Recreational Cannabis Legalization and Opioid-Related Deaths in Colorado, 2000–2015

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Objectives. To examine the association between Colorado's legalization of recreational cannabis use and opioid-related deaths.

Methods. We used an interrupted time-series design (2000–2015) to compare changes in level and slope of monthly opioid-related deaths before and after Colorado stores began selling recreational cannabis. We also describe the percent change in opioid-related deaths by comparing the unadjusted model-smoothed number of deaths at the end of follow-up with the number of deaths just prior to legalization.

Results. Colorado's legalization of recreational cannabis sales and use resulted in a 0.7 deaths per month (b = –0.68; 95% confidence interval = –1.34, –0.03) reduction in opioid-related deaths. This reduction represents a reversal of the upward trend in opioid-related deaths in Colorado.

Conclusions. Legalization of cannabis in Colorado was associated with short-term reductions in opioid-related deaths. As additional data become available, research should replicate these analyses in other states with legal recreational cannabis. (*Am J Public Health.* 2017;107: 1827–1829. doi:10.2105/AJPH.2017.304059)

As more states loosen regulations on medical and recreational cannabis use, cannabis remains illegal under US federal law. Research into the health effects of recent state cannabis policies has found mixed results. Anderson et al.[1] noted a reduction in fatal automobile crashes in states that legalized medical cannabis, whereas Hall and Lynskey[2] found an increase in the proportion of fatal crashes involving cannabis. Recreational legalization in Colorado has led to increases in cannabis-related emergency department visits for both adults and children.[3] States and the US federal government continue to consider modifying cannabis policies, and more research is warranted to assess health effects of these policies across a diverse set of outcomes.

One topic of current research is whether cannabis is substituted for opioids in pain management.[4] With this substitution, an immediate reduction in opioid-related poisonings would be expected. Bachhuber et al.[5] assessed the effect of medical marijuana laws on reducing opioid-related deaths, reporting a 25% decrease in opioid overdose mortality in states with medical marijuana laws compared with states without such laws.

Death rates from opioid poisoning continue a disturbing upward trend in the United States and now constitute the leading cause of injury-related death. In 2014, 61% of all drug poisoning deaths involved an opioid, representing nearly 30 000 deaths.[6] Experts have proposed the need for a multifaceted approach, including collaborative efforts by public health and law enforcement, and a diverse set of regulatory policies to address this epidemic.

Researchers continue studying the public health implications of medical marijuana laws, but less is known about the effects of recreational cannabis legalization, particularly whether it reduces or exacerbates the current opioid epidemic. We investigated changes in opioid-related deaths in a state that substantially increased cannabis availability by legalizing sales of cannabis for recreational use.

METHODS

We used an interrupted time-series design to evaluate the effect of Colorado's recreational cannabis legalization on opioid-related deaths. We analyzed monthly counts of opioid deaths from January 2000 through December 2015, covering 168 baseline months and the first 24 months after legalization. Most confounders change slowly over time and are accounted for by having a long baseline time series. To further strengthen the design, we included opioid-related deaths in 2 regionally similar states as covariates. We selected Nevada to allow for comparison with a state that permits the sale of only medical cannabis, helping to isolate the effect of Colorado's recreational legalization from medical legalization. Nevada is a particularly suitable comparison because its legalization of medical cannabis occurred within months of medical legalization in Colorado. A second comparison state, Utah, was incorporated into the design for comparison between Colorado and a state where cannabis use remains illegal in state law.

An important threat to interrupted time-series designs are confounders that change at the same time as the policy under study. In our case, an important concern was that

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Colorado changed their prescription drug monitoring program in May 2014, 5 months after recreational cannabis legalization. Although the prescription drug monitoring program was established in 2007, the 2014 change required that all opioid prescribers and pharmacists register with, but not necessarily use, the prescription drug monitoring program by the end of 2014. Research indicates that prescription drug monitoring programs can abruptly affect opioid-related deaths.[7] Thus, changes to Colorado's prescription drug monitoring program could have confounded associations with recreational cannabis legalization. Because of variation in state prescription drug monitoring programs, no comparable state exists with respect to Colorado's prescription drug monitoring program change. Therefore, we relied on statistical controls for the potential prescription drug monitoring program effect.

