The Association Between the Legalization of Recreational Cannabis and Fatal Motor Vehicle Collisions in the United States: An Ecological Study

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Abstract:	Background: With the recent legalization of recreational cannabis in Canada, cannabis-impaired driving is an important public safety concern. Therefore, our aim was to examine the association between recreational cannabis legalization and fatal motor vehicle collisions using data from the United States, which present a timely natural experiment of legalization. Methods: We retrieved the number of fatal motor vehicle collisions and the associated number of deaths for all 50 states and the District of Columbia (2007-2018) from the United States Fatality Analysis Reporting System. We used empirical best linear unbiased predictor random-effects models to examine rates of fatal motor vehicle collisions and associated deaths across all jurisdictions with and without recreational cannabis legalization. Results: After adjusting for calendar time and clustering by jurisdiction, legalization was associated with significant increases in rates of fatal motor vehicle collisions (rate ratio [RR]: 1.09; 95% confidence interval

	[CI] 1.07-1.11) and associated deaths (RR: 1.09; 95% CI 1.07-1.11). There was no difference in rates of fatal motor vehicle collisions (RR: 0.99; 95% CI 0.96-1.02) or associated deaths (RR: 1.01; 95% CI 0.98-1.05) in the first 12 months of legalization relative to subsequent months. Interpretation: Recreational cannabis legalization in the United States was associated with a 9% relative increased risk of fatal motor vehicle collisions and associated deaths, with no difference between the first and subsequent years of legalization. These findings raise concern that there could be a similar increase in Canada following the legalization of recreational cannabis, and that this increase could be sustained over time.

The Association Between the Legalization of Recreational Cannabis and Fatal Motor Vehicle Collisions in the United States: An Ecological Study

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ABSTRACT

Background: With the recent legalization of recreational cannabis in Canada, cannabis-impaired driving is an important public safety concern. Therefore, our aim was to examine the association between recreational cannabis legalization and fatal motor vehicle collisions using data from the United States, which present a timely natural experiment of legalization.

Methods: We retrieved the number of fatal motor vehicle collisions and the associated number of deaths for all 50 states and the District of Columbia (2007-2018) from the United States Fatality Analysis Reporting System. We used empirical best linear unbiased predictor random-effects models to examine rates of fatal motor vehicle collisions and associated deaths across all jurisdictions with and without recreational cannabis legalization.

Results: After adjusting for calendar time and clustering by jurisdiction, legalization was associated with significant increases in rates of fatal motor vehicle collisions (rate ratio [RR]: 1.09; 95% confidence interval [CI] 1.07-1.11) and associated deaths (RR: 1.09; 95% CI 1.07-1.11). There was no difference in rates of fatal motor vehicle collisions (RR: 0.99; 95% CI 0.96-1.02) or associated deaths (RR: 1.01; 95% CI 0.98-1.05) in the first 12 months of legalization relative to subsequent months.

Interpretation: Recreational cannabis legalization in the United States was associated with a 9% relative increased risk of fatal motor vehicle collisions and associated deaths, with no difference between the first and subsequent years of legalization. These findings raise concern that there could be a similar increase in Canada following the legalization of recreational cannabis, and that this increase could be sustained over time.

INTRODUCTION

Canada legalized recreational cannabis on a national scale on October 17, 2018. By 2019, more than 5.1 million Canadians (16.8% of the population aged 15 or older) reported cannabis use in the past three months (compared to 14.9% before legalization in 2018).(1) While legalization better aligned the law with Canadian values and practices, it raised public health concerns regarding impaired driving.(2) Among individuals who reported any cannabis use in the past three months, 13.2% reported driving within two hours of cannabis consumption.(1) Among daily or almost daily cannabis users, 28.8% reported driving within two hours of consumption.(1) The relationship between cannabis use and impaired driving is complicated by varied methods of consumption (e.g., smoking, vaping, edibles), individual factors (e.g., metabolism, frequency of use), and time since consumption, as well as challenges in the reliable assessment of cannabis impairment.(3) However, cannabis is known to affect psychomotor skills necessary for driving, including critical tracking, divided attention, and reaction time.(4) Despite this knowledge, few studies have examined the impact of large-scale public policies which increased access to cannabis on impaired driving and related outcomes. Given the varied approaches taken to cannabis regulation by different jurisdictions in the United States,(5) data from the United States present a timely natural experiment to assess the impact of recreational cannabis legalization. Therefore, our objective was to examine the association between recreational cannabis legalization and the rate of fatal motor vehicle collisions in the United States to inform impaired driving policy and public health prevention measures in Canada.

