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Research Paper

Examining the relationship between medical cannabis laws and cardiovascular deaths in the US

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ABSTRACT

Background: Several countries and many U.S. states have allowed, for cannabis to be used as therapy to treat chronic conditions or pain., This has increased the use of cannabis, particularly among older people. Because cannabis has been linked to adverse cardiac events in the medical literature, there may be unintended consequences on increased use among older people.
Methods: We analyze cardiac-related mortality data from the U.S. National Vital Statistics System for 1990–2014. We use difference-in-difference fixed-effects models to assess whether there are increased rates of cardiac-related mortality following passage of medical cannabis programs. We also analyze whether states with more liberal rules on dispensing cannabis show higher mortality rates.
Results: For men, there is a statistically significant 2.3% increase in the rate of cardiac death following passage. For women, there is a 1.3% increase that is also statistically significant. he effects increase or both men and women with age. The effects are also stronger in states with more a lax approach to cannabis dispensing.
Conclusion: Policymakers should be aware of a potential unintended consequence of allowing broader use of cannabis, specifically for those more at risk of cardiovascular events.
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Introduction

The use of cannabis as therapy to treat chronic conditions or pain is now legal in a number of countries, with some nations, like Canada, providing such therapy through state-sponsored programs (Hazekamp & Heerdink, 2013; Hill, 2015).[1] In the United States, there are 26 states and the District of Columbia that allowed for at least some use of cannabis as therapy be the end of 2016. Well over half of the U.S. population lives in those states.[2] Other countries are currently debating whether allowing cannabis for medicinal use is appropriate. The UK recently reclassified cannabis extract as a medicine, which some think reopens serious discussion of allowing cannabis itself to be prescribed medically.[3]

We are interested in whether cannabis use, legal or illegal, is associated with cardiac-related mortality following the passage of state medical cannabis legalization (MCL) programs, which is the moniker for allowing cannabis for therapeutic purposes in the U.S. The association between cannabis and cardiovascular health has been documented for decades (Beaconsfield, Ginsburg, & Rainsbury, 1972; Charles, Holt, & Kirkham, 1979; Collins, Higginson, Boyle, & Webb, 1985; Fant, Heishman, Bunker, & Pickworth, 1998; Bachs & Mørland, 2001; Sidney, 2002) and is receiving renewed attention now that cannabis use is becoming even more common (Franz and Frishman, 2016; Singh et al., 2016). In population-based studies, the evidence is not conclusive (Frost, Mostofsky, Rosenbloom, Mukamal, & Mittleman, 2013; Jouanjus, Raymond, Lapeyre-Mestre, & Wolff, 2017). In one recent detailed study, Reis et al. (2017) followed a cohort of young men from young adulthood to middle age. No evidence of an association between cumulative and recent cannabis use was found.

MCL, however, might increase use among groups that would be more likely to be at risk for such an adverse cardiac event—specifically, those of advanced age. Using the National Survey on Drug Use and Health, Azofeifa (2016) documents a 333% increase in cannabis use rates among those age 65 and above and a 455% increase for those between ages 55 and 65. Conversely, overall

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[1] In some countries such as Canada, the legalization of medical cannabis is supported under government programs while in the Unites States it is operationalized under state laws.
[2] See http://medicalmarijuana.procon.org/view.resource.php?resourceID=000881 for a complete list.
[3] See http://www.euroweeklynews.com/3.0.15/news/on-euro-weekly-news/world-news/142782-cannabis-extract-will-be-classed-as-medicinal-in-uk

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growth in cannabis use was only 35% or about one-tenth of that for older people. There is also ample evidence that older adults are behaving in a fashion consistent with heightened medical cannabis use. Overall, new studies suggest that the Medicare enrollees are sensitive to cannabis and opioid drug policies. Bradford and Bradford (2016) show that spending on prescription drugs as part of Medicare Part D was significantly less in states that allowed for use of cannabis treat symptoms. The spending reduction was concentrated on medicines for which cannabis would be considered a viable alternative. Further suggestive evidence is provided by Nicholas and Maclean (2016) who use the Health and Retirement Study to identify that MCL increases labor supply among older adults, as well as some evidence of general health benefits, although they do not address death from cardiac events. These findings are all dependent on a heightened number of additional users of advanced age, which certainly appears to be the case. The primary drivers for such a change in use among older people over the past decade are cannabis legalization and a more general acceptance in the population of cannabis. The latter of course is a confounding factor in any study of the effects of medical cannabis. We suspect the surge has more to do with MCL, however, as Martins et al. (2016) confirms that the relative surge in use is concentrated among older individuals in MCL states.

