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The impact of recreational cannabis markets on motor vehicle accident, suicide, and opioid overdose fatalities

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Highlights

- Recreational cannabis markets were associated with higher motor vehicle deaths.

- No evidence that recreational markets led to an increase in suicides.

- Recreation markets were associated with a reduction in opioid overdose deaths.

Abstract

In the U.S., an increasing number of states are legalizing regulated commercial markets for recreational cannabis, which allows private industry to produce, distribute, and sell

marijuana to those 21 and older. The health impacts of these markets are not fully understood. Preliminary evidence suggests recreational markets may be associated with increased use among adults, which indicates there may be downstream health impacts on outcomes related to cannabis use. Three causes of death that are linked to cannabis use are motor vehicle accidents, suicide, and opioid overdose. Drawing on data from U.S. death certificates from 2009 to 2019, we conducted a difference-in-differences analysis to estimate the impact of recreational markets on fatalities from motor vehicle accidents, suicide, and opioid overdose in seven states: Colorado, Washington, Oregon, Alaska, Nevada, California, and Massachusetts. States with comprehensive medical cannabis programs with similar pre-trends in deaths were used as comparisons. For each outcome, a pooled estimate was generated with a meta-analysis using random effects models. The results revealed substantial increases in crash fatalities in Colorado, Oregon, Alaska, and California of 16%, 22%, 20%, and 14%, respectively. Based on estimates from all seven states, recreational markets were associated with a 10% increase in motor vehicle accident deaths, on average. This study found no evidence that recreational markets impacted suicides. Most states saw a relative reduction in opioid overdose death that ranged between 3 and 28%. On average, recreational markets were associated with an 11% reduction in opioid overdose fatalities.

Introduction

In the U.S., support for the legalization of cannabis use has risen dramatically over the last several decades. According to surveys conducted by Gallup, support rose from 12% in 1969 to 66% in 2019 (Jones, 2019). This trend has been accompanied by the implementation of liberalization policies that allow cannabis use for medical and recreational purposes in many states, although cannabis remains illegal at the federal level. In 2012, Colorado and Washington became the first jurisdictions globally to legalize recreational cannabis use as well as supply (Pacula et al., 2014). Since then, many U.S. states have followed suit; as of December 2022, 21 states and Washington D.C. have legalized recreational cannabis use. Nearly all of these states have chosen to permit a regulated commercial market. This regulated market allows a private industry to produce, distribute, and sell cannabis to those aged 21 and older.

The health effects of regulated commercial markets for recreational cannabis use (referred to hereafter as recreational markets) are not fully understood, as these policies are still relatively new. While preliminary evidence on the effect of markets on adolescent use is mixed (Bailey et al., 2020; Cerda et al., 2017, 2020; Coley et al., 2021), evidence for adults suggests that recreational markets may be associated with increased use (Cerda et al., 2020;

Kerr et al., 2017, 2018). These findings indicate there may be downstream health impacts of markets on outcomes that are associated with cannabis use. According to the National Academies of Science, Engineering, and Medicine (2017) report there is substantial evidence that cannabis use is associated with increased risk of motor vehicle accidents and moderate evidence that use is linked to the development of depressive disorders and suicidality. Additionally, the report found conclusive evidence that cannabis is effective at treating chronic pain (The National Academies of Sciences, Engineering, and Medicine, 2017). Because of cannabis's potential analgesic properties, some policymakers have argued that increasing access to cannabis can mitigate the opioid epidemic (Voelker, 2018). Multiple states have allowed health professionals to recommend cannabis over prescription opioids (Humphreys and Saitz, 2019; Voelker, 2018). Additionally, some states have added opioid use disorder (OUD) as a qualifying condition for medical cannabis access (Humphreys and Saitz, 2019; Shover et al., 2020).

The purpose of this study is to evaluate the effect of recreational markets on three causes of death that are linked to cannabis use: motor vehicle accidents, suicide, and opioid overdose. Drawing on U.S. death certificate data from 2009 to 2019, this study uses a difference-in-differences (DID) research design to estimate the impact of recreational markets on deaths in seven states that implemented recreational markets prior to 2019. This study makes several contributions to the literature. First, it used more recent data to assess short-term effects in states that have not been evaluated and longer-term impacts in early adopter states. Second, the treatment period in this study started when recreational retail sales began as opposed to when recreational use was legalized. This timing difference is important because it can take one to two years for recreational markets to be implemented and these markets provide far greater access to cannabis. Lastly, we used states with comprehensive medical cannabis programs (CMCP) as comparisons because these states are most likely to be similar to the treated states.

