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Impacts of drinking-age laws on mortality in Canada, 1980–2009

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ABSTRACT

Background: Given the recent international debates about the effectiveness and appropriate age setpoints for legislated minimum legal drinking ages (MLDAs), the current study estimates the impact of Canadian MLDAs on mortality among young adults. Currently, the MLDA is 18 years in Alberta, Manitoba and Québec, and 19 years in the rest of Canada.
Methods: Using a regression-discontinuity approach, we estimated the impacts of the MLDAs on mortality from 1980 to 2009 among 16- to 22-year-olds in Canada.
Results: In provinces with an MLDA of 18 years, young men slightly older than the MLDA had significant and abrupt increases in all-cause mortality (14.2%, $p = 0.002$), primarily due to deaths from a broad class of injuries [excluding motor vehicle accidents (MVAs)] (16.2%, $p = 0.008$), as well as fatalities due to MVAs (12.7%, $p = 0.038$). In provinces/territories with an MLDA of 19 years, significant jumps appeared immediately after the MLDA among males in all-cause mortality (7.2%, $p = 0.003$), including injuries from external causes (10.4%, $p < 0.001$) and MVAs (15.3%, $p < 0.001$). Among females, there were some increases in mortality following the MLDA, but these jumps were statistically non-significant.
Conclusions: Canadian drinking-age legislation has a powerful impact on youth mortality. Given that removal of MLDA restrictions was associated with sharp upturns in fatalities among young men, the MLDA likely reduces population-level mortality among male youth under the constraints of drinking-age legislation. Alcohol-control policies should target the transition across the MLDA as a pronounced period of mortality risk, especially among males.

1. Introduction

Alcohol use is the third largest contributor to the global burden of morbidity and mortality among adolescents and young adults aged 10–24 years old (Gore et al., 2011; Lim et al., 2012; Institute for Health Metrics and Evaluation, 2013). More specifically, researchers have estimated that alcohol use is the leading risk factor for youth mortality worldwide, with approximately 6–7% of global deaths of 15- to 24-year-olds being attributable to alcohol consumption (Wang et al., 2012; Lim et al., 2012; Institute for Health Metrics and Evaluation, 2013). As a result, in an effort to minimize alcohol-related harms, countries worldwide have implemented minimum legal drinking age (MLDA) legislation, which imposes age restrictions on alcohol purchasing, possession and consumption. In Canada, the legislated MLDAs are 18 years in Alberta, Manitoba, and Québec, and 19 years in the rest of the country.

At this time, renewed public-policy debates are occurring in a number of countries about the effectiveness and most appropriate age setpoint of drinking-age legislation. In Canada in March 2013, a national alcohol-policy coalition of researchers, non-governmental-organization leaders, and public-health officials proposed a comprehensive strategy to reduce alcohol-related harms and costs in Canada, and this body recommended raising the MLDA across all provinces to at least 19 years—or, ideally, to 21 years (Canadian Public Health Association, 2011; Giesbrecht et al., 2013). Province specific recommendations to raise the MLDA to 21 years have also been made in Ontario (Giesbrecht and Wettlaufer, 2013), British Columbia (Thompson et al., 2013), and Alberta (Vallance et al., 2013). In Saskatchewan, the Saskatchewan party (the province's conservative party) voted to reduce the MLDA at their 2012 annual meeting; however this was later rejected

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Table 1
Provincial/territorial minimum legal drinking age (MLDA) laws (Smart and Goodstadt, 1977; Smart, 1980).

Province/Territory	Present MLDA	Former MLDA	Date of most recent MLDA change
Newfoundland and Labrador	19	21	July 25, 1972
Nova Scotia	19	21	April 13, 1971
Prince Edward Island[a]	19	21/18	July 1, 1972/July 1, 1987
New Brunswick	19	21	August 1, 1972
Québec	18	20	July, 1972
Ontario[b]	19	21/18	July, 1971/January 1, 1979
Manitoba	18	21	August 1, 1970
Saskatchewan[c]	19	20/18	June 1, 1972/September 1, 1976
Alberta	18	21	April 1, 1971
British Columbia	19	21	April 15, 1970
Northwest Territories	19	21	July 15, 1970
Yukon	19	21	February, 1970
Nunavut[d]	19	NA	NA

[a] In Prince Edward Island the MLDA was lowered from 21 years to 18 years July 1, 1972. The MLDA was subsequently raised to 19 years July 1, 1987.
[b] In Ontario the MLDA was lowered from 21 years to 18 years 1971. The MLDA was subsequently raised to 19 years January 1, 1979.
[c] In Saskatchewan the MLDA was lowered from 20 years to 18 years 1972. The MLDA was subsequently raised to 19 years September 1, 1976.
[d] Nunavut separated from the Northwest Territories and was named as a new territory on April 1, 1999.

by the government (CBC News, 2013). In addition, in the United States, there is ongoing argument about the MLDA, primarily initiated by the Amethyst Initiative (an organization comprised of more than 130 US college presidents and chancellors; Amethyst Initiative, 2013), calling for a reconsideration and lowering of the MLDA. Evidence-based policy recommendations in Australia have proposed raising the MLDA to 21 years (Cobiac et al., 2009; Doran et al., 2010), and in New Zealand, bills are currently undergoing legislative review to raise the minimum legal alcohol purchasing age from 18 to 20 years old (Manins, 2012).

