Drug and Alcohol Dependence 152 (2015) 68–72

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

A reexamination of medical marijuana policies in relation to suicide risk

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ARTICLE INFO

Article history:
Received 24 February 2015
Received in revised form 20 April 2015
Accepted 21 April 2015
Available online 30 April 2015

Keywords:
Marijuana
Medical marijuana
Policy
Suicide
Epidemiology

ABSTRACT

Objectives: Previous research has suggested that medical marijuana policies lead to reductions in suicide rates. In this study, we further investigate the association between these policies and within-state changes in suicide risk.
Methods: Data on suicide deaths (n = 662,993) from the National Vital Statistics System Multiple Cause of Death files were combined with living population data. Fixed-effects regression methods were employed to control for state differences in suicide rates and national and state secular trends. Analyses extended prior research that suggested a protective effect of medical marijuana policies by incorporating newer data and additional covariates.
Results: After adjustment for race/ethnicity, tobacco control policies, and other covariates, we found no association between medical marijuana policy and suicide risk in the population ages 15 and older (OR = 1.000; 95% CI: 0.956, 1.045; p = 0.98), among men overall (OR = 0.996; 95% CI: 0.951, 1.043; p = 0.87) or for any other age-by-sex groups.
Conclusion: We find no statistically significant association between medical marijuana policy and suicide risk. These results contradict prior analyses which did not control for race/ethnicity and certain state characteristics such as tobacco control policies. Failure to control for these factors in future analyses would likely bias estimates of the associations between medical marijuana policy and health outcomes.
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1. Introduction

Over the past two decades, 23 states and the District of Columbia have legalized marijuana for medical use in the U.S. (Anderson et al., 2014; Pacula et al., 2013). These policies were adopted at different times, allowing researchers to analyze the effects of policy changes as a natural experiment: differences in medical marijuana policies between states over time allow investigators to draw inferences about whether policy that could facilitate access to marijuana are causally associated with key public health outcomes (Anderson et al., 2013, 2014; Cerdá et al., 2012; Choo et al., 2014; Gorman and Charles Huber, 2007; Harper et al., 2012; Lynne-Landsman et al., 2013; Pacula et al., 2013; Rylander et al., 2014; Schuermeyer et al., 2014; Wall et al., 2011). In one of the more intriguing examples of such a study, Anderson and colleagues examined the association between legalization of medical marijuana and changes in state suicide rates over the period 1990–2007 (Anderson et al., 2014). Their results suggested that legalization of medical marijuana led to a *decrease* in suicide rates. Specifically, they reported that legalization was associated with a 5% decrease in the suicide rate for men overall, about a 10% decrease in the suicide rate of men aged 20 through 29, and a nearly 14% decrease in men aged 30 through 39.

If the legalization of marijuana for medical purposes truly leads to reductions in suicide rates, this would have important implications for public health and policy. Suicide is among the ten leading causes of death in the United States and the 4th leading contributor to years of potential life lost among people under 65 (Centers for Disease Control and Prevention, 2014; Murphy et al., 2013). Any true effect on suicide rates should be seriously considered in the policy debates surrounding both medical and recreational marijuana. However, a *protective* effect against

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http://dx.doi.org/10.1016/j.drugalcdep.2015.04.014
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suicide is surprising given that neurodevelopmental and psychiatric effects—including suicide risk—are among the primary health concerns associated with regular marijuana use (Batalla et al., 2013; Hall and Degenhardt, 2009; Meier et al., 2012; Moore et al., 2007; Price et al., 2009; Van Ours et al., 2013; Volkow et al., 2014). Given the relevance of such a finding to policy, the suggestion that medical marijuana policies might lead to *lower* rates of suicide warrants closer scrutiny.