There is concern that legalizing recreational markets may lead to an increase in motor vehicle crashes and fatalities (Kilmer, 2017). For example, experimental studies have consistently shown that the primary psychoactive compound in cannabis, tetrahydrocannabinol (THC) impairs driving ability (e.g., increases reaction times and lane weaving) (Sevigny, 2021). A limitation of these experimental studies is that they may not be externally valid.

In epidemiological studies of real-world impacts, one study of U.S. drivers involved in fatal car accidents estimated that crash involvement was 1.83 times higher for those who tested positive for cannabis compared to those that were drug free (Li et al., 2013). The results of a

study of several European countries revealed that drivers with THC in their blood were twice as likely to be deemed responsible for fatal car accidents compared to drug-free drivers (Schulze et al., 2012). In contrast, however, a study that was conducted in Virginia found testing positive for cannabis was not associated with increased crash (Compton and Berning, 2015). Some limitations of these studies include potential confounding and the fact that testing positive for THC does not necessarily indicate driver impairment at the time of the accident. Multiple meta-analyses on this topic have found that cannabis intoxication is associated with a low to moderate increase in crash risk (Els et al., 2019; Hostiuc et al., 2018; Rogeberg, 2019; Rogeberg and Elvik, 2016).

Whoa!

In 2018, 5% of Americans aged 16 and older reported driving under the influence of cannabis (Azofeifa et al., 2019). Among regular cannabis users, studies suggest intoxicated driving is exceedingly common. One study of Colorado and Washington found 44% of past-month cannabis users reported driving while high and 24% reported driving while high on five or more occasions in the past month (Davis et al., 2016). These findings are consistent with a study of college students that found 44% of males and 9% of females who used cannabis in the past 28 days self-reported driving after using cannabis (Whitehill et al., 2014). One large, national study of the U.S. found that driving under the influence of cannabis was more prevalent in states where recreational sales were legal compared to states where it was not legal (Lensch et al., 2020). However, two smaller studies found no association between intoxicated driving and living in a state with medical or recreational legalization (Benedetti et al., 2021; Berg et al., 2018).

To date, eight studies have evaluated the effects of recreational legalization and/or sales on traffic fatalities in the U.S. The earliest study by Aydelotte et al. (2017) found no impact on crash fatalities in the first three years of legalization in Colorado. Using a longer, five-year post-treatment period, Aydelotte et al. (2019) found an increase of 1.8 fatal crashes per billion vehicle miles traveled (BVMT) in Washington and Colorado, but only after recreational sales began. Estimating effects separately by state for Colorado and Washington, Santaella-Tenorio et al. (2020) found an increase of 1.46 deaths per BVMT in Colorado and no effect in Washington approximately three years after legal sales while Hansen et al. (2020) found no evidence of an effect in Colorado or Washington two years after legal sales. Lane and Hall (2019) estimated step and trend changes in traffic fatalities after recreational sales began in Colorado, Washington, and Oregon from 2009 to 2016. Their results indicated a non-significant step increase in Oregon, a step increase in Colorado, and a step increase and trend decrease in Washington (Lane and Hall, 2019). The authors state that the non-significant result in Oregon may have been due to spillover effects from the neighboring state of Washington (Lane and Hall, 2019). Kamer et al. (2020), estimated

the overall impact of recreational sales in Alaska, Oregon, Colorado, and Washington in 2016–2018. Their results showed an increase of 2.1 traffic fatalities per BVMT. Windle et al. (2021), compared crash fatality rates before and after legalization in ten states and Washington D. C. using data from 2007 to 2018. The results indicated substantial variation across states, but overall, recreational legalization was associated with a 15% increased risk of fatal motor vehicle crashes (Windle et al., 2021). Finally, Farmer et al. (2022) assessed the impact of recreational legalization and sales on injury and fatal crash rates across Colorado, Washington, Oregon, California, and Nevada from 2009 to 2019 and found legalization and sales were associated with a 5.8% and 4.1% increase in injury and fatal crash rates, respectively.

[handwritten margin note: Basically recreational marijuana = increase in crashes & crash fatalities]

Systematic reviews and meta-analyses have found cannabis use is associated with the development of depressive disorders (Lev-Ran et al., 2014; Moore et al., 2007) and suicidality (suicidal ideation, suicide attempts, and suicide completion) (Borges et al., 2016). The earliest systematic review of longitudinal studies by Moore et al. (2007) reported five of ten studies found evidence of an association between cannabis use and depressive outcomes and studies that measured frequency of use revealed a dose-response pattern. These findings are consistent with a review and meta-analysis of longitudinal and prospective studies that accounted for baseline depression and revealed cannabis use was associated with a small increase in the risk of developing depressive outcomes and that heavy use was associated with a greater risk (Lev-Ran et al., 2014). A review of the association between acute and chronic cannabis use and suicidality concluded there is a lack of evidence that acute use increases the immediate risk of suicidality, however, meta-analyses revealed an association between chronic use and suicidal ideation, suicide attempts, and suicide completion (Borges et al., 2016). Additionally, heavy users had a substantially higher risk of suicidal ideation and attempts (Borges et al., 2016).

