods. Almost half of all injuries were to the head, thorax or abdomen with only a minority causing superficial injuries. Our findings highlight the magnitude and characteristics of firearm injuries among youth in Ontario, Canada, and these numbers suggest firearm injuries are a serious and potentially preventable public health problem.

This study underscores the significant variation in firearm injury rates by jurisdiction. In the USA, firearm injury rates among children are reported to be between 19 and 23.5 injuries per 100 000 individuals.<sup>30 46</sup> Prior to this work, little data are published on children and youth outside of the USA, making other cross-jurisdictional comparisons difficult.<sup>1 13 30 47</sup> Similar to American studies, we found males to be at greatest risk of firearm injuries, especially as they emerge into adulthood.<sup>13 38</sup> Also similar to American studies, where reported, we found that most injuries occurred at home. It has been well demonstrated that injury risk from all intents is highest where there are firearms in the household. This further emphasises the importance of adherence to safe storage practices and supports child access prevention laws designed to reduce firearm injury.<sup>48</sup> Like others, we demonstrate children and youth living in low-income neighbourhoods experience the highest proportion of firearm injuries.<sup>49 50</sup> This finding was observed across all weapons and intents suggesting a need to improve community safety and target such communities for firearm safety, education and enforcement of existing legislation.<sup>30 49</sup>

We showed that 1.9% of unintentional and 18.7% of assault-related firearm injuries are fatal with an overall fatality rate of 9.3%. This is consistent with other reported fatality rates in youth, ranging from 2% to 12%.<sup>46 49 51 52</sup> The high proportion of children and youth who do not die of their injuries highlights that firearm injury surveillance must include survivors, as reporting only deaths vastly underestimates the burden of the issue.<sup>1</sup> Further, most of these were open wounds and to the head and torso. These ‘near misses’ present an opportunity for action, including potential for mandatory eye and thoracic protection while using such weapons.

**Table 2** Characteristics of firearm injury for children and emerging adults (0–24 years) in Ontario, Canada, 2003–2017. All numbers n (%)