In the present study, we sought to extend the work exploring the association between medical marijuana policy and reduced suicide risk (Anderson et al., 2014). We utilized data from individual death records, which allowed us to adjust for demographic variables at an individual level. This was not possible in the prior study, which analyzed state suicide rates instead of individual death records. Yet adjusting for demographic variables could be important because they may be associated with suicide rates, and, as key characteristics of state electorates, could influence state policy change. For example, race and educational attainment, which were not addressed in the prior study, are well known to be associated with suicide rates (Centers for Disease Control and Prevention (CDC), 2013; Crosby et al., 2013, 2011). We also adjusted for several additional state policies and characteristics that past research suggests could be relevant. For example, we have recently shown that state tobacco control policies may influence suicide risk (Grucza et al., 2014). Tobacco control policies also likely influence the prevalence of marijuana use (Chaloupka et al., 1999; Farrelly et al., 2001; Williams et al., 2004), and may influence alcohol use which could be an important determinant of suicide risk (Kaplan et al., 2014; Krauss et al., 2014; Young-Wolff et al., 2013a,b). We also included measures of state political orientation, per-capita mental health spending, and health insurance coverage, all of which may be associated with suicide risk (Kposowa, 2013; Tondo et al., 2006; Yoon and Bruckner, 2009) and are plausibly related to state policy environments. If these factors changed concurrently with adoption of medical marijuana policy, lack of explicit control for them could lead to biased estimates of the association between medical marijuana policy and suicide. Finally, we incorporated more recent data into our analyses, reflecting newly adopted state medical marijuana policies.

2. Methods

2.1. Overview

As an initial step, we conducted analyses comparable to those used in the prior report on medical marijuana policy and suicide, employing data from the same time period and including the same set of covariates (Anderson et al., 2014). However, our analyses utilized individual-level data modeled via logistic regression, whereas the previous report described the association between log-transformed state-level suicides rates modeled from aggregated data using linear regression. Because of these differences, we refer to our initial analyses as "comparison analyses" rather than "replication analyses." In these comparison analyses, we used the same medical marijuana policy coding and the same set of covariates as the previous report: average annual unemployment rate, per-capita income, beer excise taxes, zero-tolerance policies for youth driving under the influence, blood-alcohol content limits of 0.08 for drivers (vs. 0.10), and marijuana decriminalization policy indicators. In the main set of analyses, we extended the observation period from 1990–2007 to 1990–2010; four additional states (Arizona, Michigan, New Jersey, and New Mexico) and the District of Columbia passed medical marijuana policies during this time (Lynne-Landsman et al., 2013). Initial models were based on the same covariates as the comparison analyses, while subsequent models included individual-level demographic covariates (age, sex, race/ethnicity and educational attainment) and several additional state-level covariates (citizen political orientation, per-capita mental health spending, percentage of uninsured adults, cigarette excise taxes and a smoke-free air policy score).

2.2. Data

Individual-level data on suicide deaths were obtained from the Multiple Cause of Death files for 1990–2010, collected by the National Center for Health Statistics. Customized files including geographic data were obtained through the National Association for Public Health Statistics and Information Systems (NAPHSIS). From the complete set of death records, we selected observations for which suicide was either the underlying cause or among the contributing causes of death, using codes from the International Classification of Disease, versions 9 and 10 (codes E950–E959 and X60–X84, Y87, respectively). These records were combined with data on the living population obtained from the annual American Community Survey (ACS) for the years 2001–2010. For living population data prior to 2001 (when the ACS was initiated), we used data from 1% samples of the 1990 and 2000 Census. In order to estimate data for years 1991 through 1999, we used a linear interpolation procedure described elsewhere (Grucza et al., 2012, 2014). Briefly, this was done by determining the weights for records representing each possible combination of covariate parameters in each Census data set (i.e., each combination of year, state, race/ethnicity, sex, age group and education). Weights for intracensal years were estimated as: $[(2000\text{-year}) \times (1990\ \text{weight}) + (\text{year-}1990) \times (2000\ \text{weight})]/10$. These data sets were obtained from the Integrated Public Use Microdata Series maintained by the Minnesota Population Center (Ruggles et al., 2010). This process is described in more detail in Part II of the Supplemental Material. Analyses to support the validity of this approach are described there as well.