In North America, current controversies about drinking-age laws rest upon important historical debates and policy development (Vingilis and De Genova, 1984). In the 1970s, provincial and state policy makers in Canada and the United States moved to lower MLDAs [which were set at 21 years in most provinces/territories (Smart and Goodstadt, 1977; Smart, 1980) and states (Mosher, 1980; O'Malley and Wagenaar, 1990)] to coincide with the jurisdictional age of majority—typically 18 years of age—which allowed major societal rights, such as those related to voting, financial contracts, and military enrollment (Smart and Goodstadt, 1977; Smart, 1980; Mosher, 1980). As a result, MLDAs were reduced in all Canadian provinces (see Table 1) and in more than half of US states. In Canada, however, two provinces, Ontario and Saskatchewan, quickly raised their subsequent MLDAs from 18 to 19 years in response to a few studies demonstrating an association between the lowered drinking age and increases in alcohol-related harms to youth and young adults, including increases in motor vehicle accidents (MVAs) and alcohol intoxication among high school students (Smart, 1980). Following MLDA reductions in the US, research in several states provided persuasive evidence of sharp increases in rates of fatal and nonfatal MVAs appearing immediately after the implementation of lower drinking ages (Wagenaar and Toomey, 2002). These scientific findings galvanized public pressure on lawmakers to raise MLDAs and, in response, the federal government introduced the National Minimum Drinking Age Act of 1984, which imposed a reduction of highway funds for states if they did not increase their MLDA to 21 years. All states complied and implemented an MLDA of 21 years by 1988 (Wagenaar and Toomey, 2002; Carpenter and Dobkin, 2011).

Almost all research assessing the impact of MLDA legislation has occurred in the United States (Shults et al., 2001; Wagenaar and Toomey, 2002; Cook, 2007; McCartt et al., 2010a; Carpenter and Dobkin, 2011), and surprisingly few studies have examined the effects of this youth alcohol-control policy in other countries. Almost all of the Canadian MLDA evaluation literature was published from the early 1970s up to 1981, during the period when Canadian provinces/territories last experimented with MLDA changes. Similar to the current body of MLDA research, the early Canadian evidence concentrated on the effects of the MLDA on alcohol consumption (Schmidt, 1972; Smart and Schmidt, 1975; Smart and Finley, 1976; Vingilis and Smart, 1981) and fatal MVAs (Schmidt and Kornaczewski, 1975; Williams et al., 1975; Whitehead et al., 1975; Bako et al., 1976; Whitehead and Shattuck, 1976; Whitehead, 1977; Warren et al., 1977; Vingilis and Smart, 1981). In general, the results indicated that lowering the MLDA was associated with increased frequency of drinking among young people, and raising the MLDA was associated with alcohol-consumption reductions. In relation to fatal/nonfatal MVAs, MLDA changes were associated with more inconsistent results: age reductions of the MLDA were associated with significant increases in MVAs (especially alcohol-related MVAs) among young people, while a single study of MLDA increase (from 18 to 19 years) found no evidence of significant changes (Vingilis and Smart, 1981). In more recent evidence employing a regression-discontinuity approach, Callaghan and his colleagues also found that in comparison to young adults slightly younger than the MLDA, those just older than the MLDA had significant increases in Emergency Department visits/inpatient admissions for alcohol-use disorders, self-inflicted injuries (suicide), and assault, as well as those due to MVAs and other external causes (injuries) among males (Callaghan et al., 2013a,b). In view of the current policy discussions in Canada (Giesbrecht et al., 2011, 2013) and other countries worldwide, the current study assesses the impact of the MLDA on the most serious and costly alcohol-related harm among young people—mortality. Based on our prior work, we expected to find significant increases in mortality appearing immediately after the transition across the MLDA in Canada.

2. Methods

2.1. Mortality data source

Mortality information was drawn from the Vital Integration Capture and Edit System (VICES), an information system capturing all deaths in Canada (Statistics Canada, 2006, 2012b).

Our data comprised all deaths of individuals aged 16–22 years old from 1980 to 2009 in Canada. We chose the 1980–2009 span of data because the last major change to MLDAs in populous Canadian provinces occurred in Ontario in 1979 (see Table 1 for dates and age changes to MLDAs).