METHODS

We performed an ecological study to examine the association between recreational cannabis legalization and fatal motor vehicle collisions and associated deaths in the United States between

2007 and 2018. The numbers of fatal motor vehicle collisions and deaths due to motor vehicle collisions (as each collision could result in more than one fatality) were retrieved by month for all 50 states and the District of Columbia from the United States Fatality Analysis Reporting System (FARS).(6) The FARS database includes collisions which occurred on public roadways and resulted in at least one death within 30 days. We selected 2007 as the start of our study period to include at least five years prior to the first year in which legalized recreational cannabis was in effect (2012). The most recent year of FARS data available at the time of analysis (April 2020) was 2018.

Exposure was defined using a time-dependent approach using two categories: 1) legalized recreational cannabis; and 2) no legalization of recreational cannabis (the reference group). For the primary analyses, we defined legalization for each jurisdiction as the date for which recreational cannabis legalization was in effect, rounded up or down to the nearest full month. Jurisdictions for which legalization was in effect prior to 2019 contributed person-time of observation (determined using the population of each jurisdiction between 2007 and 2018)(7) and fatal motor vehicle collision data to both legalized and non-legalized categories in the analysis, with all remaining jurisdictions contributing data for non-legalized recreational cannabis only.

Statistical Analyses

We used empirical best linear unbiased predictor random-effects models to examine the rates of fatal motor vehicle collisions and associated deaths across all jurisdictions with and without recreational cannabis legalization. Rates were estimated per 100,000 person-years for years during which recreational cannabis was legal and not legal for each state and the District of Columbia between 2007 and 2018. We then determined crude and adjusted rate ratios (RRs) and 95% confidence intervals (CIs) for the associations between legalization and 1) fatal motor vehicle

collisions; and 2) fatalities due to motor vehicle collisions. Models included a random-effect to account for clustering by jurisdiction. The primary analyses were adjusted for calendar year as a categorical variable to account for underlying time trends (e.g., baseline trends in substance use and driving, impaired driving policies). In sensitivity analyses, we adjusted for calendar year as a continuous variable.

Two secondary analyses were performed. In the first, we defined exposure using the date commercial cannabis dispensaries opened (rounded up or down to the nearest full month) instead of the date legalization was in effect. In the second, we sub-categorized data from legalized months (or months in which commercial dispensaries were opened) into the first 12 months and subsequent months to assess if any observed increased risk was short-term. Rates from the first 12 months and subsequent months were then compared to each other and to those from non-legalized periods. All analyses were conducted using SAS Version 9.4.

Ethics Approval

Ethics approval was not required for this research as it used publicly available data.

RESULTS

As of June 2020, 11 states and the District of Columbia had passed legalized recreational cannabis legislation (Table 1).(8) Legalization was in effect in 11 jurisdictions prior to 2019: Washington and Colorado (2012); Alaska, the District of Columbia, and Oregon (2015); California and Massachusetts (2016); Nevada and Maine (2017); and Vermont and Michigan (2018). Recreational cannabis legalization came into effect in Illinois on January 1, 2020, however FARS data were only available through 2018; therefore, Illinois contributed data for non-legalized months only. Among jurisdictions with legalization, commercial dispensaries were open in seven states prior to 2019 (Alaska, California, Colorado, Massachusetts, Nevada, Oregon, and

Washington). The remaining jurisdictions either do not currently plan to allow commercial dispensaries (District of Columbia and Vermont) or opened/plan to open dispensaries after the study period (Michigan in 2019 and Maine in 2020).