Data

We examined monthly opioid-related deaths from 2000 to 2015 with the Multiple Cause of Death files available through the Centers for Disease Control and Prevention WONDER (Wide-Ranging Online Data for Epidemiologic Research) system. Opioid-related deaths were defined as any deaths with an *International Classification of Diseases, 10th Revision,* code indicating opioid poisoning (both pharmaceutical and nonpharmaceutical).[8]

We calculated policy variables based on the date retail stores began selling recreational cannabis directly to consumers (January 1, 2014).

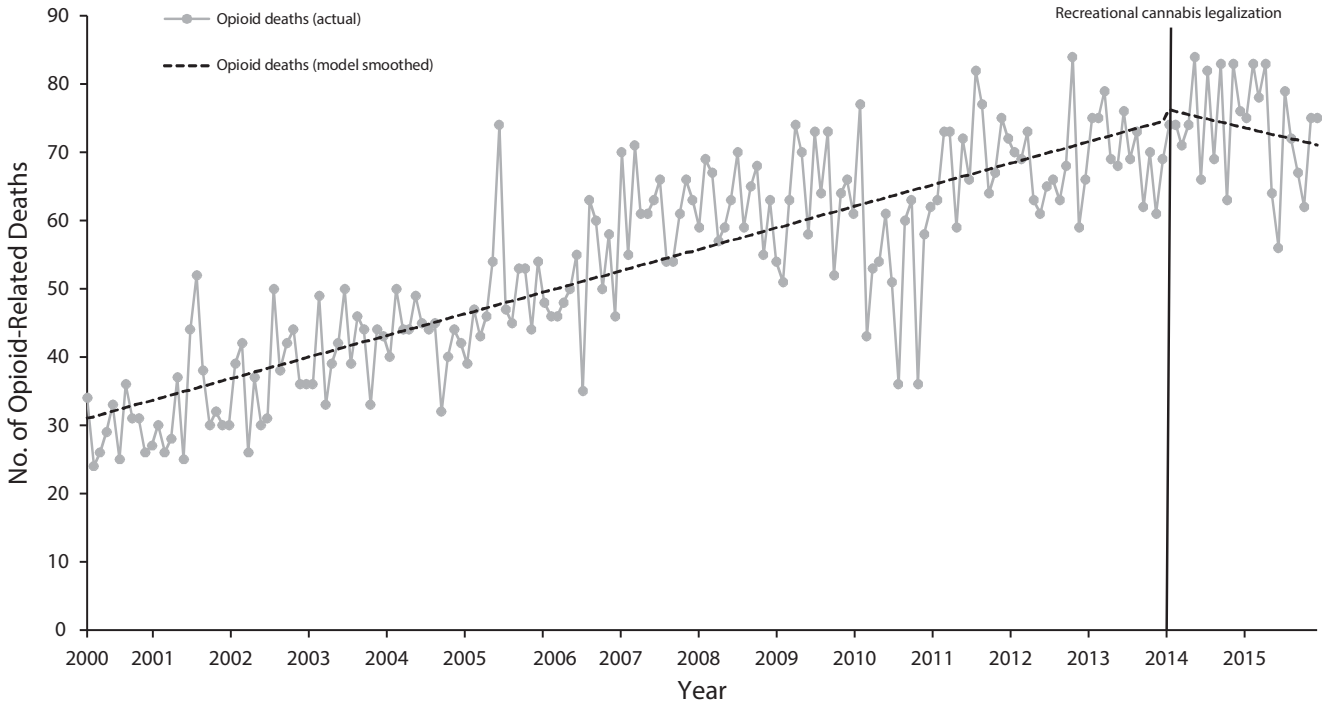
Statistical Analysis

To estimate the effect of recreational cannabis legalization on monthly opioid-related deaths in Colorado, we analyzed 3 separate segmented regressions:

$$(1)\quad Y_t = \beta_0 + \beta_1 * \mathbf{Time_t} + \beta_2 * \mathbf{Int_t} + \beta_3 * \mathbf{Post\ Time_t} + \beta_4 * \mathbf{Z_t} + \beta_5 * \mathbf{PDMP} + \mathbf{ARIMA}(0,0,3)$$