One explanation for these associations is that cannabis use affects depressive outcomes and suicidality through causal mechanisms which could be biological and relate to the pharmacological characteristics of cannabis (Agrawal and Lynskey, 2014) or could be due to consequences of cannabis use (Fergusson et al., 2002). A second possible explanation is reverse causation. People who are suffering from depression may seek out cannabis as a form of self-medication to alleviate their symptoms (Agrawal and Lynskey, 2014). A third possible reason for the linkage is that there may be difficult-to-measure or unknown confounders. Examples include genetics (Agrawal and Lynskey, 2014), personality traits (e.g., impulsivity), and early psychosocial adversity (e.g., childhood trauma) (Fergusson et al., 2002).

To date, a small number of studies have evaluated the impacts of medical and recreational cannabis legalization on suicide. Anderson et al. (2014) assessed the effects of medical legalization on changes in state-level suicides from 1990 to 2007 and found a 5% reduction in suicides for men overall, a 10% decrease for men aged 20–29, and 15% decrease for men 30–39. Grucza et al. (2015) extended the work of Anderson et al. (2014) and found no evidence of a protective effect after controlling for demographic characteristics and additional state characteristics and policies. Another study of medical cannabis legalization by Bartos et al. (2020) used the synthetic control method to estimate the impacts on gun and non-gun suicides in California using data from 1970 to 2004. The analysis found a reduction in gun suicides (Bartos et al., 2020). To our knowledge, only one study has evaluated the impact of recreational markets on suicide. Doucette et al. (2021) examined Colorado and Washington using the synthetic control method and found no overall impact on suicide, however, stratified analyses revealed an increase in suicides of 18% among 15 to 24-year-olds in Washington.

Opioid overdose deaths are a significant public health problem in the U.S. Between 1999 and 2019, nearly 500,000 Americans died from an opioid related overdose (Centers for Disease Control and Prevention, 2021). The initial rise of opioid deaths, which began in the 1990s, was primarily due to overdose from prescription opioids (Centers for Disease Control and Prevention, 2021). An important driver of these deaths was the over-prescription of opioids for pain management (Bohnert et al., 2011; Deweerdt, 2019).

Cannabis has been considered a potential alternative to opioids because it has been shown to be effective at treating pain (The National Academies of Sciences, Engineering, and Medicine, 2017). Compared to opioids, cannabis has a substantially lower risk of addiction and no risk of overdose death (Pacula and Hall, 2003). Studies have suggested that medical cannabis laws (MCL) and recreational cannabis laws (RCL) may have reduced opioid prescriptions. Using Medicare Part D enrollee data, Bradford et al. (2018) found MCL states saw an 8.5% decrease in opioid prescribing relative to states without MCL. These findings are consistent with a study of opioid prescribing among Medicaid enrollees (Wen and Hockenberry, 2018). Wen and Hockenberry (2018) report MCL and RCL are associated with a 5.9% and 6.4% lower rate of opioid prescribing, respectively, compared to prohibition states.

Other works have evaluated the effects of MCL on opioid-related hospitalizations and deaths. Shi (2017) found MCL was associated with a 23% decrease in hospitalizations related to opioid dependence or abuse and a 13% reduction in hospitalization from opioid overdose. Bachhuber et al. (2014) were the first to examine the relationship between MCL and opioid overdose mortality and they found MCL were associated with a 24.8% lower annual rate of opioid deaths. Powell et al. (2018) replicated the work of Bachhuber et al. (2014) and found

no effect after controlling for additional time-varying factors and extending the treatment period. However, further analysis revealed that the presence of dispensaries were associated with a 25% reduction in opioid deaths (Powell et al., 2018). Shover et al. (2019) also replicated the work of Bachhuber et al. (2014) and estimated a similar decline in opioid death using the original study period; however, after extending the study period, the estimate reversed in direction (+23%) and was statistically significant.