A total of 389,396 fatal motor vehicle collisions occurred in the United States between 2007 and 2018, resulting in 424,785 deaths (Table 2). Of these collisions, 17,116 occurred in jurisdictions where recreational cannabis was legal, resulting in 18,580 fatalities (Table 2). After adjusting for calendar time and clustering by jurisdiction, legalization was associated with increased rates of fatal motor vehicle collisions (RR: 1.09; 95% CI 1.07-1.11) and deaths from motor vehicle collisions (RR: 1.09; 95% CI 1.07, 1.11). When analyses used the date commercial dispensaries opened, rather than the date legalization was in effect, the findings were virtually identical for the risk of motor vehicle collisions (RR: 1.08; 95% CI 1.05-1.10) and deaths from motor vehicle collisions (RR: 1.08; 95% CI 1.06-1.11).

In secondary analyses, we compared the rates of fatal motor vehicle collisions and associated deaths in the first 12 months of legalization versus subsequent months of legalization (Table 3). After adjusting for calendar time and clustering by jurisdiction, there was no difference in the first 12 months versus subsequent months of legalization in the rates of fatal motor vehicle collisions (RR: 0.99; 95% CI 0.96-1.02) or deaths from motor vehicle collisions (RR: 1.01; 95% CI 0.98-1.05). In contrast, when analyses used the date commercial dispensaries opened rather than the date legalization was in effect, we found decreased rates of fatal motor vehicle collisions (RR: 0.94; 95% CI 0.90-0.98) and deaths from motor vehicle collisions (RR: 0.94; 95% CI 0.91-0.98) in the first 12 months compared to subsequent months.

Sensitivity analyses which adjusted for calendar time as a continuous rather than categorical variable produced slightly stronger associations between legalization (and open

dispensaries) and the risk of fatal motor vehicle collisions and associated fatalities (Supplementary Table 1). Adjusting for calendar time as a continuous variable produced similarly decreased rates of fatal motor vehicle collisions and associated deaths in the first 12 months of open commercial dispensaries compared to subsequent months (Supplementary Table 2).

INTERPRETATION

We found that recreational cannabis legalization in United States' jurisdictions was associated with a relative 9% increased risk of fatal motor vehicle collisions and associated deaths, with no difference between the first and subsequent years of legalization. In 2018, an estimated 30,270 motor vehicle fatalities occurred in jurisdictions without legalized recreational cannabis; these results suggest that legalization on a national scale could result in an additional 2,765 motor vehicle fatalities per year in the United States.

Previous literature concerning the association between cannabis legalization and impaired driving is limited. A small number of observational studies suggest that medical and/or recreational cannabis legalization may increase the proportion of drivers with detectable levels of cannabis in analyses of blood or urine; however, these observations may be confounded by increases in enforcement activities and cannabis testing and reporting following legalization.(9-12) Likewise, an increase in detectable levels of cannabis (e.g., due to increased use following legalization) would not necessarily correspond directly to increases in impaired driving.(3) Another study found an increase in self-reported driving under the influence of cannabis following legalization.(13) However, individuals may be more likely to report cannabis use and temporally-associated driving after cannabis use is legal.

Several previous studies have been reported that used ecological approaches which did not rely on the measurement and reporting of the presence of cannabis or self-reported impaired

driving data. Aydelotte at al. (2019) used a differences-in-differences approach to compare changes in fatal motor vehicle collisions associated with legalization, using FARS data (2007-2017) from Colorado and Washington and nine control states.(14) Their analysis suggested a potential increase in fatal motor vehicle collisions in Colorado and Washington in the five years after recreational cannabis legalization (+1.2 crashes/billion vehicle miles traveled; 95% CI -0.6, 2.1). In their study, legalization was associated with an increase in fatal motor vehicle collisions when the date of commercial dispensaries opening was used (+1.8 crashes/billion vehicle miles traveled; 95% CI 0.4, 3.7). Santaella-Tenoirio et al. (2020) examined similar data (2005-2017) from Colorado and Washington which were compared with synthetic reference groups (created from a pool of comparison states best resembling fatality rates of the exposed states pre-legalization).(15) The study found an increase in motor vehicle fatalities in Colorado (+1.5 fatalities/billion vehicle miles traveled; $p = 0.047$) but not in Washington (+0.08 fatalities/billion vehicle miles traveled; $p = 0.67$) following the legalization of recreational cannabis retail sales. The authors hypothesized that higher retail density, cannabis use, and cannabis tourism in Colorado relative to Washington may have contributed to the observed increase in traffic fatalities in Colorado.