2.3. Variables

Medical marijuana policy was coded as "1" for years when use of marijuana for medical purposes was legally sanctioned and "0" for years when it was not. When the policy was in place for only part of the year, we coded the value for the fraction of the year during which the policy was in place; for example, if the policy in a state was implemented on July 1, we coded a value of 0.5 for that year. Sources for policy data included Anderson et al. (2014) for the years 1990–2007 and Lynne-Landsman et al. (2013) for subsequent years. Individual-level covariates extracted from mortality and living population records included state of residence, age, race/ethnicity, and education. Race/ethnicity was coded as non-Hispanic white, non-Hispanic black, Hispanic, and other. Age was grouped into the categories used by Anderson et al. (2014): 15–19, 20–29, 30–39, 40–49, 50–59, 60 and above. Education was dichotomized, with individuals classified as having a high-school diploma or less versus having had some post-secondary education.

The unemployment, per-capita income and insurance coverage variables were obtained from the United Health Foundation (2013). Alcohol policy variables (excise taxes, zero-tolerance laws, and BAC limit policies) were obtained from the Alcohol Policy Information System for years 1998-present and from the Statewide Data Availability System for earlier years (National Institute on Alcohol Abuse and Alcoholism, 2013; Ponicki, 2004). Indicators for marijuana decriminalization policy were coded from (Pacula et al., 2003) with updated data provided by a coauthor of that report (Chriqui, 2013). Data on smoke-free air policies were obtained from the State Cancer Legislative Database (2013). Cigarette excise taxes were obtained from "The Tax Burden on Tobacco" (Orzechowski and Walker, 2012). Development of the state political orientation measure was described by Berry et al. (1998) and updated data was obtained from Fording (2014). State per-capita mental health spending was obtained from the National Association of State Mental Health Directors Research Institute (2013). State unemployment rate and health insurance coverage were coded as percentages. BAC limit policies, marijuana decriminalization policy, and zero-tolerance policies were coded using dichotomous indicators. Beer and cigarette excise taxes, per-capita income and per-capita mental health spending were coded as dollar amounts. Mental health spending data were available only for years 1990, 1997 and 2001–2010; missing years were estimated via linear interpolation. The smoke-free air policy measure was obtained by summing scores for policies covering private worksites, restaurants, and bars and ranged from 0 to 6, representing the sum of a two point scale for each domain (0 for no policy, 1 for restrictions with less than a complete ban, and 2 for a complete ban; International Agency for Research on Cancer, 2009). The political orientation measure was coded as described in (Berry et al., 1998).

2.4. Statistical analysis

All models used logistic regression in which individual suicide outcomes were modeled from medical marijuana legalization policy within all 50 states and Washington, DC. Parameter estimates and standard errors were calculated using the SAS statistical package "surveylogistic" procedure, treating states as sampling clusters to account for intra-correlation of outcomes within states when estimating standard errors (Angrist and Pischke, 2008).

The comparison analyses paralleled those described in the prior report analyzing suicide rates in relation to medical marijuana policy (Anderson et al., 2014). Data from years 1990–2007 were analyzed; the most basic model included medical marijuana policy and categorical indicators for state and year. State covariates were added in the second model, and state-specific linear time trends were added in the third model. State-specific linear time-trends are modeled as state by year interactions, with year specified as a continuous, rather than a categorical variable.

Model development is summarized in Table 1. The main analyses incorporated data on state suicides and medical marijuana policy through 2010. Model 1 of the main analyses included state and year indicators, state time-trends, and the six state covariates that were included in the comparison analyses. Model 2 included individual-level demographic covariates. The full model (Model 3) included the additional state covariates and a refined model (Model 4) removed covariates that

Table 1
Covariates included in main analysis models, data years 1990–2010.

