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The Impact of State Medical Marijuana Legislation on Adolescent Marijuana Use

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A B S T R A C T

Purpose: The state-level legalization of medical marijuana has raised concerns about increased accessibility and appeal of the drug to youth. The objective of this study was to assess the impact of medical marijuana legalization across the United States by comparing trends in adolescent marijuana use between states with and without legalization of medical marijuana.

Methods: The study utilized data from the Youth Risk Behavioral Surveillance Survey between 1991 and 2011. States with a medical marijuana law for which at least two cycles of Youth Risk Behavioral Surveillance data were available before and after the implementation of the law were selected for analysis. Each of these states was paired with a state in geographic proximity that had not implemented the law. Chi-squared analysis was used to compare characteristics between states with and without medical marijuana use policies. A difference-in-difference regression was performed to control for time-invariant factors relating to drug use in each state, isolating the policy effect, and then calculated the marginal probabilities of policy change on the binary dependent variable.

Results: The estimation sample was 11,703,100 students. Across years and states, past-month marijuana use was common (20.9%, 95% confidence interval 20.3–21.4). There were no statistically significant differences in marijuana use before and after policy change for any state pairing. In the regression analysis, we did not find an overall increased probability of marijuana use related to the policy change (marginal probability .007, 95% confidence interval −.007, .02).

Conclusions: This study did not find increases in adolescent marijuana use related to legalization of medical marijuana.

IMPLICATIONS AND CONTRIBUTION

This study, which used a difference-in-difference analysis to control for secular changes in drug use, found no observed effect of medical marijuana laws on adolescent marijuana use. This may alleviate concerns about one potential negative effect of state medical marijuana laws.

Marijuana is the most commonly used illegal substance in the United States [1,2], with 42% of U.S. adolescents reporting use of marijuana by 12th grade [3]. Marijuana has a demonstrated impact on the still-developing adolescent brain. Individuals initiating cannabis use before age 17 have been found to have less cortical grey matter and larger white matter volumes on magnetic resonance imaging and positron emission tomography imaging [4]. These observed differences in brain tissue are consistent with the poor psychosocial outcomes found in individuals who initiated marijuana at a young age. A number of studies have demonstrated decreased memory, learning, attention, and executive functioning in adolescents using marijuana

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that persist even after several weeks of abstinence from use [5–7]. In early adolescence, marijuana may have permanent detrimental effects on cognition [8]. Marijuana has also been linked to schizophrenia and other psychotic disorders among adolescents [9]. Longitudinal cohort studies of adolescents using marijuana found associations between use and later respiratory problems, general malaise, and neurocognitive problems, as well as social problems including lower academic achievement and functioning, welfare dependence, unemployment, low relationship satisfaction, and low life satisfaction [10–12].

Marijuana is classified as a Schedule I drug, and by federal law, the prescription, dispensing, possession, cultivation, and selling of marijuana remain illegal [13]. Nevertheless, to date, 20 U.S. states and the District of Columbia have passed legislation allowing the use of marijuana for medical reasons [14]. There is considerable variability in the medical conditions that qualify for treatment; some states allow conditions to be considered by the public health department on a case-by-case basis. Proponents of the use of marijuana for medical reasons cite relief of multiple conditions, including intractable pain, nausea and vomiting, cachexia due to conditions such as AIDS or cancer-related treatments, and muscle spasm in multiple sclerosis and other chronic neurologic diseases after failure of all other available therapies [1,14]. In contrast, opponents of medical marijuana use raise concerns about downstream effects such as increased recreational drug use and increased crime, especially in neighborhoods where medical marijuana dispensaries are located [15,16]. Among the chief concerns are the fears that it would "encourage widespread youth drug abuse," [17] that any liberalization of current drug use laws would contradict antidrug messages aimed at youth and counter existing perceptions of marijuana as a harmful substance, and that youth would seek prescriptions for use when it is not clearly indicated [18].

The objective of this study was to further investigate potential increases in marijuana use among youth associated with legalization of medical marijuana. To do this, we examined trends in reported adolescent drug use in a cohort of states before and after state policy change and compared these trends to geographically matched states that had not adopted medical marijuana legislation.

Methods

The Youth Risk Behavioral Surveillance System (YRBS) was developed by the Centers for Disease Control and Prevention (CDC) in 1990 to estimate the prevalence of health risk behaviors among youth and young adults, to assess the change in these behaviors over time, and to examine the co-occurrence of these behaviors [19]. The YRBS uses local and state school-based surveys to monitor six categories of priority health-risk behaviors, including behaviors that contribute to unintentional injuries and violence; tobacco use; and alcohol and other drug use. Individual states are responsible for administering the survey.