Two additional ecological studies included data from other states with recreational cannabis legalization. Kamer et al. (2020) used a differences-in-differences approach to compare motor vehicle fatalities reported in FARS (2008-2018) in Colorado, Washington, Oregon, and Alaska to the 20 states without legalized recreational or medical cannabis as of the beginning of 2018.(16) After adjusting for covariates, this study found an increase in motor vehicle fatalities (+2.1 fatalities/billion vehicle miles traveled; 95% CI 1.3-3.0) following the opening of recreational cannabis retail stores. Lane et al. (2019) used data from the Centers for Disease

Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (WONDER) web application and RoadSafetyBC to examine changes in traffic fatalities occurring between 2009 and 2016 in three states with recreational cannabis legalization (Colorado, Washington, and Oregon), using neighboring jurisdictions without legalization as comparators.(17) The authors conducted an interrupted time-series analysis of traffic fatality rates using generalized least squares regression models adjusted for seasonality and autocorrelation to test the association between legalization and traffic fatalities. They found a pooled step increase of 1.08 traffic fatalities per million residents ($p < 0.001$), suggesting an increase in traffic fatalities less than one year following legalization, followed by a reduction in trend of 0.06 per month ($p < 0.001$).

Our analysis extends the findings of these previous studies by including an additional seven jurisdictions with recreational cannabis legalization through 2018. Overall, our results support previous literature which suggest that recreational cannabis legalization is associated with increased impaired driving. In contrast to Lane et al. (2019), our findings additionally suggest that this increase may be sustained over time. We found fatal collisions and associated deaths to be lower in the first 12 months following the opening of commercial dispensaries, compared to subsequent years. This may be due to relatively limited cannabis availability in many jurisdictions during the first year when dispensaries were open (e.g., fewer stores open, product shortages due to high demand), which might deter new cannabis users in particular. While we might have expected a similar finding for the first 12 months of legalization, the lack of difference could be related to lower cannabis availability across multiple early years of legalization (e.g., commercial dispensaries opened more than two years after legalization in Colorado and Washington), making subsequent years more similar to the first year of legalization.

In Canada, a total of 1,922 motor vehicle fatalities were reported in 2018; a relative increase of 9% would correspond to 173 additional deaths yearly.(18) However, the national approach taken to recreational cannabis legalization may have the potential to mitigate increases in impaired driving in Canada. For example, Bill C-46 (2018) established national "*per se*" driving limits for THC, with corresponding minimum penalties for exceeding these limits.(19) While these limits are controversial owing to a lack of direct correlation between THC levels and driving impairment,(20, 21) public awareness of the establishment of legal limits alone has the potential to decrease substance-impaired driving.(22, 23) Among the 11 United States jurisdictions which contributed legalized months to our analyses, seven did not have a threshold limit for THC.(24) Overall, our analysis suggests that Canada should remain vigilant to the potential for increases in cannabis-impaired driving.

Limitations

Our study has potential limitations. First, our study is observational and there are a number of factors which vary between jurisdictions and are likely to influence fatal motor vehicle collisions (e.g., substance use, population density, speed limits). While our analyses included a random-effects term to account for clustering by jurisdiction and we adjusted for calendar time to account for temporal trends, confounding remains possible. Second, in contrast to previous studies, we did not select neighbouring or matched control jurisdictions as comparators. Our approach included data from all 50 states and the District of Columbia, with all jurisdictions contributing data from non-legalized months, which served as the comparator for legalized months. Given the growing number of United States jurisdictions with legalized cannabis, this approach maximizes the available data and minimizes the effect of spillover (i.e., residents of neighboring states without

legalization consuming cannabis purchased in states with legalized cannabis) on the analyses of association.

CONCLUSIONS

Our analysis of data from the United States suggests that there is the potential for an important increase in fatal motor vehicle collisions following the legalization of recreational cannabis in Canada. While differences between the United States and Canada may mitigate potential increases in impaired driving, the observed 9% relative increase in fatal motor vehicle collisions and associated deaths could result in 173 additional road fatalities annually in Canada.

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DATA SHARING STATEMENT

Data used in this interrupted time-series analysis were accessed from the publicly-available FARS database. These data are available at https://www-fars.nhtsa.dot.gov/Main/index.aspx.