	Model I	Model II	Model III	Model IV
Policy determinants				
State Indicators	X	X	X	X
Year Indicators	X	X	X	X
State Linear Trends (State x Year)	X	X	X	X
State Covariates (Set 1)[a]				
Average Annual Unemployment Rate	X	X	X	X
Per Capita Income	X	X	X	
Beer Excise Taxes	X	X	X	X
Zero-tolerance Law	X	X	X	
BAC 0.08 Policy	X	X	X	
Marijuana Decriminalization	X	X	X	
Individual Demographics				
Age		X	X	X
Sex		X	X	X
Race		X	X	X
Education		X	X	X
State Covariates (Set 2)[b]				
Citizen Political Orientation			X	
Per Capita Mental Health Spending			X	
Percent of Uninsured Adults			X	
Cigarette Excise Taxes			X	X
Smoke-free Air Policy			X	X

[a] Covariates utilized in Anderson et al. (2014).
[b] Covariates introduced in this report.

were not significantly associated with suicide risk. Several post hoc analyses were conducted to examine the association of these additional variables with state medical marijuana policy. These are described and summarized in the Supplemental Material.

3. Results

Initial analyses examined the association between medical marijuana policies and suicide risk over the period 1990–2007 to allow for comparison with results obtained by Anderson et al. (2014). Model development is described in Table S1 (see Supplemental Material); results are shown in Tables S2 and S3 (see Supplemental Material). Similar to the prior results, medical marijuana policies exhibited a significant protective association among men overall, and among the 20–29 and 30–39 year age groups. However, these results do not adjust for the full set of covariates that we included in our main analyses.

Models for the main analyses are described in Table 1; Tables 2 and 3 summarize these results. These analyses cover the extended time period of 1990–2010, and the fully adjusted models include additional covariates (demographic factors, and additional state covariates). In the first partially adjusted model (Model 1), similar to the prior report (Anderson et al., 2014), the overall association between medical marijuana policy and suicide risk suggested a statistically significant protective effect (OR = 0.956; 95% CI: 0.923, 0.992; $p = 0.02$), particularly among men (OR = 0.956; 95% CI: 0.929, 0.984; $p = 0.002$). However, after addition of demographic covariates (Model 2), the magnitudes of the estimates were slightly reduced and no longer nominally significant. In the fully adjusted Model 3, which included the additional state characteristics, the odds ratio was exactly 1 (OR = 1.000; 95% CI: 0.956, 1.045; $p = 0.98$). Likewise, the association was not statistically significant in the sex-stratified analyses after adjusting for demographic variables, and odds ratios were very close to 1 in the fully adjusted models (OR = 0.996; 95% CI: 0.951, 1.043; $p = 0.87$ for men; OR = 1.011; 95% CI: 0.948, 1.078; $p = 0.74$ for women; Table S4, see Supplemental Material). Odds ratios describing covariate associations for Model 3 are listed in Table S4 (see Supplemental Material). We estimated an additional model in which all covariates that were not significantly associated with suicide at $p < 0.05$ in either the overall or sex-specific models were excluded (zero-tolerance policy, BAC 0.08 policy, marijuana decriminalization, citizen political orientation, per-capita mental health spending and percentage of uninsured adults). In this refined model (Model 4), the ORs of interest were identical to the previous model and the confidence intervals were only slightly larger (Table 2).

The report by Anderson et al. (2014) highlighted several age and sex-specific associations between medical marijuana policies and suicide rates and we also sought to examine whether these would remain significant in our final models. Thus, Table 3 reports the results of our analyses stratified by sex and age group. These stratified analyses utilized the fully adjusted Model 3 and the refined Model 4. For comparison, we also show the results of the partially adjusted Model 1, which was most similar to that employed in the report from Anderson et al. (2014). In the fully adjusted Model 3, the associations between medical marijuana policy and suicide risk among the twelve age-by-sex groups were non-significant with only one exception: men over 60 (OR = 1.04; 95% CI: 1.005, 1.105; $p = 0.04$). This association would suggest that medical marijuana policy *increases* risk for suicide; however, it would not meet nominal significance criteria after adjustment for multiple testing and therefore will not be considered further. In the refined model (Model 4), the ORs were again very similar to the previous model, with slightly larger confidence intervals (Table 2).