2.2. Classification of underlying cause of death

We categorized deaths according to the VICES underlying cause of death code, which identifies the disease which initiated the train of morbid events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury. We used the Statistics Canada classification scheme to categorize our death outcomes using the ICD-9 and ICD-10 frameworks. In our statistical modeling, we used the following five death categories: all causes; external causes; internal

Table 2
ICD-9 and ICD-10 codes and associated comparability ratios for target mortality outcomes.[a]

ICD-9 codes	ICD-10 codes	Cause of death (ICD-10 titles)	Comparability ratio[b]	95% confidence limits	
				Lower	Upper
001 to 799, E800 to E999	A00 to R99, V01 to Y98	All causes	1.00	–	–
001 to 799	A00 to R99	Internal causes[c]	0.84–1.36[d]	–	–
E800 to E999	V01 to Y98	External causes	1.02	0.99	1.05
E810 to E825	V02 to V04, V09.0, V09.2, V12 to V14, V19.0 to V19.2, V19.4 to V19.6, V20 to V79, V80.3 to V80.5, V81.0 to V81.1, V82.0 to V82.1, V83 to V86, V87.0 to V87.8, V88.0 to V88.8, V89.0, V89.2	Motor vehicle accidents	0.98	0.97	0.99
E800 to E809, E826 to E999	V01, V05–V06, V09.1, V09.3–V09.9, V10–V11, V15–V18, V19.3, V19.8–V19.9, V80.0–V80.2, V80.6–V80.9, V81.2–V81.9, V82.2–V82.9, V87.9, V88.9, V89.1, V89.3, V89.9, V90–V99, W00–Y98	External causes, excluding motor vehicle accidents			

[a] This table was adapted from a Statistics Canada product – *Table 4. Bridge-coding of 1999 deaths: ICD-10/1CD-9 comparability ratios* (Statistics Canada, 2005).
[b] The comparability ratio is a statistic which represents the net effect of the ICD-10 revision on ICD-9 cause-of-death statistics.
[c] The ICD-10 codes for internal causes of mortality are comprised of chapters I-XVIII: certain infectious and parasitic diseases; neoplasms; diseases of the blood and blood forming-organs and some immune disorders; endocrine, nutritional and metabolic diseases; mental and behavioural disorders; diseases of the nervous system and sense organs; diseases of the circulatory system; diseases of the respiratory system; diseases of the digestive system; diseases of the skin and subcutaneous tissue; diseases of the musculoskeletal system and connective tissue; diseases of the genitourinary system; pregnancy, childbirth and the puerperium; conditions in the perinatal period; congenital malformations, deformation and chromosomal abnormalities; and non-classified.
[d] We provide the range of comparability ratios across all major categories of internal causes.

causes; motor vehicle accidents (MVAs); and external causes, excluding MVAs (see Table 2 for ICD-9/10 definitions).

2.3. Provincial groupings according to MLDA ages

Alberta, Manitoba, and Québec were placed into the MLDA of 18 years old category; and the rest of the provinces and territories were put into the MLDA of 19 years old category. Given that Prince Edward Island (PEI; Canada's least populated province) changed its MLDA from 18 to 19 years old on July 1, 1987, mortality data from PEI was placed in the 18-year-old MLDA provincial grouping for the years January 1, 1980–June 30, 1987; and then PEI deaths were placed into the 19-year-old MLDA provincial grouping from July 1, 1987 onwards.

3. Analytic plan

3.1. Regression-discontinuity statistical approach

The current paper uses a regression-discontinuity (RD) design (Thistlethwaite and Campbell, 1960; Shadish et al., 2002), a quasi-experimental approach, which can provide credible estimates of the causal effect of an intervention or policy on a specified outcome (Lee and Lemieux, 2009). The RD approach is ideally suited to assess the impact of the MLDA on mortality outcomes. The RD design takes advantage of the marked discontinuity in the legality of alcohol purchasing and consumption appearing at the MLDA in Canada: our study assigns patients younger than the MLDA to the "alcohol-restricted" group and youth no longer subject to the MLDA to the "alcohol-accessible" group. The fundamental, intuitive idea of the RD approach is that individuals slightly older than the MLDA and those slightly younger than the MLDA will be similar on observed (and unobserved) characteristics, except for the influence of the removal of the MLDA in the "alcohol-accessible" group. The RD design assumes that all observed and unobserved variables (which might influence mortality outcomes) are smoothly distributed across the drinking-age cutoff (Hahn et al., 2001), and the effects of the MLDA can be inferred if the regression line shows a discontinuity—a change in intercept—at the MLDA (Imbens and Lemieux, 2007).

Our RD approach worked upon aggregated totals of our chosen mortality outcomes across finely graded age groupings—age in months—leading up to and following the MLDA. For each of the mortality outcome categories, we summed the number of outcome deaths for each age group, defined as age in months in relation to the provincial MLDA of 18 or 19 years old. Analyses were conducted on mortality counts within each age-in-month category, rather than rates, for a number of reasons. Choice of exact population number for the denominator within each age-in-months bin is somewhat arbitrary, especially given our time span from 1980 to 2009. Also, census data does not provide population counts for age-in-month groups, but rather age-in-year categories and, as a result, this might introduce artifact differences at the discontinuity transition.