Detailed questions regarding substance use are administered to high school students (9th–12th grade). The survey employs a two-stage, cluster sample design to produce representative samples of students across grades in each jurisdiction, with schools selected at random. The probability of school selection is proportional to its enrollment. Participation by students in each sampled class is voluntary and anonymous. A weight is applied to each record to adjust for student nonresponse and the distribution of students by grade, sex, and race/ethnicity in each jurisdiction. The final weighted estimates, therefore, are representative of all students in grades 9–12 attending schools in each jurisdiction [19].

The YRBS is administered biannually on odd years. States were identified that had legalized medical marijuana and had participated in YRBS for at least two cycles prior to the policy change and at least two cycles after the policy change. For each state, a geographically close comparison state for which YRBS data were also available for at least two cycles prior to and after the policy change was selected; for each state with medical marijuana laws, only one such comparison state was available.

Measures

The primary (dependent) outcome was defined as any 30-day marijuana use (yes/no). YRBS variables of interest to the analysis included student demographics of grade (9th–12th), gender, and race/ethnicity. Categorical variables were created to represent state, year, and whether or not the medical marijuana law was in place in a given year.

Data analysis

Demographics of the students participating in the survey were examined. Univariate (chi-squared) analyses were used to compare the proportions of students in demographic categories (age, race, and gender) and in self-report of 30-day marijuana use (the primary outcome), lifetime marijuana use, 30-day alcohol use, and binge drinking.

A difference-in-difference regression model was developed to isolate the policy effect on marijuana use:

$$Y_{ist} = m(A_s + B_t + cX_{ist} + b_{ist} + \varepsilon_{ist}),$$

where Y_{ist} represents adolescent marijuana use, m is a general function indicating the relationship between the outcome Y and the independent variables, A_s represents a fixed effect for each state, B_t represents a fixed effect for each year, cX_{ist} represents individual level variables (age, gender, race), b_{ist} (the term of interest) is an indicator variable that takes a value of 1 if the medical marijuana policy is present at time t in state s, and 0 otherwise, and ε_{ist} represents a state- and time-specific error term. Models included demographic covariates of race, gender, and grade. Models were developed for each state pairing and then on the combined dataset as a whole. In each case, a state without a medical marijuana policy served as the reference.

Generally, the difference in difference can be considered the average difference in outcome(s) of interest among youth in one state (with the policy change of interest), less the average difference among the comparison group (the state without the policy change). The first difference reflects the change in the primary outcome (drug use) that occurs after the policy implementation. By subtracting the second difference—the change that occurs in the comparison group—secular changes that may have occurred for reasons not related to the policy are excluded from the analysis. Any remaining differences in outcome—the difference in difference—are attributed to the policy change (in this case, the medical marijuana legislation). The difference in difference is a well-established tool in the health services literature [20] and one that is particularly useful for examining the effects of state-level policies [21,22]. The model described above is a modification of the standard difference-in-difference approach, using state and time fixed effects to allow additional flexibility in

the ways in which marijuana use may differ across states and times, independent of the policy timing. Because coefficients for binary dependent variables can be difficult to interpret, we calculated the marginal probabilities (derivative of the mean expected probability) of policy change on 30-day marijuana use for each model and used this as the primary reported outcome. To assess the robustness of the logistic regression, additional analyses were conducted using linear probability models for estimation. Hosmer–Lemeshow tests for survey data (*svylogitgof*) were used to test model goodness of fit.

We also performed a number of sensitivity analyses. First, we performed subpopulation analysis, examining outcomes for individual grade categories (grades 9–12), to see whether specific ages were more likely to be susceptible to effects of changes in marijuana law. Second, given the amount of missing data, we performed multiple imputation on data aggregated by year and state. Although we could not recreate individual-level data for entire years in which YRBS data were not available from a state, in this way we were able to create estimates for overall prevalence of marijuana use and proportions of students within race/ethnicity, gender, and grade categories. We then repeated the analysis using linear regression (since only aggregate estimates of prevalence, rather than individual-level data for marijuana use, were available) with the imputed data.

YRBS employs a two-stage cluster sampling design to estimate rates of health-related behaviors among high school students. All analyses were performed using Stata 12.0 (StataCorp LP, College Station, TX). For all analyses, the *svy* commands in Stata were used to account for weights and clustering and obtain accurate point estimates, confidence intervals (CIs), and tests of hypothesis. In addition, to account for the likelihood of similarities of responses within a given year, we added year as an additional stratum [23].

Results

Descriptive statistics

Demographic characteristics of students, stratified by state, are listed in Table 1. Marijuana use was common among the students in the total sample, with lifetime use of 37.3% (95% CI 36.5–38.1) and past-month use of 20.9% (95% CI 20.3–21.4). Overall, states with the medical marijuana law had a significantly higher percentage of students reporting past month marijuana use and a significantly lower percentage of nonwhite students.

