

RESEARCH ARTICLE

Off-Road Vehicle Crash Risk during the Six Months after a Birthday

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Abstract

Background

Off-road vehicles are popular and thrilling for youth outside urban settings, yet sometimes result in a serious crash that requires emergency medical care. The relation between birthdays and the subsequent risk of an off-road vehicle crash is unknown.

Methods

We conducted a population-based before-and-after longitudinal analysis of youth who received emergency medical care in Ontario, Canada, due to an off-road vehicle crash between April 1, 2002, and March 31, 2014. We identified youth injured in an off-road vehicle crash through population-based health-care databases of individuals treated for medical emergencies. We included youth aged 19 years or younger, distinguishing juniors (age ≤ 15 years) from juveniles (age ≥ 16 years).

Results

A total 32,777 youths accounted for 35,202 emergencies due to off-road vehicle crashes within six months of their nearest birthday. Comparing the six months following a birthday to the six months prior to a birthday, crashes increased by about 2.7 events per 1000 juniors (18.3 vs 21.0, $p < 0.0001$). The difference equaled a 15% increase in relative risk (95% confidence interval 12 to 18). The increase extended for months following a birthday, was not observed for traffic crashes due to on-road vehicles, and was partially explained by a lack of helmet wearing. As expected, off-road crash risks did not change significantly following a birthday among juveniles (19.2 vs 19.8, $p = 0.61$).

Conclusions

Off-road vehicle crashes leading to emergency medical care increase following a birthday in youth below age 16 years. An awareness of this association might inform public health

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messages, gift-giving practices, age-related parental permissions, and prevention by primary care physicians.

Introduction

Off-road vehicles are a popular means of transportation [1], recreation, and industry away from urban regions worldwide [2–3]. Modern definitions include all motorized vehicles used on rough terrain and include two-wheeled dirt-bikes, three or four wheeled all-terrain vehicles, and snowmobiles [4]. Unsafe riding is problematic, however, due to limited rider protection [5], lack of safety restraints [6], difficult trail terrain [7], exposure to adverse weather, high impact velocities [8], and remote crash locations [9–10]. Most regions, therefore, have regulations against alcohol intoxication [11], riding with excess passengers, or failure to wear a helmet [12–13]. Yet risky behavior persists due to popular attitudes among riders [14] and impractical enforcement strategies for off-road vehicles [15–16].

Unintentional injury is a leading cause of morbidity and mortality in youth [17–20]. The general risk of unintentional injury is partially caused by a propensity for risk-seeking [21], impulsive behavior [22–24], peer pressure, and limited judgment [25]. The risk might be further accentuated by a lack of positive role modeling [26–27], inadequate supervision [28], defiant personal mindsets [29], and recreational drug usage [30]. The popular media sometimes also encourages unsafe behaviors, as with the reporting of numerous celebrities influencing youth toward joy riding [31–36]. Both the incidence and severity of off-road vehicle crashes during modern years are increasingly skewed toward young riders in rural, remote, underserved, and other marginalized settings [37–40].

The literature provides no information on how a birthday might influence the subsequent risk of an off-road vehicle crash among youth. Birthdays are among the most noteworthy landmarks of childhood and are associated with distinct changes in status, privilege, identity, and responsibility [41–43]. Parents, for example, may enable usage by connecting the freedom to ride with a child's specific birthday. On the other hand, a youth may also experience increased freedoms of all sorts that obscure the effect of any single lifestyle risk [44–45]. We conducted a before-and-after longitudinal study using linked health databases to test whether birthdays were associated with an increased subsequent risk of a serious off-road vehicle crash among youth. We tested the null hypothesis that the risk of a crash would be the same in the 6 months following a birthday compared to the 6 months preceding a birthday.

Materials and Methods

Study Setting

Ontario is Canada's most populous region with a youth population (age < 20) of 3,117,893 in 2008 (study midpoint) [46]. The population was dispersed over a land area of 917,741 square kilometers (larger than the entire American Midwest), yielding a total population density of 14.1 per square kilometer (similar to Kansas) [47]. A total of 639,834 off-road vehicles were registered in Ontario in 2008 [48] [49]. Unlike bicycles, off-road vehicles required government-approved plates, insurance coverage, and formal registration with the Ministry of Transportation. Although Ontario law mandated that riders wear helmets (a legal standard still in effect at the time this manuscript was written) and limit alcohol consumption [50] youth of any age were permitted to operate a vehicle with no licensing examination required [51]. During the entire study, Ontario health insurance covered emergency department care throughout

the region with no out-of-pocket costs to patients. Our study protocol was approved by the Sunnybrook Research Ethics Board and included a waiver of individual consent. Our analysis used individual patient data housed at the Institute for Clinical Evaluative Sciences in Ontario and data access is available online at the ICES Data Access webpage.