	Weapon type							
	Firearm injury survivor	Firearm deaths	Total injuries and deaths	Handguns	Rifles	BB guns or non-powdered firearm	Legal	Other or unspecified
<b>Place of injury</b>								
Home	476 (9.6)	31 (6.1)	507 (9.2)	42–46*	46 (13.6)	246 (10.2)	1–5*	168 (7.3)
School	30–34*	1–5*	35 (0.6)	1–5*	1–5*	9 (0.4)	0 (0.0)	19 (0.8)
Athletic facility	22–26*	1–5*	27 (0.5)	1–5*	1–5*	1–5*	0 (0.0)	18 (0.8)
Street	275 (5.5)	23 (4.5)	298 (5.4)	44 (11.5)	13–17*	53 (2.2)	1–5*	183 (8.0)
Trade	133–137*	1–5*	138 (2.5)	15–19*	1–5*	26 (1.1)	0 (0.0)	92 (4.0)
Farm	12 (0.2)	0 (0.0)	12 (0.2)	0 (0.0)	1–5*	7 (0.3)	0 (0.0)	1–5*
Other/not specified	4073 (81.9)	121 (23.7)	4194 (76.4)	282 (73.6)	220 (65.1)	2103 (87.0)	19 (31.1)	1570 (68.6)
<b>Nature of injury</b>								
Fracture	685 (13.8)	27 (5.3)	712 (13.0)	121 (31.6)	73 (21.6)	45 (1.9)	13 (21.3)	460 (20.1)
Internal organ injury	434 (8.7)	76 (14.9)	510 (9.3)	97 (25.3)	44 (13.0)	10 (0.4)	17 (27.9)	342 (15.0)
Open wound	3300 (66.3)	215 (42.2)	3515 (64.1)	262 (68.4)	194 (57.4)	1559 (64.5)	36 (59.0)	1464 (64.0)
Amputation	16 (0.3)	0 (0.0)	16 (0.3)	1–5*	1–5*	1–5*	0 (0.0)	8 (0.3)
Blood vessel	114 (2.3)	19 (3.7)	133 (2.4)	26 (6.8)	11 (3.3)	1–5*	1–5*	90 (3.9)
Superficial contusion	689–693*	1–5*	694 (12.7)	19 (5.0)	20 (5.9)	494 (20.4)	6 (9.8)	155 (6.8)
Effect of foreign bodies entering orifice	72 (1.4)	0 (0.0)	72 (1.3)	0 (0.0)	5–9*	50 (2.1)	1–5*	13 (0.6)
Other specified	400 (8.1)	21 (4.1)	421 (7.7)	51 (13.3)	35 (10.3)	116 (4.8)	12 (19.7)	209 (9.1)
Unspecified	370 (7.4)	4 (0.8)	374 (6.8)	8 (2.1)	9 (2.7)	240 (9.9)	0 (0.0)	117 (5.1)
<b>Type of injury</b>								
Traumatic brain	849 (17.1)	107 (21.0)	956 (17.4)	66–70*	85 (25.1)	512 (21.2)	1–5*	288 (12.6)
Head (no brain)	883 (17.7)	6 (1.2)	889 (16.2)	20–24*	34 (10.1)	645 (26.6)	1–5*	185 (8.1)
Neck	155 (3.1)	22 (4.3)	177 (3.2)	18 (4.7)	8–12*	58 (2.4)	1–5*	88 (3.8)
Thorax	384 (7.7)	105 (20.6)	489 (8.9)	62 (16.2)	29 (8.6)	64 (2.6)	20 (32.8)	314 (13.7)
Vertebral column/spine	119 (2.4)	12 (2.4)	131 (2.4)	28 (7.3)	7–11*	1–5*	1–5*	87 (3.8)
Abdomen, lower back, pelvis	826 (16.4)	86 (16.9)	912 (16.7)	146 (38.1)	59 (17.4)	74 (3.0)	27 (44.2)	606 (26.5)
Upper extremity	1504 (30.2)	27 (5.3)	1531 (27.9)	125 (32.6)	81 (24.0)	749 (31.0)	18 (29.5)	558 (24.4)
Lower extremity	1238 (24.9)	18 (3.5)	1256 (22.9)	126 (32.9)	74 (21.9)	363 (15.0)	13 (21.3)	680 (29.7)
Multiple/system wide region	102 (2.0)	23 (4.5)	125 (2.3)	18 (4.7)	14 (4.2)	8–16*	1–5*	76 (3.3)
Unspecified region	50–54*	1–5*	55 (1.0)	1–5*	0 (0.0)	11 (0.5)	1–5*	42 (1.8)

\*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

**Table 3** Firearm injuries among children and emerging adults (0–24 years) in Ontario, Canada, 2003–2018, by weapon type and intent. All numbers n, (rate per 100 000 population)