Post hoc analyses examined which variables might have contributed to the initially observed association between medical marijuana policy and suicide in models that were not fully adjusted. These results are shown in Table S5 (see Supplemental Material). Briefly, adoption of medical marijuana policy was associated with shifts toward populations that were older, less white, and higher in percentage of women. Trends in medical marijuana states also favored stronger tobacco control policies and higher per-capital mental health spending.

4. Discussion

In this report, we show that the association between state medical marijuana policy and suicide risk was not statistically significant, nor even suggestive of a protective effect, after adjustment for key covariates. Though an earlier report demonstrated an apparent correspondence between the legalization of medical marijuana and a decrease in suicide rates among men (Anderson et al., 2014), incorporation of demographic variables and additional state characteristics into the regression models reduced the magnitude of this association such that it was no longer consistent with even a modest protective effect.

The analytical design used both here and in the former study corresponds to a quasi-experiment that controls for state differences in suicide rates, as well as both national and state-specific secular trends (Angrist and Pischke, 2008). This approach can be very powerful in that it analyzes within-state changes in an outcome in relation to policy change. However, confounding can be an issue when state characteristics that change over time are correlated with both policy and outcome. We showed that adoption of medical marijuana policy was associated with shifts toward populations that were older and higher in percentages of minorities and women (Table S5, see Supplemental Material), which is problematic because minorities and women have much lower suicide rates than whites and men, respectively (Centers for Disease Control and Prevention (CDC), 2013; Crosby et al., 2011). Medical marijuana states also trended toward stronger tobacco control policies and higher per-capita mental health spending. Our own recent work suggests that implementation of strong tobacco control policies is associated with reductions in suicide risk

Table 2
Odds ratios describing the association between medical marijuana policy and suicide risk, 1990–2010.

	Suicides total		Suicides, men		Suicides, women	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
I. Partially adjusted model[a]	0.956 (0.923, 0.992)	0.02	0.956 (0.929, 0.984)	0.002	0.968 (0.892, 1.051)	0.44
II. Same as I, but also adjusted for demographic covariates	0.974 (0.939, 1.010)	0.15	0.972 (0.941, 1.004)	0.09	0.979 (0.903, 1.062)	0.61
III. Same as II, but also adjusted for additional state covariates	1.000 (0.956, 1.045)	0.98	0.996 (0.951, 1.043)	0.87	1.011 (0.948, 1.078)	0.74
IV. Same as III but removing covariates not significantly associated with suicide	1.000 (0.949, 1.053)	0.99	0.996 (0.944, 1.051)	0.89	1.011 (0.946, 1.080)	0.74

[a] See Table 1 for model development. Each odds ratio describes the policy–suicide association from a model in which suicide risk was modeled from medical marijuana policy and listed covariates. Full covariate coefficients for the fully adjusted model (III) are listed in Table S4 (see Supplemental Material).

Table 3
Odds ratios describing the association between medical marijuana policy and suicide risk, by age and sex, 1990–2010.