Data

We use mortality data from National Vital Statistics System through the National Center for Health Statistics for 1990–2014 period to identify the number of deaths due to cardiovascular diseases in each state in each year. This dataset includes all deaths that occurred in the United States with information about socioeconomic background, including age at death, sex, the state of residence, and the cause of death for each individual. This allows us to separate deaths by age and sex as well. The underlying cause of death is based on the *International Classification of Diseases*, ninth (ICD-9) (in 1990–1998 period) and tenth (ICD-10) (in 1999–2014 period) revisions. We identify as our outcome of interest all deaths that were cardiovascular in cause in a state year per 100,000 residents in the same age-sex group.[4] We also verified that the results generally hold for a more narrow classification that includes acute myocardial infarctions only. Those effects, along with additional alternative estimates, are reported in the Appendix A.

As additional explanatory variables, we include state-level annual unemployment rates (from Bureau of Labor Statistics), state-level annual per capita income in 2014 dollars (from Bureau of Economic Analysis), state-level tobacco taxes in 2014 dollars (from the Tax Burdon on Tobacco), and indicators for whether states are 100% smoke-free in workplaces, restaurants, and bars. All of these variables vary by state-year. We also include demographic variables related to the percentage of white, black, and Hispanic in the state in a given year. Finally, we include cancer death rates (per 100,000 population in the same age-sex group) to capture general health in the population and because cancer treatment strategies, especially chemotherapy, could have adverse effects on the heart (Lenihan & Cardinale, 2012). If MCL is enacted exogenously to trends in heart-related mortality, which seems likely and is verified statistically below, these controls add to the efficiency of our estimations but have no effect on their consistency.

[4] In addition to reporting a separate ICD code for each health problem, NCHS groups certain disease categories and reports a 72-cause record for them. We use codes 300 to 490 from the 72-cause record, which include all deaths due to cardiovascular diseases for the 1990–1998 time period based on ICD-9 revision. We also use *I00–I99* codes in ICD-10 revision to calculate the number of deaths due to cardiovascular disease for the 1999–2014 period.

Table 1
MCL effective dates as of December 2014.

State	Effective date	State	Effective date
Alaska	March 1999	Michigan*	December 2008
Arizona*	April 2011	Minnesota	June 2014
California*	November 1996	Montana*	November 2004
Colorado*	June 2001	Nevada*	October 2001
Connecticut	October 2012	New Hampshire	July 2013
Delaware	May 2011	New Jersey	October 2010
District of Columbia	June 2010	New Mexico	July 2007
Hawaii	December 2000	New York	July 2014
Illinois	January 2014	Oregon*	December 1998
Maine	December 1999	Rhode Island	January 2006
Maryland	June 2014	Vermont	July 2004
Massachusetts	January 2013	Washington*	November 1998

Note: States with a * are considered lax states in our analysis of heterogeneities in state policy.

The next step was to link deaths attributable to cardiovascular diseases to effective dates for MCL implementation in each state. Table 1 provides the detail for each state that passed an MCL law during our sample period. We further identify those states that have relatively "lax" requirements, as defined by Ullman (2016). These include Arizona, California, Colorado, Michigan, Montana, Nevada, Oregon and Washington. Ullman (2016) based his classification on the numbers of users and regulation of dispensaries in the state. There was a very large break in terms of numbers of users in these states vs. the remaining states. We will use this classification to further assess the impact of MCL on cardiac-related deaths, with assumption that the places with more users (and "lax" requirements) experiencing the greater numbers of death. Because this is a somewhat arbitrary distinction between states, Williams, Olfson, Kim, Martins, and Kleber, 2016 also classify states based on how "medicalized" programs are, with the more medicalized programs defined by how closely they followed traditional medical care and pharmaceutical regulation while allowing cannabis use. The less medicalized programs would likely have more users and less regulation on who uses. The Ullman (2016) and Williams et al. (2016) ratings are very similar. Our results are similar using either the Ullman or Williams et al. classification.

Statistical approach

We employ a standard difference-in-difference research design to assess the impact of MCL on cardiac mortality, similar to that used by Anderson, Rees, and Sabia, 2014.[5] Specifically, we estimate the following regression:

$$\text{CVD rate}_{st} = \alpha + \beta_1 \text{MCL}_{st} + X_{st}\beta_2 + \delta_s + \tau_t + T_t{}^*\delta_s + \varepsilon_{st}. \quad (1)$$

In model (1), the dependent variable is the number of cardiovascular deaths per 100,000 people in a particular sex-age group. MCL_{st} is the policy variable, which is zero for states with no MCL and states with MCL before the law takes effect. It is set to one if a state has the law implemented for a full year, as well as the following years. For the states that implement the law in the middle of the year, this variable is set to 0.5 for that year, and 1 in the following years. Therefore, $\beta_1$captures the effect of MCL policy on cardiovascular deaths. X_{st} is a vector of additional policy variables that we include in the analysis. δ_s and τ_t are sets of state and year fixed effects, respectively. $T_t{}^*\delta_s$ represent state-specific linear time trends. T_t is an annual linear time trend beginning at 1 for the first year of the sample and continuing to the end of the

[5] They study the effect of MCL on another cause of mortality—suicide.

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