CONTRIBUTIONS OF AUTHORS

Drs. Filion and Eisenberg conceived of the study idea and supervised the study. Ms. Windle drafted the manuscript, and Ms. Reynier and Mr. Cabaussel conducted the statistical analyses. All authors contributed to the study design, the interpretation of data, and approved the final version of the manuscript. Dr. Filion is the guarantor.

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Table 1. United States jurisdictions with legalized recreational cannabis regulations*

Jurisdiction	Date Legalization in Effect	First Month Legalization in Effect for Primary Analysis†	Date Commercial Dispensaries Open	First Month Commercial Dispensaries Open for Sensitivity Analysis†	Cannabis-Specific Impaired Driving Laws(24)
Alaska(25, 26)	February 24, 2015	March 2015	October 29, 2016	November 2016	None
California(27, 28)	November 9, 2016	November 2016	January 1, 2018	January 2018	None
Colorado(29, 30)	December 10, 2012	December 2012	January 1, 2014	January 2014	Reasonable inference for impairment ≥ 5 ng/mL THC¶
District of Columbia(31)	February 26, 2015	March 2015	No Commercial Dispensaries	N/A	None
Illinois(32)	January 1, 2020	N/A	January 1, 2020	N/A	*Per se* limit ≥ 5 ng/mL THC**
Maine(33-35)	January 30, 2017	February 2017	Mid-late 2020 (tentative)‡	N/A	None
Massachusetts(36, 37)	December 15, 2016	December 2016	November 20, 2018	December 2018	None
Michigan(38-40)	December 6, 2018	December 2018	December 1, 2019§	N/A	Zero tolerance – no detectable presence of cannabis permitted
Nevada(41, 42)	January 1, 2017	January 2017	July 1, 2017	July 2017	*Per se* limit ≥ 2 ng/mL THC**
Oregon(43-45)	July 1, 2015	July 2015	October 1, 2015‖	October 2015	None
Vermont(46)	July 1, 2018	July 2018	No Commercial Dispensaries	N/A	None
Washington(47, 48)	December 6, 2012	December 2012	July 8, 2014	July 2014	*Per se* limit ≥ 5 ng/mL THC**

* As of June 2020.

† Rounded up or down to the nearest full month of legalization (or commercial dispensaries opening); N/A = No data available for legalized (or commercial dispensaries open) months prior to 2019.

‡ Delayed from June 2020 due to COVID-19 pandemic.
§ On December 1, 2019, existing medical cannabis dispensaries in Michigan were permitted to transfer up to 50% of their medical cannabis inventory to recreational cannabis inventory. Until November 2021, retailers must hold a medical cannabis license in order to apply for a recreational cannabis license.
‖ On October 1, 2015, existing medical cannabis dispensaries in Oregon were permitted to sell recreational cannabis. The first licenses were issued to recreational cannabis retailers on October 1, 2016.
¶ Reasonable inference requires that in addition to exceeding the THC limit, the jurisdiction must also prove that the driver was impaired with other evidence.
** *Per se* limits do not require that the jurisdiction prove that the driver was impaired in order to charge them with driving under the influence if they exceeded the THC limit.

Table 2. Fatal motor vehicle collisions and associated deaths in the United States from 2007-2018 by recreational cannabis legalization and opening of recreational cannabis dispensaries.

	Number of Events	Person-Years of Observation	Rate per 100,000 Person-Years* (95% CI)	Rate Ratio (95% CI) *	
				Crude	Adjusted†
Fatal Motor Vehicle Collisions					
No Legalization	372,280	3,572,373,096	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
Legalization	17,116	206,984,000	11.4 (10.2-12.7)	1.08 (1.06-1.10)	1.09 (1.07-1.11)
No Open Dispensaries	379,153	3,659,070,227	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
Open Dispensaries	10,243	120,286,869	11.3 (10.2-12.6)	1.07 (1.05-1.10)	1.08 (1.05-1.10)
Overall	389,396	3,779,357,096	10.6 (9.5-11.8)	-	-
Deaths from Motor Vehicle Collisions					
No Legalization	406,205	3,572,373,096	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
Legalization	18,580	206,984,000	12.4 (11.1-13.8)	1.08 (1.06-1.10)	1.09 (1.07-1.11)
No Open Dispensaries	413,635	3,659,070,227	11.6 (10.4-12.9)	1.00 (ref)	1.00 (ref)
Open Dispensaries	11,150	120,286,869	12.3 (11.1-13.8)	1.07 (1.05-1.09)	1.08 (1.06-1.11)
Overall	424,785	3,779,357,096	11.6 (10.4-12.9)	-	-

Abbreviations: CI = Confidence Interval

* Models included a random-effects term to account for clustering of data by jurisdiction.