The negative association between MCL and opioid-related harms has been interpreted as evidence that individuals substitute from opioids to cannabis. There is some evidence from small non-controlled surveys among medical cannabis patients to support this hypothesis. For example, one retrospective study of medical cannabis patients in Michigan found that cannabis use was associated with a 64% decrease in opioid use (Boehnke et al., 2016). While there is some evidence of a substitution effect, other research suggests that cannabis use may be a risk factor for opioid misuse and OUD. Using nationally representative data, Caputi and Humphreys (2018) found that medical cannabis patients were more likely than non-cannabis users to use prescription drugs non-medically. Similarly, Liang et al. (2019) find medical and recreational cannabis users had increased risk of opioid misuse and OUD compared to non-cannabis users. A limitation of these studies is that they used cross-sectional data. However, their findings are consistent with Olfson et al. (2018) who used longitudinal and nationally representative data and found that cannabis users in the baseline period were more likely to misuse opioids or meet the criteria for OUD than non-users three years later.

Relatively few studies have focused on the impacts of RCL on opioid outcomes. If cannabis and opioids are substitutes, recreational markets have the potential to ameliorate the opioid epidemic. Conversely, if cannabis is a gateway drug, it could increase opioid initiation. To our knowledge, four studies have investigated the association between recreational markets and death from opioid overdose.

The first study, conducted by Livingston et al. (2017), found that Colorado saw a 6.5% reduction in opioid deaths in the first year of legal sales. However, another study by Alcocer (2020) used data from 1999 to 2017 and found no impact of legalization on opioid deaths in Colorado compared to a synthetic control, which was a weighted combination of states with MCL. Chan et al. (2020) estimated the average effect of legalization and recreational dispensaries on deaths from all opiates, prescription opioids, and synthetic opioids from 1999 to 2017. Recreational dispensaries were associated with a 23%, 24%, and 40% decline in overdose mortality from all opiates, prescription opioids, and synthetic opioids, respectively (Chan et al., 2020). A recent study examined the effect of county-level medical and

recreational dispensary counts on opioid mortality from 2014 to 2018 and found that an increase from one to two recreational dispensaries was associated with a 21% decrease in opioid deaths (Hsu and Kovacs, 2021).

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Section snippets

Data

Detailed Multiple Cause of Death Research Files from 2009 to 2019 were obtained from the National Center for Health Statistics' Division of Vital Statistics. This dataset includes death certificate data for all U.S. deaths, including the state where the death occurred and underlying cause of death. …

Study design

A DID research design was used to evaluate the impact of recreational markets on deaths from motor vehicle accidents, suicide, and opioid overdose in seven states that opened markets prior to 2019: Colorado, Washington, Oregon, Alaska, Nevada, California, and Massachusetts. This DID design used time series data—state-level number of deaths per 100,000 population (referred to hereafter as the death rate) for each quarter—to estimate the pre-post change in deaths in the intervention states …

Statistical analysis

For each treated state and outcome, we employed a linear regression model to estimate the pre-post changes in the death rate relative to comparison states (DID estimator). The statistical model was the following: $\log(Y_{st}) = \beta_0 + \beta_1 RCM_{st} + \delta_s + \gamma_t + \varepsilon_{st}$ Where Y_{st} is the death rate in state s at time t; RCM_{st} is an indicator for when the recreational cannabis market was implemented; δ_s is state fixed effects; and γ_t is time fixed effects. As a sensitivity analysis, the state unemployment rate was added to …

Results

A list of comparison states used in the analysis and the alternate analysis are provided in Appendix Table 1A.

Descriptive statistics for the total number of deaths during the study period, the quarterly death rate in the pre-treatment and post-treatment periods, and the percentage change in the death rate are provided in Table 2. The pre-treatment period used for the comparison states was the period prior to the first legal recreational sales in the U.S. (2009–2013) and the post-treatment ...

Discussion

In this study, we examined the impact of recreational cannabis markets on three causes of death that are linked to cannabis use: motor vehicle accident, suicide, and opioid overdose. Overall, following the implementation of recreational markets, we found evidence of substantial increases in motor vehicle accident deaths in four states – Colorado, Oregon, Alaska, and California. Overall, the pooled effect across all seven states suggests recreational markets were associated with a 10% increase ...

Conclusions

In the U.S., an increasing number of states are legalizing recreational cannabis use and implementing recreational markets. It is important to evaluate whether recreational markets, which provide greater access to cannabis, lead to increased health harms associated with cannabis use. In this study, we investigated the impact of recreational markets on three causes of death that are linked to cannabis use: motor vehicle accidents, suicide, and opioid overdose. Overall, following the legalization ...

Credit author statement

Samantha Marinello: Conceptualization, Methodology, Formal analysis, Writing – original draft. Lisa M. Powell: Methodology, Writing – review & editing, Supervision. ...

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. ...

Recommended articles

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