	Overall			Age, years			Sex			Income quintile			Rurality		
	Total	0–12	13–17	18–24	Female	Male	Lowest	Highest	Major urban	Urban	Rural				
<b>Overall</b>															
Handgun	383 (0.61)	6 (0.02)	59 (0.44)	318 (1.63)	32 (0.11)	351 (1.10)	193 (1.56)	24 (0.19)	351 (0.77)	19 (0.16)	11 (0.26)				
Rifle	338 (0.54)	22 (0.07)	80 (0.60)	236 (1.21)	42 (0.14)	296 (0.93)	97 (0.78)	41 (0.32)	187 (0.41)	77 (0.64)	52 (1.22)				
BB gun	2417 (3.88)	410 (1.40)	927 (6.91)	1080 (5.53)	257 (0.85)	2160 (6.76)	628 (5.08)	337 (2.64)	1129 (2.49)	825 (6.90)	359 (8.44)				
Unspecified	2287 (3.67)	116 (0.39)	480 (3.58)	1691 (8.66)	214 (0.70)	2073 (6.49)	970 (7.85)	150 (1.17)	1861 (4.11)	260 (2.18)	125 (2.94)				
<b>Firearm injuries by intent</b>															
<b>Unintentional</b>															
Handgun	96 (0.15)	–	23 (0.14)	73 (0.37)	17 (0.06)	79 (0.25)	41 (0.33)	8 (0.06)	79 (0.17)	11 (0.09)	6 (0.14)				
Rifle	161 (0.26)	15 (0.05)	41 (0.31)	105 (0.54)	28 (0.09)	133 (0.42)	45 (0.36)	26 (0.20)	70 (0.15)	49 (0.41)	30 (0.71)				
BB gun	1913 (3.07)	340 (1.16)	767 (5.72)	806 (4.13)	192 (0.63)	1721 (5.39)	479 (3.88)	273 (2.14)	841 (1.86)	683 (5.71)	304 (7.15)				
Unspecified	1246 (2.00)	98 (0.33)	281 (2.10)	867 (4.44)	125 (0.41)	1121 (3.51)	503 (4.07)	96 (0.75)	947 (2.09)	190 (1.59)	85 (2.00)				
<b>Assault</b>															
Handgun	265 (0.43)	–	36 (0.25)	229 (1.17)	13 (0.04)	252 (0.79)	143 (1.16)	12 (0.09)	257 (0.56)	6 (0.05)	–				
Rifle	94 (0.15)	–	14 (0.09)	80 (0.41)	–	94 (0.28)	36 (0.29)	–	83 (0.18)	8 (0.07)	–				
BB gun	246 (0.39)	38 (0.13)	81 (0.60)	127 (0.65)	41 (0.13)	205 (0.64)	73 (0.59)	27 (0.21)	151 (0.33)	64 (0.54)	20 (0.47)				
Unspecified	847 (1.3)	9 (0.03)	151 (1.13)	687 (3.52)	67 (0.22)	780 (2.44)	410 (3.32)	37 (0.29)	811 (1.78)	29 (0.24)	–				
<b>Self-harm</b>															
Handgun	13 (0.02)	–	–	13 (0.05)	–	13 (0.04)	–	–	13 (0.02)	–	–				
Rifle	59 (0.09)	–	19 (0.13)	40 (0.20)	–	59 (0.17)	12 (0.10)	8 (0.06)	26 (0.06)	15 (0.13)	13 (0.31)				
BB gun	30 (0.05)	–	11 (0.05)	19 (0.10)	–	30 (0.09)	9 (0.07)	–	15 (0.03)	14 (0.11)	–				
Unspecified	102 (0.16)	–	22 (0.16)	80 (0.41)	11 (0.04)	91 (0.28)	23 (0.19)	10 (0.08)	43 (0.09)	28 (0.23)	25 (0.59)				
<b>Undetermined</b>															
Handgun	9 (0.01)	–	–	9 (0.04)	–	9 (0.03)	7 (0.06)	–	9 (0.02)	–	–				
Rifle	24 (0.04)	–	13 (0.07)	11 (0.06)	–	24 (0.06)	–	–	15 (0.02)	–	7 (0.16)				
BB gun	228 (0.37)	28 (0.10)	72 (0.54)	128 (0.66)	22 (0.07)	206 (0.64)	67 (0.54)	33 (0.26)	122 (0.27)	65 (0.54)	34 (0.80)				
Unspecified	92 (0.15)	9 (0.03)	26 (0.19)	57 (0.29)	11 (0.04)	81 (0.25)	34 (0.28)	7 (0.05)	65 (0.14)	13 (0.11)	10 (0.24)				

Small cell sizes (<6) have been suppressed and combined with largest group in row to prevent back calculation as per institutional policy. Legal intervention not included due to small cell sizes.