† Adjusted for calendar year as a categorical variable.

Table 3. First 12 months versus subsequent months of fatal motor vehicle collisions and associated deaths in the United States from 2007-2018 by recreational cannabis legalization and opening of recreational cannabis dispensaries.

	Number of Events	Person-Years of Observation	Rate per 100,000 Person-Years* (95% CI)	Rate Ratio (95% CI)*	
				Crude	Adjusted†
Fatal Motor Vehicle Collisions					
No Legalization	372,280	3,572,373,096	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
First 12 Months of Legalization‡	5,802	69,525,782	11.4 (10.2-12.7)	1.08 (1.05-1.11)	1.08 (1.05-1.11)
Subsequent Months of Legalization	11,314	137,458,217	11.4 (10.2-12.7)	1.08 (1.06-1.10)	1.09 (1.07-1.12)
First 12 Months vs Subsequent Months	-	-	-	1.00 (0.97-1.04)	0.99 (0.96-1.02)
No Open Dispensaries	413,635	3,659,070,227	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Open Dispensaries‡	5,426	60,437,734	11.9 (10.6-13.3)	1.03 (1.001-1.06)	1.06 (1.03-1.09)
Subsequent Months of Open Dispensaries	5,724	59,849,135	13.0 (11.6-14.5)	1.12 (1.09-1.16)	1.12 (1.08-1.15)
First 12 Months vs Subsequent Months	-	-	-	0.92 (0.88-0.95)	0.94 (0.91-0.98)
Overall	389,396	3,779,357,096	10.6 (9.5-11.8)	-	-
Deaths from Motor Vehicle Collisions					
No Legalization	406,205	3,572,373,096	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Legalization‡	6,290	69,525,782	12.4 (11.1-13.9)	1.08 (1.05-1.11)	1.08 (1.05-1.11)
Subsequent Months of Legalization	12,290	137,458,21	12.4 (11.1-13.8)	1.08 (1.05-1.10)	1.10 (1.07-1.12)
First 12 Months vs Subsequent Months	-	-	-	1.00 (0.97-1.03)	1.01 (0.98-1.05)
No open dispensaries	413,635	3,659,070,227	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Open Dispensaries‡	5,426	60,437,734	11.9 (10.6-13.3)	1.03 (1.001-1.06)	1.06 (1.03-1.09)
Subsequent Months of Open Dispensaries	5,724	59,849,135	13.0 (11.6-14.5)	1.12 (1.09-1.16)	1.12 (1.08-1.15)
First 12 Months vs Subsequent Months	-	-	-	0.92 (0.88-0.95)	0.94 (0.91-0.98)
Overall	424,785	3,779,357,096	11.6 (10.4-12.9)	-	-

Abbreviations: CI = Confidence Interval

* Models included a random-effects term to account for clustering of data by jurisdiction.

† Adjusted for calendar year as a categorical variable.
‡ Includes up to 12 months for each jurisdiction (some jurisdictions contributed less than 12 months, depending on their dates of legalization and/or commercial dispensaries opening).

Supplementary Table 1. Fatal motor vehicle collisions and associated deaths in the United States from 2007-2018 by recreational cannabis legalization and opening of recreational cannabis dispensaries, with calendar time modeled as a continuous variable.