Identification of Youth

We identified youth injured in an off-road vehicle crash through established population-based health-care databases of individuals treated for medical emergencies throughout Ontario from April 1, 2002 through March 31, 2014 (reflecting all data available) [52–55]. Patients below age 20 years (age < 20 years) were defined as youth, and eligible for inclusion. Youth below age 16 years (age ≤ 15 years) were defined as juniors, in accordance with prevailing legal restrictions against on-road driving [56]. The remaining youth above age 16 years (age ≥ 16 years) were defined as juveniles, in accordance with the legal limit for initiating on-road driving. Youth with missing health card numbers, faulty records, blank identifiers, or declared dead at the scene as coroner's cases were not included due to unavailable data.

Defining a Birthday

Each youth's birthday served as the primary predictor under the assumption that such milestone events might be linked to lifestyle changes. For analysis we identified the nearest birthday relative to the crash date for each individual. For example, a youth born on August 1, 2001 and injured on August 7, 2012 was coded as having a crash 6 days after their birthday. Conversely, a youth who had the same crash date but was born on August 27, 2001 was coded as having a crash 20 days before their birthday. If multiple crashes related to multiple separate birthdays, we analyzed individuals according to the birthday associated with the earliest identified crash. When necessary, those born on February 29 were assigned a birthday of March 1 to ensure that each youth had exactly one birthday each year.

Characteristics of Youth

Additional baseline characteristics were defined at the time of the youth's birthday and obtained through computerized linkages to health care records [57]. The official vital statistics registry served as the source of data on age, sex, and home location (urban or rural) [58]. The Statistics Canada algorithm based on neighborhood income quintile was used to estimate socioeconomic status, as validated in past research [59–61]. The physician services database provided data on prior hospitalizations, emergency visits, and outpatient contacts in the prior year [62–65]. The available databases contained no information on distances travelled, formal training, community by-laws, peer relationships, adult supervision, personality, or other determinants of behavior.

Emergency Department Visits

The main study outcome was an off-road vehicle crash that led to an emergency department visit (ICD-10 codes: V20-V29, V30-V39, V86) [4]. In secondary analyses we distinguished dirt-bikes from more stable vehicle types as well as examined the role of birthdays on helmet use, seating position, and night riding. The time lag between the date of each crash and the date of the nearest birthday was calculated based on a pre-specified ascertainment interval of 6 months before and after each birthday to allow sufficient sample size and consistent non-overlapping time spans for all comparisons. The emergency department databases also provided 7

indirect measures of injury severity assessed as ambulance involvement, triage urgency, concussion, transfusion, hospital admission, critical care unit admission, and discharge status.

Statistical Analysis

The primary analysis examined the incidence of crashes and compared counts before and after each birthday for each youth (self-matched control design) [66]. Our statistical analysis defined the point of reference as the birthday nearest to the crash date so that each youth served as their own control. We characterize the six months preceding a birthday as “before” and the six months following a birthday as “after” in our statistical analysis. For example, an individual born August 21, 1996 and injured on August 1, 2012 was defined as 15 years old at the time of their crash but nearly 16 years old in statistical analysis [67–68]. We analyzed only crashes associated with the first identified birthday, therefore, the counts provided in our figures represent a subset of the total number of crashes that an individual might experience over their lifetime. Graphical displays of incidence were plotted using histograms of equal time segments of 7-day duration. Secondary analyses extended analogous models to examine relevant subgroups. Missing data were coded explicitly as missing where applicable. All p-values were two-tailed and calculated with exact 95% confidence intervals.

Results

A total of 32,777 youths accounted for 35,202 emergency visits for an off-road vehicle crash within 6 months of their birthday during the study. The majority of individuals (30,577) had only a single observed crash, a few (2,004) had exactly two crashes, a few (168) had exactly 3 crashes, and a few (28) had more than 4 crashes. The modal junior was a 12-year-old boy with higher socio-economic status and almost half lived in a rural location (Table 1). The modal juvenile was 17 years old; otherwise, the distribution of baseline characteristics were similar for juniors and juveniles at the time of the crash. A high proportion of emergencies occurred in spring or summer, during the afternoon, and on weekends. About one-in-thirty had a past history of concussion, whereas about one-in-seven had a past history of a disruptive behavioral disorder (S1 Table).