The mathematical formula (Eq. (1)) for the RD analyses was:

$$Y = \alpha + \beta_1 \mathrm{MLDA} + \beta_2 \mathrm{Birth} + \sum_{k=1}^{p} \left(\gamma_k \,\mathrm{Age}^k + \lambda_k \,\mathrm{Age}^k \,\mathrm{MLDA} \right) + \varepsilon$$

The term Y is the number of deaths in the outcome categories; MLDA is the indicator of legal drinking age and its coefficient β_1 is the estimate of the MLDA effect ("MLDA" was coded as "1" if the death occurred when the individual was at MLDA or older, the MLDA being 18 or 19 years old, depending on the province grouping); Birth is the indicator of the MLDA birthday month (which accommodates "birthday-celebration" effects occurring immediately at the MLDA month); Age (in months) is a running variable, centered at the MLDA, with $p = 1,2$ representing the degree of the polynomial equation across Age, which includes the MLDA–Age interaction term (the interaction allows for different regression equations before and after the MLDA cutoff); α is the intercept, which is the estimate of the baseline mortality counts (i.e., the number of deaths just prior to the legislated MLDA) of each mortality outcome category; and ε is the error term.

We chose 16 years of age as the lower cutoff for the RD analyses because this lower bound is usually the age that adolescents learn to drive across Canada and alcohol-related MVA fatalities comprise a substantial proportion of overall mortality among adolescents and young adults (Shield et al., 2012). Our RD modeling used the same number of years of data before and after the MLDA.

In our RD modeling, the quadratic term Age, the cubic term Age, and their interaction with MLDA were tested, and these were retained in the model, if these terms showed statistical significance. However, these terms were not significant in any model; so the final models presented in Figs. 1–4 and Table 3 have only the linear term and its interaction with MLDA.

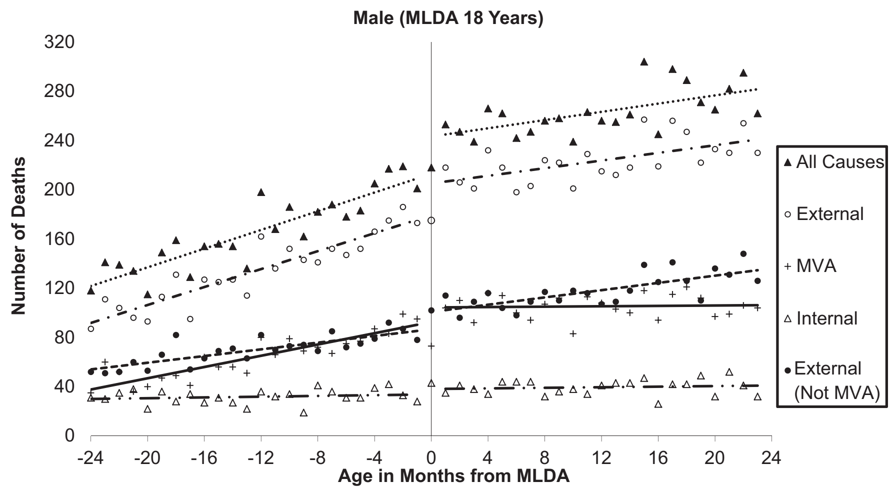

Fig. 1. Fatalities among males in provinces with a minimum legal drinking age (MLDA) of 18 from all causes, external injuries, motor vehicle accidents (MVAs), internal causes and external injuries (not MVAs).

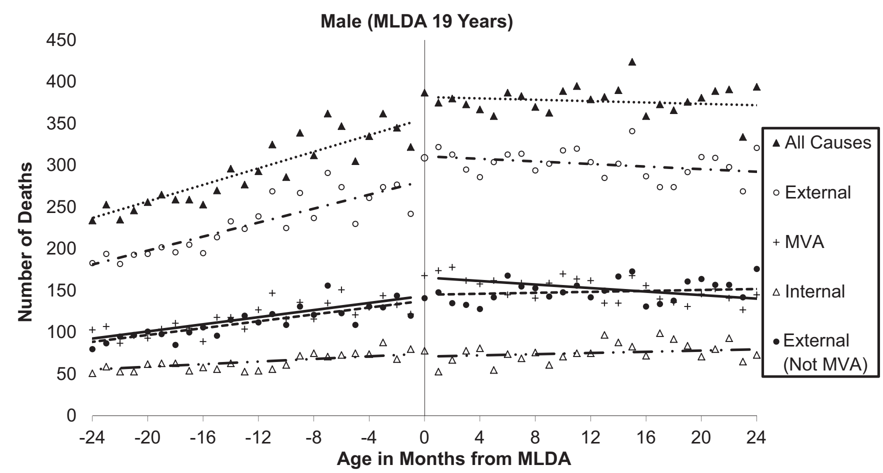

Fig. 2. Fatalities among males in provinces with a minimum legal drinking age (MLDA) of 19 from all causes, external injuries, motor vehicle accidents (MVAs), internal causes and external injuries (not MVAs).