	Number of Events	Person-Years of Observation	Rate per 100,000 Person-Years* (95% CI)	Rate Ratio (95% CI) *	
				Crude	Adjusted†
Fatal Motor Vehicle Collisions					
No Legalization	372,280	3,572,373,096	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
Legalization	17,116	206,984,000	11.4 (10.2-12.7)	1.08 (1.06-1.10)	1.15 (1.12-1.17)
No Open Dispensaries	379,153	3,659,070,227	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
Open Dispensaries	10,243	120,286,869	11.3 (10.2-12.6)	1.07 (1.05-1.10)	1.13 (1.10-1.16)
Overall	389,396	3,779,357,096	10.6 (9.5-11.8)	-	-
Deaths from Motor Vehicle Collisions					
No Legalization	406,205	3,572,373,096	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
Legalization	18,580	206,984,000	12.4 (11.1-13.8)	1.08 (1.06-1.10)	1.15 (1.13-1.17)
No Open Dispensaries	413,635	3,659,070,227	11.6 (10.4-12.9)	1.00 (ref)	1.00 (ref)
Open Dispensaries	11,150	120,286,869	12.3 (11.1-13.8)	1.07 (1.05-1.09)	1.14 (1.11-1.16)
Overall	424,785	3,779,357,096	11.6 (10.4-12.9)	-	-

Abbreviations: CI = Confidence Interval

* Models included a random-effects term to account for clustering of data by jurisdiction.

† Adjusted for calendar year as a continuous variable.

Supplementary Table 2. First 12 months versus subsequent months of fatal motor vehicle collisions and associated deaths in the United States from 2007-2018 by recreational cannabis legalization and opening of recreational cannabis dispensaries, with calendar time modeled as a continuous variable.

	Number of Events	Person-Years of Observation	Rate per 100,000 Person-Years* (95% CI)	Rate Ratio (95% CI)*	
				Crude	Adjusted †
Fatal Motor Vehicle Collisions					
No Legalization	372,280	3,572,373,096	10.6 (9.5-11.7)	1.00 (ref)	1.00 (ref)
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Subsequent Months of Legalization	11,314	137,458,217	11.4 (10.2-12.7)	1.08 (1.06-1.10)	1.15 (1.13-1.18)
First 12 Months vs Subsequent Months	-	-	-	1.00 (0.97-1.04)	0.99 (0.96-1.02)
No Open Dispensaries	413,635	3,659,070,227	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Open Dispensaries‡	5,426	60,437,734	11.9 (10.6-13.3)	1.03 (1.001-1.06)	1.08 (1.05-1.11)
Subsequent Months of Open Dispensaries	5,724	59,849,135	13.0 (11.6-14.5)	1.12 (1.09-1.16)	1.20 (1.16-1.24)
First 12 Months vs Subsequent Months	-	-	-	0.92 (0.88-0.95)	0.90 (0.86-0.94)
Overall	389,396	3,779,357,096	10.6 (9.5-11.8)	-	-
Deaths from Motor Vehicle Collisions					
No Legalization	406,205	3,572,373,096	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Legalization‡	6,290	69,525,782	12.4 (11.1-13.9)	1.08 (1.05-1.11)	1.14 (1.11-1.17)
Subsequent Months of Legalization	12,290	137,458,21	12.4 (11.1-13.8)	1.08 (1.05-1.10)	1.16 (1.13-1.18)
First 12 Months vs Subsequent Months	-	-	-	1.00 (0.97-1.03)	0.98 (0.95-1.02)
No Open Dispensaries	413,635	3,659,070,227	11.5 (10.4-12.8)	1.00 (ref)	1.00 (ref)
First 12 Months of Open Dispensaries‡	5,426	60,437,734	11.9 (10.6-13.3)	1.03 (1.001-1.06)	1.09 (1.06-1.12)
Subsequent Months of Open Dispensaries	5,724	59,849,135	13.0 (11.6-14.5)	1.12 (1.09-1.16)	1.20 (1.16-1.24)
First 12 Months vs Subsequent Months	-	-	-	0.92 (0.88-0.95)	0.91 (0.87-0.94)
Overall	424,785	3,779,357,096	11.6 (10.4-12.9)	-	-

Abbreviations: CI = Confidence Interval

* Models included a random-effects term to account for clustering of data by jurisdiction.

† Adjusted for calendar year as a categorical variable.

‡ Includes up to 12 months for each jurisdiction (some jurisdictions contributed less than 12 months, depending on their dates of legalization and/or commercial dispensaries opening).

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3-4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4-5
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	4-5
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	5
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-7; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	Report numbers of outcome events or summary measures over time	5-6

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5-6; Tables 2-3 N/A 7
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.