	Partially adjusted (Model 1)[a]		Fully adjusted (Model 3)		Refined (Model 4)	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Men						
Age <20 years	0.965 (0.827, 1.126)	0.65	1.026 (0.928, 1.135)	0.62	1.023 (0.923, 1.134)	0.66
Age 20–29 years	0.937 (0.889, 0.988)	0.02	0.965 (0.889, 1.047)	0.39	0.964 (0.884, 1.051)	0.40
Age 30–39 years	0.907 (0.861, 0.956)	0.002	0.944 (0.876, 1.018)	0.14	0.947 (0.871, 1.030)	0.21
Age 40–49 years	0.928 (0.877, 0.983)	0.01	0.967 (0.898, 1.041)	0.37	0.962 (0.895, 1.034)	0.30
Age 50–59 years	1.005 (0.947, 1.067)	0.87	1.039 (0.958, 1.127)	0.36	1.048 (0.965, 1.138)	0.27
Age ≥60 years	1.014 (0.974, 1.055)	0.49	1.054 (1.005, 1.105)	0.03	1.053 (0.995, 1.114)	0.07
Women						
Age <20 years	1.062 (0.788, 1.433)	0.69	1.114 (0.851, 1.458)	0.43	1.126 (0.857, 1.480)	0.39
Age 20–29 years	0.952 (0.838, 1.081)	0.45	0.988 (0.850, 1.148)	0.87	0.982 (0.844, 1.143)	0.81
Age 30–39 years	0.986 (0.866, 1.122)	0.83	1.025 (0.916, 1.146)	0.67	1.017 (0.906, 1.142)	0.77
Age 40–49 years	0.935 (0.867, 1.009)	0.08	0.939 (0.856, 1.031)	0.19	0.950 (0.864, 1.045)	0.29
Age 50–59 years	1.004 (0.903, 1.116)	0.94	1.034 (0.932, 1.148)	0.53	1.043 (0.943, 1.153)	0.41
Age ≥60 years	0.971 (0.846, 1.113)	0.67	1.069 (0.980, 1.166)	0.13	1.058 (0.979, 1.143)	0.16

[a] See Table 1 for model development. Each odds ratio describes the policy–suicide association from a model in which suicide risk was modeled from medical marijuana policy and listed covariates.

(Grucza et al., 2014). These findings are corroborated by analyses presented here (Table S4, see Supplemental Material). It is likely that these factors, if not explicitly controlled, could bias estimates toward a protective effect of medical marijuana policy on suicide risk.

In summary, this study finds no association between medical marijuana policy and suicide risk, contradicting an earlier report suggesting that legalization of medical marijuana might protect against suicide (Anderson et al., 2014). That earlier work did not control for individual-level demographics or for state tobacco control policies, both of which are associated with medical marijuana policy and with suicide risk (Centers for Disease Control and Prevention (CDC), 2013; Crosby et al., 2011; Grucza et al., 2014; Tables S4 and S5, see Supplemental Material). The primary limitation of this report is that we did not account for the various dimensions of medical marijuana policy (e.g., provisions for dispensaries, home growth, etc.). This was intentional so that our methods would match those of the earlier report as closely as possible, but future research should examine the roles of these various policy components (Pacula et al., 2013). Meanwhile, we conclude that medical marijuana legalization does not appear to lead to changes in suicide rates. Instead, it appears that medical marijuana legalization is correlated with changes in other factors that contribute to suicide risk, such as the demographic makeup of states and tobacco control policies. Medical marijuana legalization also corresponded with changes in age of state populations and per-capita mental health spending. These variables were not associated with suicide risk in our study, but may be relevant to other public health outcomes. Thus, extant studies of medical marijuana policy and public health outcomes that have not accounted for these differences should be interpreted cautiously, and future studies should take these factors into account.

Role of the funding source

The authors are responsible for the content; the NIH played no role in the development of this content aside from funding.

Contributors

Richard A. Grucza conceived and designed the study, conducted analyses, and led writing of the manuscript. Michael Hur and Melissa J. Krauss conducted analyses and critically reviewed the manuscript. Arpana Agrawal and Andrew D. Plunk drafted portions of the manuscript and critically reviewed it. Patricia A. Cavazos-Rehg critically reviewed the manuscript. Frank J. Chaloupka advised on analyses and critically reviewed the manuscript. Laura J. Bierut advised on the interpretation of the data and critically reviewed the manuscript.

Conflicts of interest

L.J.B. is listed as an inventor on Issued U.S. Patent 8,080,371,"Markers for Addiction" covering the use of certain genetic polymorphisms in determining the diagnosis, prognosis, and treatment of addiction.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.drugalcdep.2015.04.014

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