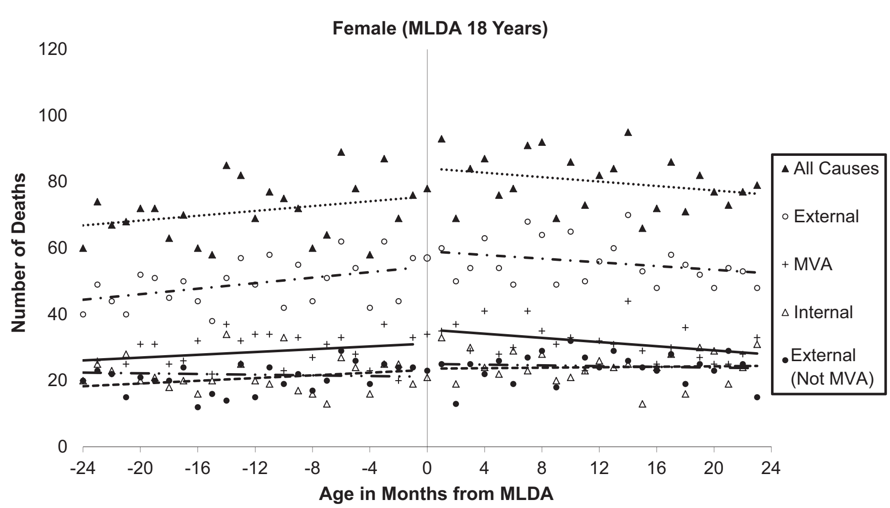

Fig. 3. Fatalities among females in provinces with a minimum legal drinking age (MLDA) of 18 from all causes, external injuries, motor vehicle accidents (MVAs), internal causes and external injuries (not MVAs).

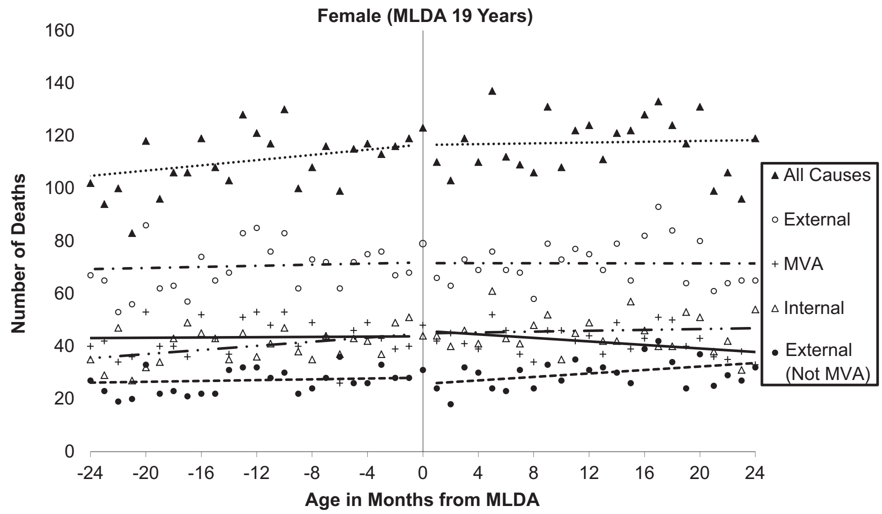

Fig. 4. Fatalities among females in provinces with a minimum legal drinking age (MLDA) of 19 from all causes, external injuries, motor vehicle accidents (MVAs), internal causes and external injuries (not MVAs).

4. Results

Based on our initial regression-discontinuity modeling of the gender-by-MLDA effect, as well as prior regression-discontinuity results showing differential impacts of the MLDA on mortality (Carpenter and Dobkin, 2009), we chose to run separate models across gender.

In provinces with an MLDA of 18 or 19 years, males slightly older than the MLDA had significant and abrupt increases in mortality from all-causes and external causes, including MVAs, in comparison to their male counterparts slightly younger than the MLDA (Figs. 1 and 2). For females in provinces with an MLDA of 18 years old, there were increases in mortality immediately following the MLDA, but these changes were statistically non-significant at the conventional level (Fig. 3). Similarly, regression trend lines showed little evidence of any change across the MLDA for females in provinces with the MLDA of 19 years (Fig. 4). A visual summary of the outcome rate changes immediately following the MLDA can be found in Fig. 5.

In Table 3 and Figs. 1–4, we only present key information about linear models, which were chosen as the "best" models, according to standard criteria described above. Results from the quadratic

Table 3
Key results of regression-discontinuity analyses assessing the impact of the minimum legal drinking age (MLDA) legislation across gender and provinces with an MLDA of 18 or 19 years of age.