The group of juniors accounted for 19,216 total emergencies caused by an off-road vehicle crash. Overall, 8,770 of these emergencies occurred during the 25 weeks preceding their birthday and 10,072 occurred during the 25 weeks following their birthday (Fig 1). The 1,302 excess crashes was equivalent to a relative risk increase of 15% following a birthday (95% confidence interval 12% to 18%). The absolute increase in risk was equal to an average of about 2.7 additional crashes per 1000 juniors each week following a birthday (18.3 vs 21.0, $p < 0.0001$). Analyses restricted to the two months before and after each birthday yielded a relative risk increase of 7% following a birthday (95% confidence interval 1% to 12%). The group of juveniles accounted for the remaining 15,218 emergencies and showed no significant increase in crashes following a birthday (19.2 vs. 19.8, $p = 0.31$).

The increased risk among juniors was significant for different ages, sexes, times of the day, seating positions and vehicle types. Crashes were more prevalent among juniors with a higher socio-economic status, yet the relative risk of a crash following a birthday extended from lower to higher levels of socio-economic status (Fig 2). General measures of past medical history were not significant predictors of the relative risk of crash following a birthday. The increase in risk following a birthday was accentuated for drivers and attenuated for those who wore helmets. All age groups among juniors showed a significant relative increase in risk (Fig 3) and the 14th birthday showed the highest increase in absolute risk (9.7 additional crashes per week)

Table 1. Characteristics of Patients and Crashes.

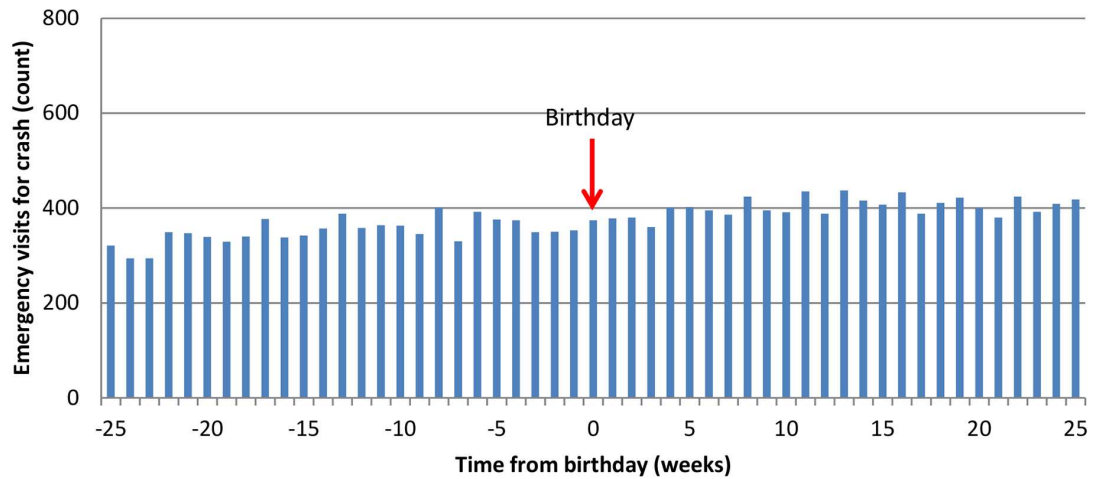
Patient Characteristic	Juniors (n = 20,359)*	Juveniles (n = 12,418) †
Sex		
Boys	15,316 (75%)	9,518 (77%)
Girls	5,043 (25%)	2,900 (23%)
Socio-economic status		
Highest	4,226 (21%)	2,504 (20%)
Next to highest	4,609 (23%)	2,821 (23%)
Middle	4,355 (21%)	2,572 (21%)
Next to lowest	3,860 (19%)	2,433 (20%)
Lowest	3,067 (15%)	1,973 (16%)
Missing	242 (1%)	115 (1%)
Home location		
Urban	12,032 (59%)	7,357 (59%)
Rural	8,322 (41%)	5,054 (41%)
Missing	≤5 (0%)	7 (0%)
Prior hospitalizations §		
≥ 1	388 (2%)	357 (3%)
Prior emergency visits §		
≥ 1	7,766 (38%)	5,418 (44%)
Prior outpatient contacts §		
≥ 7	3,083 (15%)	2,226 (18%)
Crash Characteristic	Juniors (n = 21,693) *	Juveniles (n = 13,509) †
Day of week		
Weekday	11,964 (55%)	8,211 (61%)
Weekend	9,729 (45%)	5,298 (39%)
Time of day		
Morning	3,179 (15%)	2,083 (15%)
Afternoon	13,629 (63%)	7,661 (57%)
Night	4,885 (23%)	3,765 (28%)
Helmet use		
Yes	6,143 (28%)	3,719 (28%)
No	15,550 (72%)	9,790 (73%)
Position		
Driver	12,988 (60%)	8,828 (65%)
Other	8,705 (40%)	4,681 (35%)