**Table 4** Rate ratios of firearm injuries by intent for children and emerging adults (0–24 years) in Ontario, Canada, 2003–2018

Variable	Model 1						Model 2									
	Unintentional injuries		Assault-related injuries		Self-harm injuries		Unspecified injuries		Unintentional injuries		Assault-related injuries		Self-harm injuries		Unspecified injuries	
	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	RR (CI <sub>95%</sub> )	
<b>Weapon type</b>																
Handgun	0.17 (0.14 to 0.21)	0.51 (0.44 to 0.58)	0.47 (0.26 to 0.83)	0.56 (0.28 to 1.14)	0.10 (0.08 to 0.13)	0.34 (0.30 to 0.40)	0.40 (0.22 to 0.71)	0.39 (0.19 to 0.77)								
Rifle	0.19 (0.16 to 0.22)	0.24 (0.19 to 0.29)	0.63 (0.45 to 0.87)	0.55 (0.35 to 0.87)	0.15 (0.13 to 0.75)	0.14 (0.11 to 0.17)	0.58 (0.42 to 0.80)	0.53 (0.34 to 0.84)								
BB gun	1.42 (1.32 to 1.52)	0.26 (0.23 to 0.30)	0.39 (0.26 to 0.58)	1.85 (1.45 to 2.36)	1.53 (1.42 to 1.64)	0.29 (0.25 to 0.33)	0.41 (0.26 to 0.61)	2.20 (1.73 to 2.81)								
Unspecified (ref)	1.00	–	–	–	–	–	–	–								
<b>Age</b>																
0–12					0.18 (0.16 to 0.20)				0.08 (0.06 to 0.11)				0.34 (0.14 to 0.87)		0.21 (0.15 to 0.29)	
13–17					0.88 (0.82 to 0.95)				0.39 (0.34 to 0.44)				0.83 (0.61 to 1.15)		0.89 (0.71 to 1.13)	
18–24 (ref)					1.00				–				–		–	
<b>Sex</b>																
Female					0.14 (0.12 to 0.15)				0.14 (0.11 to 0.17)				0.37 (0.22 to 0.60)		0.39 (0.28 to 0.54)	
Male (ref)					1.00				–				–		–	
<b>Contrasts</b>																
Rifles vs handgun	1.12 (0.87 to 1.45)	0.47 (0.37 to 0.59)	1.34 (0.74 to 2.44)	0.98 (0.46 to 2.12)	1.43 (1.11 to 1.84)	0.40 (0.32 to 0.50)	1.47 (0.80 to 2.68)	1.38 (0.64 to 2.97)								
BB guns vs handgun	8.34 (6.79 to 10.23)	0.52 (0.44 to 0.62)	0.83 (0.43 to 1.58)	3.29 (1.69 to 6.41)	14.75 (12.01 to 18.12)	0.84 (0.70 to 1.00)	1.01 (0.52 to 1.95)	5.68 (2.90 to 11.11)								
Unspecified vs handgun	5.88 (4.78 to 7.24)	1.98 (1.72 to 2.27)	2.14 (1.20 to 3.81)	1.78 (0.90 to 3.53)	9.65 (7.84 to 11.88)	2.90 (2.53 to 3.33)	2.52 (1.41 to 4.50)	2.58 (1.30 to 5.13)								

Model 1 includes firearm type only. Model 2 adds in covariates (ie, age and sex).

Ref, reference category; RR, rate ratio.



Among those with self-inflicted injuries, 72% died, demonstrating that in this context, firearms are a highly lethal injury mechanism. We have previously reported 12% of suicide deaths in Ontario youth occur by firearm.<sup>53</sup> Eliminating access to firearms for those experiencing mental illness or distress may help to reduce both attempted and completed suicides by firearm.<sup>54</sup> There were 14.7% of self-inflicted firearm injuries from non-powdered firearms with risk of injury not different from those from handguns or rifles. This suggests access to non-powdered firearms must also be considered when counselling youth with mental health concerns at risk for intentional self-injury. In the current study, rifles were involved in 28.7% of self-inflicted injuries, a proportion almost identical to that described by Hanlon *et al.*<sup>55</sup>