Gender/MLDA[a]	Mortality	Intercept (SD)[b]	MLDA (SD)[c]	Effect (%)[d]	*p*-Value[e]
Male 18 (AB, MB, QC)[h]	All causes	212.95[f] (6.23[g])	30.29 (8.91)	14.2	0.002
	External causes	179.24 (5.46)	25.84 (7.81)	14.4	0.002
	MVA	92.59 (3.86)	11.79 (5.72)	12.7	0.038
	Internal causes	33.71 (2.57)	4.46 (3.68)	13.2	0.233
	External causes (excluding MVA)	86.66 (3.54)	14.04(5.09)	16.2	0.008
Male 19 (rest of Canada)	All causes	356.09 (5.78)	25.79 (8.24)	7.2	0.003
	External causes	281.67 (5.50)	29.20 (7.84)	10.4	< 0.001
	MVA	143.76 (3.86)	22.05 (5.50)	15.3	< 0.001
	Internal causes	74.41 (3.01)	−3.42 (4.28)	−4.6	0.428
	External causes (excluding MVA)	137.92 (3.70)	7.15 (5.27)	5.2	0.179
Female 18 (AB, MB, QC)	All causes	75.59 (3.61)	8.50 (5.17)	11.2	0.107
	External causes	54.41 (2.75)	4.63 (3.93)	8.5	0.245
	MVA	31.18 (2.19)	4.25 (3.14)	13.6	0.183
	Internal causes	21.18 (2.21)	3.87 (3.16)	18.3	0.227
	External causes (not MVA)	23.23 (1.87)	0.38 (2.67)	1.6	0.886
Female 19 (rest of Canada)	All causes	116.70 (3.68)	−0.21 (5.24)	−0.2	0.968
	External causes	71.85 (2.98)	−0.27 (4.25)	−0.4	0.950
	MVA	43.78 (2.09)	2.09 (2.98)	4.8	0.486
	Internal causes	44.85 (2.37)	0.06 (3.38)	0.1	0.987
	External causes (excluding MVA)	28.07 (1.72)	−2.36 (2.44)	−8.4	0.339

[a] Indicates the gender/provincial MLDA grouping, where 18 and 19 refer to the provinces with an MLDA of 18 or 19 years old, respectively. Given that Prince Edward Island (PEI) changed its MLDA from 18 to 19 years old on July 1, 1987, mortality data from PEI was placed in the 18-year-old MLDA provincial grouping for the years January 1, 1980-June 30, 1987; and then PEI deaths were placed into the 19-year-old MLDA provincial grouping from July 1, 1987 onwards.
[b] This is the intercept of the model, which reflects the estimated number of deaths immediately preceding the MLDA.
[c] The coefficient of the model representing the discontinuity or "jump" immediately following the MLDA; it can be interpreted as the incremental number of increases/decreases in deaths immediately following the MLDA.
[d] Represents the percentage of increases/decreases in deaths immediately following the MLDA. It is calculated as column **MLDA**[c] divided by column **Intercept**[b].
[e] The *p*-value refers to the coefficient in column **Intercept**[b] and indicates whether the jump in deaths was statistically significant.
[f] Estimated mortality count within the age-in-months for individuals during the entire study span (1980–2009) immediately preceding the MLDA.
[g] Numbers in parentheses are standard deviations.
[h] AB = Alberta; MB = Manitoba; QC = Québec.

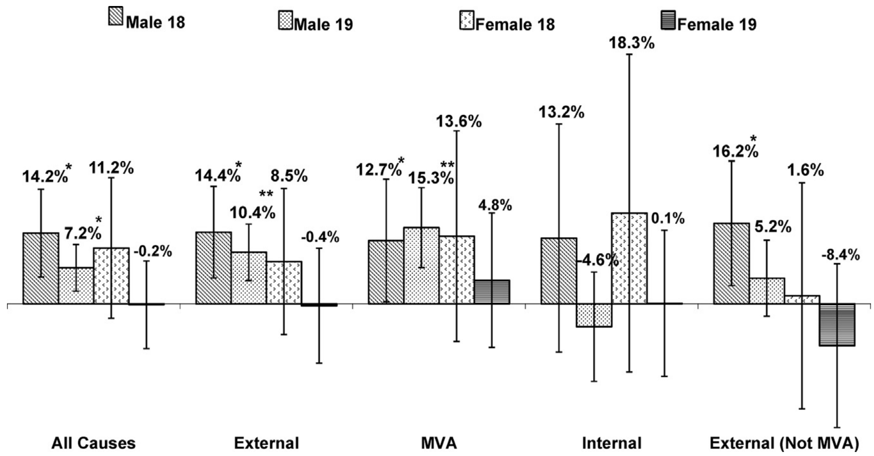

Fig. 5. Summary of effects of the minimum legal drinking age (MLDA) on mortality rate changes (in %) in fatalities immediately following the MLDA: males/females across provincial groupings with an MLDA of 18 or 19 years old. The rate change (in %) was calculated as: [(post-MLDA regression *Y* intercept value − pre-MLDA regression *Y* intercept value)/pre-MLDA regression *Y* intercept value]. For example, the rate change (in %) for all-cause mortality for males in provinces with the MLDA of 18 years (first bar, in Fig. 5) would be: [(243.24 − 212.95)/212.95] = 14.2% "jump" at MLDA. $^{*}p < 0.05$; $^{**}p < 0.001$.

models are available from the first author. We conducted additional sensitivity analyses using age bins constructed from bi-weekly data (i.e., ages defined by 2-week periods) rather than monthly data. The results (not shown) from this modeling did not differ in direction or statistical significance from those presented.