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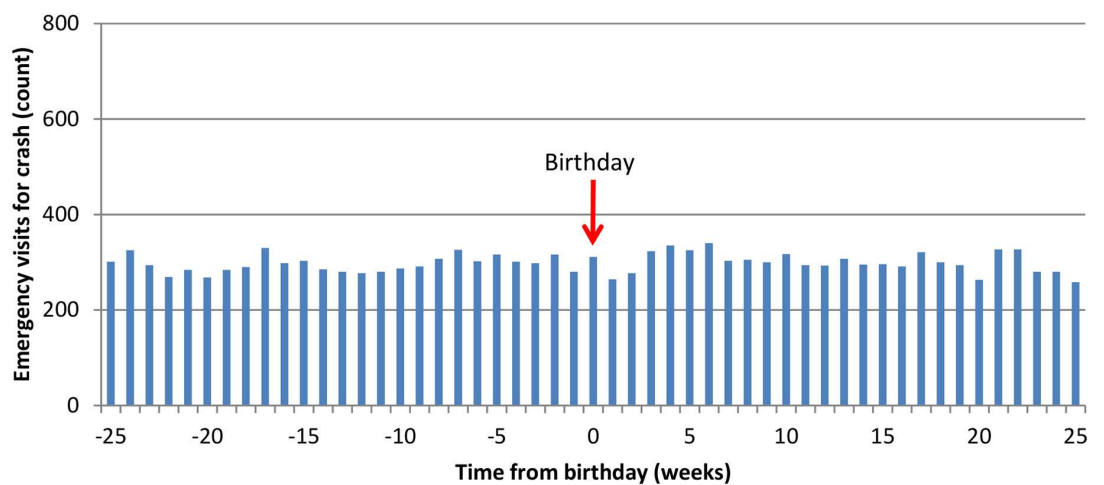
Birthdays were not associated with a sudden increase in maturity as assessed by the measured safety behaviors of youth involved in a crash. About two-thirds were not wearing a helmet—and this proportion was no different for youth involved in a crash before or after a birthday (Fig 4). Similarly, the proportion driving at night was no different for youth involved in a crash before or after a birthday. The lack of growth in safe driving behaviors was equally evident for both juniors and juveniles involved in a crash. Secondary analyses of specific birthdays showed no significant exceptions to this overall pattern.

We directed special attention to seating position under the assumption that parental permissions linked to birthdays primarily focus on a youth being a driver rather than passenger (or being a passenger rather than a bystander). As expected, most juniors were passengers rather than drivers. Juniors, however, were somewhat more likely to be drivers during the weeks following their birthday than the weeks before their birthday (odds-ratio = 1.10, 95%

Panel A. Juniors (n = 18,028)



Panel B. Juveniles (n = 14,039)