where Y_t is the number of opioid-related deaths, β_0 is the intercept, β_1 is the prelegalization trend, β_2 is an abrupt change in level postlegalization, Int_t is the dummy variable estimating an immediate level change postlegalization, β_3 is the change in trend starting at the time of legalization, β_4 is the association between Colorado's opioid-related deaths and those of the comparison state in each model, $\mathbf{Z_t}$ is the number of opioid-related deaths in the comparison state each month, β_5 is the change in level resulting from the May 2014 change in Colorado's prescription drug monitoring program (PDMP), and ARIMA is autoregressive integrated moving average.[9] This model assumes an immediate effect of legalization allowing for an immediate change in either the mean or the slope postlegalization. Following inspection of the autocorrelation and partial autocorrelation functions, we included an MA(3) parameter to achieve white-noise residuals.[10]

We describe the total effect of cannabis legalization as the percent change at the end of the follow-up period (December 2015). To be conservative, we estimated the percent change by comparing the model-smoothed number of deaths at the



Note. Change in opioid-related deaths per month following legalization = –0.68 (95% confidence interval = –1.34, –0.03; $P = .043$). Change in model-estimated opioid-related deaths was robust to covariate control of opioid-related deaths in all comparison states. Change in model-estimated opioid-related deaths was robust to whether the prescription drug monitoring program (PDMP) covariate was modeled at the beginning of implementation or at full implementation of the 2014 PDMP change.

FIGURE 1—Changes in Monthly Opioid-Related Deaths Following Recreational Cannabis Legalization in Colorado, 2000–2015

end of follow-up relative to the number of deaths just prior to legalization.

RESULTS

Analyses showed a statistically significant reduction in trend in opioid-related deaths following recreational cannabis legalization in Colorado. When we controlled for comparison state trends and Colorado's PDMP, opioid-related deaths decreased by approximately 0.7 deaths per month relative to the baseline period (b = –0.68; 95% confidence interval = –1.34, –0.03) (Table A, available as a supplement to the online version of this article at http://www.ajph.org). Comparing the model-smoothed opioid-related deaths per month just prior to legalization with the modeled number at the end of follow-up resulted in an estimated 6.5% reduction in opioid-related deaths.

These results were robust to controlling for trends in opioid-related deaths in the 2 comparison states and Colorado's strengthening of their PDMP by implementing mandatory registration (Figure 1). Results also did not change in any substantive way with Poisson rather than ARIMA models.

DISCUSSION

After Colorado's legalization of recreational cannabis sale and use, opioid-related deaths decreased more than 6% in the following 2 years. These findings extend Bachhuber et al.'s[5] results on the potential protective effect of medical cannabis legalization on opioid-related deaths. Available data provide only an assessment of the short-term effects of Colorado's recreational cannabis legalization. However, these initial results clearly show that continuing research is warranted as data become available, involving longer follow-ups and additional states that have legalized recreational cannabis.

Without being able to randomize recreational cannabis legalization to states, an interrupted time-series design offers the strongest quasi-experimental design for assessing effects. To nullify our results, remaining confounders would need to occur near the time of legalization in Colorado and differentially affect Colorado more than the comparison states. A potential confounder was Colorado's prescription drug monitoring program registration mandate in 2014. We addressed this by modeling the effect of both policies simultaneously. Part of the effect attributed here to a change in cannabis policy could be a result of changes in Colorado's prescription drug monitoring program. As additional data become available, research should replicate these analyses in other states with legal recreational cannabis.

PUBLIC HEALTH IMPLICATIONS

As of 2016, 8 states and Washington, DC, have legalized recreational cannabis. Given the rapidly changing landscape of cannabis and opioid policy in the United States, the need for evidence of the diverse health effects of these laws is increasing. Although we found an apparent public health benefit in a reduction in opioid-related deaths following recreational cannabis legalization in Colorado, we note that expanded legalized cannabis use is also associated with significant potential harms. For policymakers to balance the potential beneficial and deleterious effects of these laws, researchers must continue to examine the full range of health effects in both clinic- and population-level research. AJPH

CONTRIBUTORS

M. D. Livingston conceptualized the study, led the writing of the article, and analyzed the data. T. E. Barnett, C. Delcher, and A. C. Wagenaar contributed to the writing and editing of the article.

HUMAN PARTICIPANT PROTECTION

The institutional review board at the University of North Texas Health Science Center approved this study.

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