We used our regression-discontinuity results and provincial/territorial mortality data from 2009 (Statistics Canada, 2012a) to generate estimates of preventable all-cause mortality among male youth 18–20 years of age, if the MLDA were to be raised to 21 years. We applied a conservative estimate for the effect on all-cause mortality of 20-year-old males, equal to half of the effect on 19-year-old males in our results (i.e., a 3.6% reduction). In provinces with an MLDA of 18 years, raising the MLDA to 21 years would result in about 15 fewer total deaths among 18- to 20-year-old males [(14.2% × 47 18-year-old male deaths) + (7.2% × 80 19-year-old male deaths) + (3.6% × 67 20-year-old male deaths)]. In provinces with an MLDA of 19 years age, raising the MLDA to 21 years would result in about 17 fewer total deaths among 19- to 20-year-old males [(7.2% × 164 19-year-old male deaths) + (3.6% × 134 20-year-old male deaths)]. Thus, an MLDA of 21 years across Canada could result in approximately 32 fewer annual all-cause deaths among male youth 18–20 years of age.

5. Discussion

Our national study found that immediately after gaining the MLDA threshold young men had significant and abrupt increases in deaths from a broad class of injuries, especially from MVAs. Also, increases in mortality appeared immediately following the MLDA among 18-year-old females, but these jumps were statistically non-significant, at the conventional level. Granting that the major assumptions of our regression-discontinuity analytic strategy were met, our approach can provide credible estimates of the impact of MLDA restrictions on mortality among young people in Canada.

Our study found differential effects of the MLDA across gender. Despite the large body of research assessing effectiveness of drinking-age legislation, few studies have provided gender-specific estimates in this area (Wagenaar and Toomey, 2002). Most research has aggregated males and females into a combined sample, probably because of the statistical modeling limitations associated with the relatively small number of included female fatality outcomes (Bellows, 1980), or because of a focus on males as a high risk group (Asch and Levy, 1990; Durant and Legge, 1993). A notable exception is the work of Carpenter and Dobkin on MLDA-related mortality in the United States (Carpenter and Dobkin, 2009)—a project which also used a regression-discontinuity approach. This work found that both males and females had a significant jump in all-cause mortality immediately following the transition across the US MLDA of 21 years old (10% jump for males, 6% for females). Likewise, Kypri et al. (2006) found that the New Zealand legislation to lower the MLDA from 20 to 18 years was associated with significant increases among both males and females in the incidence of alcohol-involved MVAs and hospitalized injuries among 15- to 19-year-olds. Our findings of gender differences might be due to a number of factors. Among Canadian youth, males are more likely to binge drink (21% vs. 13%), drive after drinking (20–29% vs. 9–6%; Adlaf et al., 2003; Adlaf and Demers, 2005), drink while driving (Adlaf and Demers, 2005), and engage in riskier driving behaviors than females (Harré et al., 2000; Rhodes and Pivik, 2011). Also, it is likely that males participate in drinking-related behavior which puts them at greater risk for injury, as young men are more likely to report negative consequences and injury related to hazardous alcohol consumption (Adlaf and Demers, 2005).

While our results do not directly answer the counterfactual question—What would be the impact on youth mortality if we were to raise the MLDA to 19 years across the country?—our results can inform a response. Assuming that the 14% jump in fatalities among 18-year-old males appearing immediately after the MLDA of 18 years is a reasonable estimate of the deaths which might be avoided if MLDA was increased from 18 to 19 years, then approximately 7 total deaths of 18-year-old males would be avoided each year across the combined provinces of Alberta, Manitoba and Québec (given the 47 total annual male deaths of 18-year-olds across these provinces in 2009; Statistics Canada, 2012a). If the MLDA were set at 21 years across Canada, we estimate that approximately 32 annual deaths from all causes would be prevented among youth 18–20 years of age.