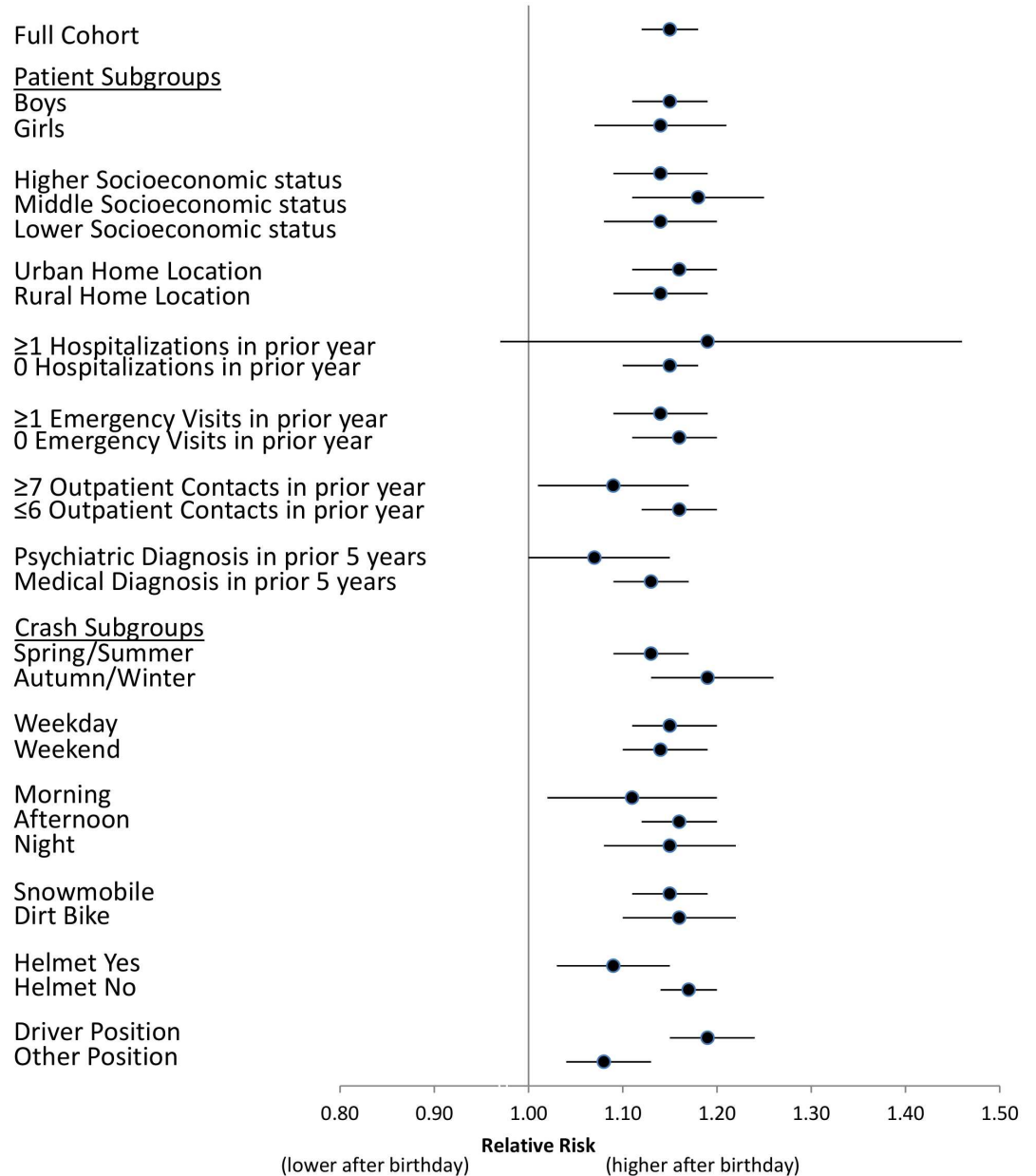


Footnote

Bar graphs showing off-road vehicle crashes occurring in youth over year span. Panel A for juniors (crash date nearest to 15th birthday or earlier), and Panel B for juveniles (crash date nearest to 16th birthday or later). X axis divided into segments of 7 days, with time zero defined as birthday nearest to the crash. Y axis shows total count of crashes that resulted in emergency department care. Red vertical arrow indicates birthday. Result for juniors shows substantial counts before birthday and increased counts afterwards. Results for juveniles shows no major difference before and after birthday.

Fig 1. Emergencies from off-road vehicle crashes.