A high number of unintentional injuries in this study were from non-powdered firearms. Young children under 12 years have a disproportionate risk of firearm injury by non-powdered firearms (73.8% of all firearm injuries) with a still important proportion affecting adolescents (59.6%) and emerging adults (32%).<sup>56</sup> Others have shown non-powdered firearms injuries cause morbidity, especially to the eyes,<sup>40</sup> and depending on the mass of the bullet, can penetrate skin at 53 m/s.<sup>41</sup> Most prior studies on non-powdered firearms have been small, single centred or limited to paediatric hospitals only.<sup>42 57 58</sup> However, one US study using a nationally representative sample showed children have 13 486 visits to emergency departments annually for non-powdered firearms.<sup>58</sup> Regulations and legislation around possession, acquisition, use and transport of non-powdered firearms vary considerably by jurisdiction. In the USA, some jurisdictions have adopted laws to address safety concerns with some states defining non-powdered firearms as firearms subject to the same or similar regulations.<sup>56 58</sup> In Canada, lower velocity (<152.4 m/s) firearms do not fall under the Canada Firearms Act, nor are they regulated by the Consumer Protection and Safety Act. There is no mandatory training, supervision or equipment required. Given the number of injuries associated with these weapons, increased regulation of non-powdered firearms, particularly for minors, may be warranted.

Understanding factors related to firearm injuries in varying jurisdictions is important for informing strategies for prevention. While the scale of the issue may be different, there may be opportunities to learn from leading jurisdictions in terms of successful injury prevention strategies. Diversity in firearm regulations and legislation and corresponding injury rates as seen in the USA, Australia, Canada and Japan, points to a need to consider adopting firearm injury prevention approaches used in jurisdictions with low rates of injury.<sup>25–29 59</sup>

### Strengths and limitations

This is the largest population-based study in Canada to examine the extent of firearm injuries in youth, with specific attention to weapon type. While data used have validated codes for intent and weapon type, we do not

report data on perpetrators and have limited data on the circumstances surrounding the injury. Many firearm injuries were of undetermined intent and weapon type, highlighting the need for better firearm injury surveillance to be able to measure if strategies to reduce injury are effective. Further, because of there was a high degree of missingness for the weapon type, the proportional contribution of each weapon type may be over or underestimated. There is wide variation in firearm ownership and weapon type across Canada and rates of injury are likely higher in regions with greater firearm ownership. Our measures likely underestimate the true burden of injury, especially for milder injuries from non-powdered firearms that may not present to a hospital.

### CONCLUSIONS

We report weapon type and intent of firearm injuries among youth in Ontario. Where the intent was known, approximately two-thirds were unintentional and likely preventable with appropriate and enforced firearm safety standards for youth. Firearm injuries with non-powdered firearms are concerning high and assaults and self-injury contributed to substantial firearm-related deaths and must be a focus of ongoing injury prevention efforts and surveillance for youth.

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**Contributors** NRS conceptualised and designed the study, interpreted the results, drafted the initial manuscript, revised the manuscript and approved the final manuscript as submitted. CMH, CdO, RS, LF, PP, DG and AM interpreted the results, revised the manuscript and approved the final manuscript as submitted. AH and NL had access to and analysed the data, interpreted the results, revised the manuscript and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. NRS is acting as the guarantor.

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**Competing interests** NRS reports receiving an editorial honorarium from Archives of Diseases in Childhood and an honorarium from MSI Foundation, outside the submitted work. DG is a member of national and international medical associations that advocate for the reduction of firearm injuries: the American College of Surgeons, the Trauma Association of Canada and the Panamerican Trauma Society. In addition, DG is a member of the Canadian Doctors for Protection from Guns, which is an advocacy group. The other authors received no external funding and have no relevant conflicts of interest to disclose.

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**Ethics approval** Use of these data was authorised under Section 45 (1) of Ontario's Personal Health Information Protection Act. This does not require review by a Research Ethics Board. This study was approved by the ICES privacy office (ICES logged study: 2020 0990 246 000).

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**Data availability statement** Data may be obtained from a third party and are not publicly available. The data sets from this study are held securely in coded form at ICES. Data-sharing agreements prohibit ICES from making the data sets publicly available, but access may be granted to those who meet pre-specified criteria for confidential access, available at [www.ices.on.ca/DAS](http://www.ices.on.ca/DAS). The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

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