Our results have important implications for policy development. In light of our findings, a persuasive argument can be made that raising the MLDA would result in substantial decreases in mortality among Canadian young people, particularly males. However, major political obstacles may arise in the implementation of increased MLDAs: it is unclear whether there would be broad population support in Canada for implementing higher MLDAs; underage voters would likely oppose such legislative efforts; and the alcohol industry would likely work to undermine proposals to raise MLDAs. Nonetheless, if the proposal of raising MLDAs does not receive popular or legislative support, it may be possible to achieve the same public-health aims of reducing harms among young people by implementing zero-tolerance blood-alcohol policies—legislation which restricts the blood alcohol content (BAC) among young drivers to 0% BAC until substantial driving experience has been gained (usually 3–5 years after the initial driver's license; Hall et al., 2010; Chamberlain and Solomon, 2008). In the United States, for example, zero-tolerance laws require drivers less than 21 years of age to maintain a BAC of 0.02% or less (Carpenter, 2004). Recent research has shown that US zero-tolerance legislation has a similar effect on reducing driving-related harms as does MLDA legislation—both policies appear not only to have independent effects on reducing fatal MVAs by 19–24%, but these alcohol-control policies work even more effectively in tandem with a combined effect of a 39% reduction (Voas et al., 2003). At this time, the Canadian 0% BAC laws are not uniform across provinces: some provinces have imposed 0% BAC restrictions on drivers less than 22 years of age (i.e., Ontario in 2010; and Québec in 2012), while other provinces have implemented 0% BAC restrictions on drivers until the end of graduated driver licensing (GDL) programs—which usually end at an younger age than the MLDA. Zero-percent BAC laws have not been evaluated in Canada, and future research will need to assess the impacts of such legislation on morbidity and mortality among Canadian young people.

Our findings must be interpreted in the context of a number of study limitations. Our analyses were based on all youth deaths from 1980 to 2009 in Canada, and it is possible that MLDA legislation may have had different impacts across this span of time. We chose to aggregate deaths across this historical period so as to meet the Statistics Canada small-cell-size confidentiality restrictions and still provide reasonably stable estimates based on data stratification by provincial MLDA (18 versus 19 years old), five death outcomes, gender, and decedents' age-in-months. In addition, our study aggregated provinces according to provincial MLDA, but within each grouping, variability in provincial alcohol consumption and alcohol-related harms does exist (Adlaf et al., 2005; Health Canada, 2009). It is possible that the impact of the MLDA within a specific province may differ from those associated with the aggregated regions. Also, regression-discontinuity analyses assume that observed (and unobserved) variables—those factors which might affect the outcome (mortality)—are distributed smoothly across the discontinuity (in our case, the MLDA). Given the paucity of relevant variables in the VICES database, we were not able to test this assumption. As a result, it is important to acknowledge that variables unaccounted for in our analyses could possibly influence our results, especially those potential factors differentially influencing individuals on either side of the MLDA threshold. In a related point, the age of receiving a full driver's license [in provincial GDL programs] coincided with the age of the MLDA in two provinces—Alberta, and British Columbia (Mayhew et al., 2005). As a result, our estimates of the impact of the MLDA on MVAs may have been confounded by the end of the provincial GDL programs in these two provinces. While a substantial body of work has assessed the pronounced risk of MVA fatalities among novice drivers (Boase and Tasca, 1998; Mayhew et al., 2003; Dee et al., 2005; McCartt et al., 2010b; Masten et al., 2011), as well as the beneficial effect of GDL programs (Boase and Tasca, 1998; Mayhew et al., 2003; Dee et al., 2005; McCartt et al., 2010b; Masten et al., 2011), only one study has given direct evidence indicating potential increases in MVA fatalities among 18-year-olds, possibly coinciding with completion of GDL or removal of GDL applicability (Masten et al., 2011). Also, in the mid-1990s, Canadian provinces/territories began to introduce and revise region-specific 0%-BAC laws, which usually extended until the end of the GDL system. Given that 0% BAC laws have been shown to impact fatal MVAs among youth in the United States (Voas et al., 2003), these laws may have influenced our results. However, during the study period, in most provinces/territories, the minimum age of release from 0% BAC laws was at a younger age than the MLDA in all but two provinces. Only in British Columbia and Alberta did the minimum age of release from 0% BAC restrictions coincide with the MLDA. Thus, if release from 0% BAC laws resulted in increases in mortality before the MLDA, it is likely that such a pattern would attenuate the "jumps" seen at the MLDA in our regression-discontinuity results.

At least in our understanding, our study provides the first national estimates of the powerful impacts of the MLDA on deaths among young people in Canada. An additional strength was the inclusion of gender-specific mortality estimates associated with MLDAs across provincial groupings, with the MLDAs having pronounced impacts on males, but manifesting no evidence of corresponding effects among females. Given that release from MLDA restrictions was associated with sharp upturns in mortality among young men, it seems reasonable to argue that the MLDA reduces population-level mortality among male youth under the constraints of drinking-age legislation. In addition, alcohol-control policies and public-health initiatives should target the transition across the MLDA as a pronounced period of mortality risk, especially among young men.

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Contributors

All authors have made substantial contributions warranting authorship on the current manuscript. RCC conceived of the study and supervised the statistical analyses and manuscript preparation; MS conducted the statistical analyses and contributed to manuscript preparation; JG provided a critical review of relevant literature and contributed to manuscript preparation; TS contributed to the drafting and revision of the manuscript. All authors have given her approval for the current version to be submitted for peer-review at the journal.

Conflict of interest

No conflict declared.

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