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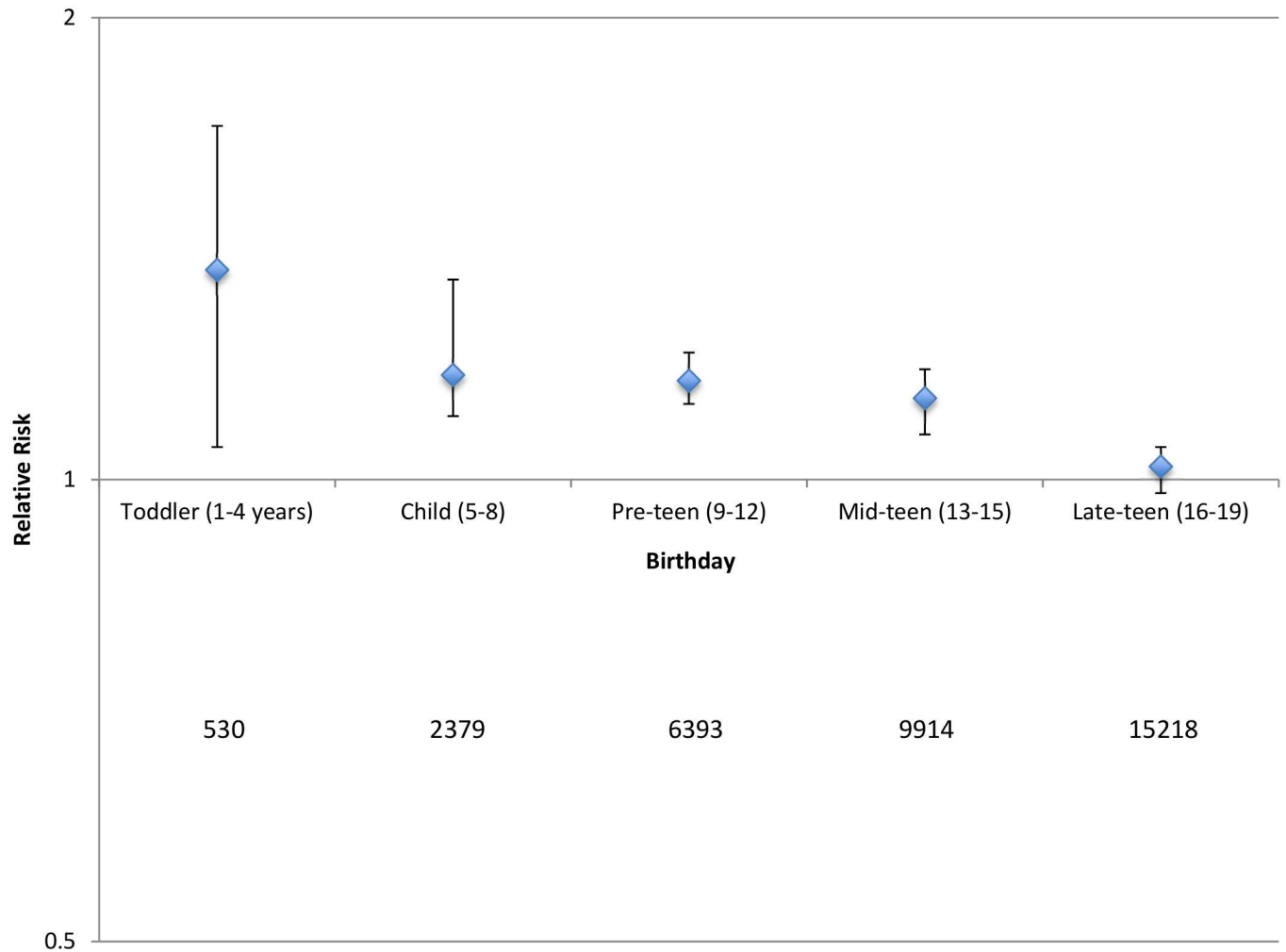
Footnote

Tornado diagram showing relative risks of an off-road vehicle crash following a birthday for various subgroups of individuals and crashes. X axis shows the relative risks. Y axis shows relevant subgroups. Relative risks greater than 1 indicate that risk of a crash is increased after a birthday compared to before a birthday. Horizontal bars indicate 95% confidence intervals.

Fig 2. Relative risks for Juniors in different subgroups.

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confidence interval 1.04–1.17). Injuries were significantly more extensive for drivers than passengers across all measures of crash severity (S2 Table). The increased crash risk after a birthday, however, was still significant when tested for the subgroup of youth involved as passengers in a crash.

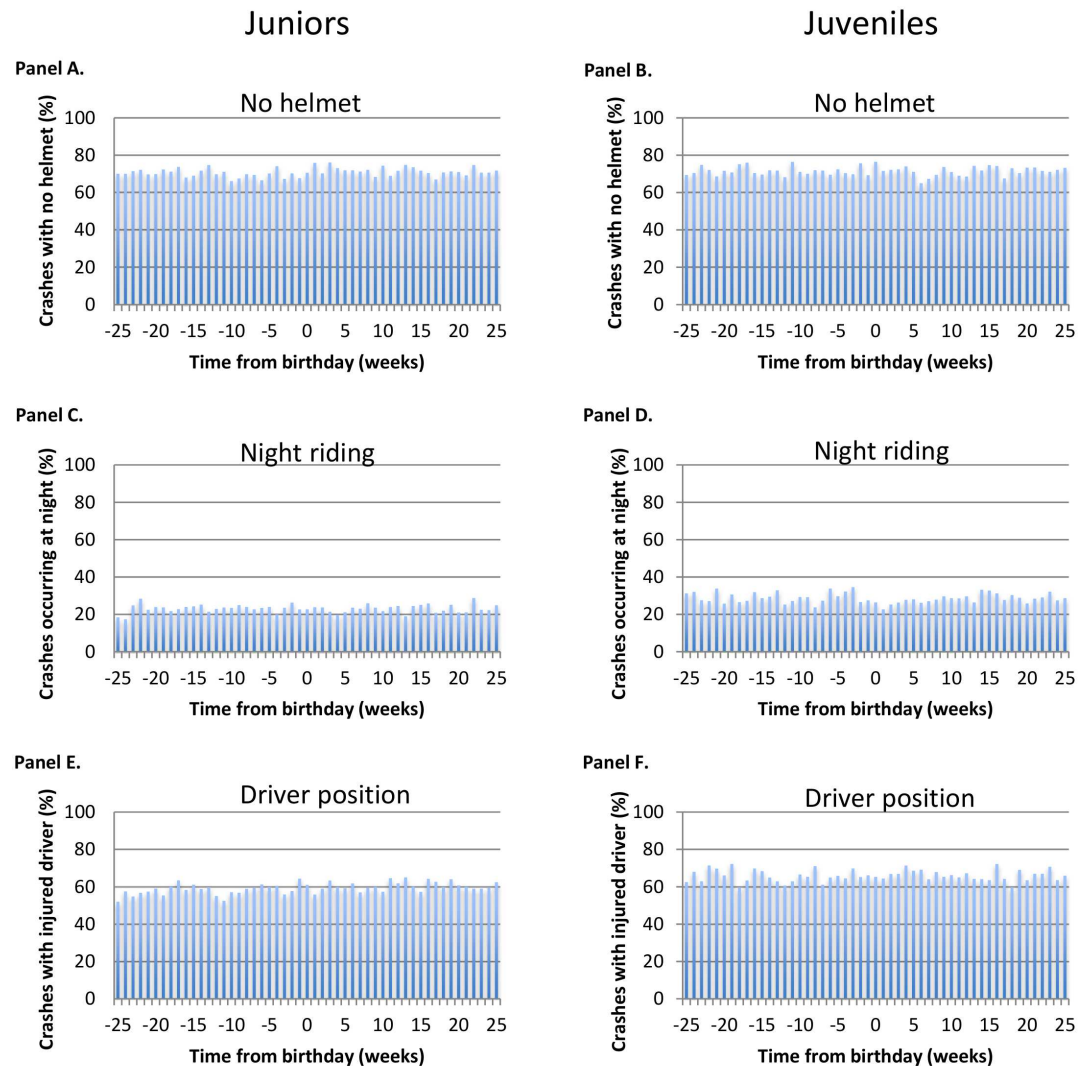


Footnote

Summary plot showing relative risk of off-road vehicle crash following a birthday by age group. Total count of crashes for each subgroup shown as underlying numbers. X axis is divided into five specific groups for analysis. Y axis shows relative risk of a crash that resulted in emergency department care (logarithmic scale). Error bars indicate 95% confidence intervals. Results show consistent increase in relative risk of a crash following birthday for toddler, child, pre-teen, and mid-teen groups.

Fig 3. Relative risk of a crash by age group.

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Footnote

Bar graphs showing off-road vehicle crashes occurring in youth. Panels A, C, E for juniors and panels B, D, F for juveniles. Top panels for crashes characterized by no helmet, middle panels for crashes characterized by night riding, and bottom panels for crashes characterized by driver position. X axis divided into segments of 7 days, with time zero defined as birthday nearest to crash. Results show majority of crashes without a helmet and no increase following birthday. Baseline frequencies for other behaviors less frequent and again show no increase following a birthday. All patterns similar for both juniors and juveniles.

Fig 4. Indicators of safety behavior in injured youth.

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Of the 35,202 total emergency department visits, 49% (n = 17,341) received a higher triage urgency score, 7% (n = 2,637) led to hospital admission, and a total of 3,739 hospital bed-days were accounted for over the study interval. The crashes attributed to a birthday equated to about 1 extra hospital admission per month in Ontario. Among youth admitted to hospital, 47% (n = 1,273) required surgery and 6% (n = 165) required mechanical ventilation. At discharge, 91% (n = 2,367) returned home, 8% (n = 212) were transferred to long-term care, and

1% ($n = 18$) were dead. Measures of injury severity were not statistically significantly different before and after a birthday (and similar for juniors and juveniles).

Interpretation

We studied a sample of over thirty thousand youth to explore the association of birthdays with the subsequent risk of an off-road vehicle crash. We observed more than one thousand extra emergency department visits caused by crashes among juniors in the six months following their birthday compared to the six months before their birthday, equivalent to about a 15% relative risk increase. The absolute increase in risk was greatest with the 14th birthday. The relative increase in risk was not observed for juvenile birthdays, perhaps explained by the start of road driving (and decreased off-road activities) [55]. These data suggest that birthdays are associated with an increase in subsequent emergencies for off-road vehicle crashes in juniors.

Several limitations of our research merit attention. We have no data about crashes that did not receive emergency medical care, including those that resulted in vehicle damage only, minor injury, or immediate death [64]. We also lack data about alcohol [69], drugs [70], peer pressure [71], parental supervision [72], and other factors that influence risky behavior [73–74]. Our study assessed individuals according to first presentation and thereby underestimated total rates of recurrence. Our study was based in Canada, which has a higher frequency of snowmobile crashes relative to other industrial countries [47,75–77]. Our study did not control for the distribution of birthdays throughout the year as a potential confounder and there remain opportunities for future research. Our study cannot easily separate the effects of a birthday from the effects of growing older; however, the data show no further increases between the fifth and twenty-fifth week following a birthday (Fig 1).

A further limitation of our research is that the observed relationship between birthdays and crashes may be difficult to modify. Parents may fail to read or follow scientific research recommendations, underestimate the adverse consequences of a crash [78–79], or believe that aggregate statistics do not apply to their individual children [80–81]. Policies attempting to influence rider behavior might also be perceived as threats to privacy, autonomy, and liberty [82–84]. In addition, excessive restrictions might deter youth from engaging in other outdoor activities that promote physical fitness, an appreciation of nature, and overall quality of life [85–88]. Some increase in injuries might also be explained as natural acts of childhood rebellion despite effective parenting and community supports [89–90].

The complete mechanism underlying the observed rise in crashes among youth is unknown [91–92]. Parents may bestow privileges by granting the freedom to ride after an age milestone, such as the youth's fourteenth birthday. Attractive miniature off-road vehicles designed specifically for juniors age 6 years are often marketed as gifts for special occasions [93–94]. Prevailing community and cultural norms shape the practices of parents [95], marketing behaviors of retailers [96], and expectations of youth [97–99]. Privileges like hunting, driving, drinking, flying and voting all have age thresholds when freedoms are granted; thus, youths may have similar expectations about riding an off-road vehicle [55,100–101].

Our study is the first to observe a link between childhood birthdays and medical emergencies, hence justifying the need for more research. The overall rates of emergencies were consistent with past literature, but our analysis excluded off-road vehicle injuries treated by primary care physicians outside emergency medical settings and those that resulted in immediate death [102]. We observed a helmet compliance rate that agrees with current literature although far below legal standards [103]. Measures of injury severity including triage scores [104], length of hospital stay, and discharge status were consistent with the literature yet lack details on long-

term outcomes for survivors [105–106]. Similar to most preceding studies, the typical injured youth was a young boy in a rural area [107–108].

Our study demonstrates the low compliance rate of helmets among seriously injured youth despite laws requiring riders to wear a helmet [49]. One explanation might be misunderstandings around the risk of operating an off-road vehicle that lead to undervaluing the importance of safety [109–112]. In addition, youth are usually financially dependent upon their parents, so that the failure to wear a helmet could also reflect more general challenges inside the home [113–114]. Policies that required a helmet to be included with the sale of every vehicle might help address this gap, although might neglect passengers who did not purchase an off-road vehicle [115–116]. Furthermore, subsidized programs for exchanging damaged or undersized helmets might ensure sustained helmet use [117].

Off-road vehicles enhance the quality of life for youth in rural regions yet require careful riding during every trip. Parents and their children should consider the benefits of wearing a helmet [118], emergency preparedness, and other safety strategies before each ride [119–120]. The results of this study could inform parental gifting habits, commercial marketing policies, and public awareness campaigns [121–122]. More efforts encouraging riders to wear helmets also merit reinforcement by primary care physicians [123–125]. Our study also shows significant differences in injury severity according to seating position, suggesting that past experience as a passenger does not necessarily prepare youth to drive safely. Age milestones provide a convenient time to grant riding privileges to youth, yet adventures will sometimes lead to misadventures.

Ethics Statement

The study protocol was approved by the Research Ethics Board of the Sunnybrook Health Sciences Centre. The views expressed are those of the authors and do not necessarily reflect the Institute for Clinical Evaluative Sciences or the Ontario Ministry of Health and Long-term care.

Supporting Information

S1 Fig. Relative risks in different subgroups of juveniles.
(JPG)

S1 Table. More characteristics of injured youth.
(PDF)

S2 Table. More crash characteristics.
(PDF)

S3 Table. Seating position and crash severity in all patients.
(PDF)

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Author Contributions

Conceived and designed the experiments: JDW DAR DT.

Performed the experiments: JDW DAR DT.

Analyzed the data: JDW DAR DT.

Contributed reagents/materials/analysis tools: DAR JDW DT.

Wrote the paper: DAR JDW DT.

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