Year-by-year state trends

Figure 1 shows comparisons of trends in past 30-day marijuana use in states paired by region.

Difference-in-difference analyses

The results of the difference-in-difference analyses are listed in Table 2. A positive coefficient indicates an increase in the probability of past 30-day marijuana use. Controlling for individual-level covariates, the regression analysis shows that medical marijuana legislation has had no effect on increasing reported past 30-day marijuana use. In the Utah-Nevada comparison and the Idaho-Montana comparison, the state with the medical marijuana policy (Nevada, enacted in 2000, and Montana, enacted in 2004) demonstrated a *decreased* probability of marijuana use after implementation of the policy. There was no change in the probability of marijuana use in any of the other state pairings or in the combined dataset with all states (marginal probability .007, 95% CI −.007, .02); the latter model provided the narrowest CI. Linear regression provided similar results for all models. The addition of 30-day or binge alcohol to models generated similar results as well but led to poor model fit, likely due to multicollinearity.

In the subanalysis by grade, decreased marginal probabilities for marijuana use in the Utah/Nevada model seem to be predominantly in grades 10 and 12; for the New York/Vermont model, 9th graders demonstrated a decreased marginal probability of marijuana use in the presence of the policy, despite the overall lack of effect of the policy in this state pairing. Otherwise, stratification by grade did not demonstrate any specific subgroup particularly vulnerable to increase in marijuana use following the implementation of medical marijuana laws.

The results from the models using imputed values are listed in Table 3. No state demonstrated a change in reported marijuana use associated with implementation of medical marijuana laws.

Discussion

The CDC's YRBS has been administered for >20 years, allowing examination of the longitudinal effect of states' policies on adolescents. Our study suggests that—at least thus far—the legalization of marijuana for medical purposes has not increased adolescent marijuana use, a finding supported by a growing body of literature. Wall et al. [24] used National Survey on Drug Use and Health data and reported higher prevalence of marijuana use in eight states that had legalized marijuana for medical purposes; however, this study did not control for state-specific trends, and the authors acknowledged that their findings may reflect increased implementation of medical marijuana laws in states where marijuana is more commonly used. Harper et al. [25] replicated and expanded on this study by adding in state fixed effects and found no consistent evidence of an increase in adolescent marijuana use or perceived riskiness of using marijuana. In another study, Lynne-Landsman et al. [23] used a switching replication model (in which states served as a comparison group prior to a law change) across four states and found no evidence for an effect of passage of medical marijuana laws on adolescent marijuana use.

Interestingly, in two state pairings in the current study—Utah/Nevada and Idaho/Montana—the state with the medical marijuana law was estimated to have *decreased* marijuana use after the implementation of the policy. It may be that normalizing marijuana use through medical legalization, as well as associating its use with chronically or even terminally ill populations, makes the use of the drug less appealing to adolescents. Alternatively, it may be that such legislation tends to be passed during times when marijuana use is at a peak in a given state, leading to a natural subsequent fall due to regression to the mean. The answer is beyond the scope of this study but merits further investigation if this finding is true. Notably, in the sensitivity analyses with imputed values for missing years of data, there was no association between implementation of medical marijuana law and reported use in any state pairing, consistent with our findings from the combined data for all states and years available. The possibility remains that the negative

Table 1
Characteristics of the study population, by state pairings, prelegislation

	Gender (% female)	Race/ethnicity (% nonwhite)	Grade	Past 30-day marijuana use	Lifetime marijuana use
States without medical marijuana law					
Idaho	48.6 (47.2–50.1)	11.6 (10.2–13.1)	9th 27.0 (22.2–31.9) 10th 25.9 (22.8–29.1) 11th 24.1 (21.0–27.3) 12th 23.0 (19.9–25.9)	14.0 (12.7–15.4)	29.4 (27.1–31.8)
Montana[a]	48.3 (47.3–49.4)	12.8 (10.8–14.8)	9th 27.1 (24.6–29.7) 10th 25.7 (23.5–27.8) 11th 24.0 (22.0–25.9) 12th 21.7 (19.6–23.9)	22.9 (21.8–24.0)	40.7 (39.2–42.2)
Massachusetts	49.3 (48.1–50.5)	25.6 (23.0–28.3)	9th 28.9 (26.7–31.2) 10th 25.7 (23.5–27.8) 11th 23.7 (21.6–25.8) 12th 22.2 (20.4–24.1)	30.0 (28.7–31.3)	49.5 (48.0–51.0)
Rhode Island[a]	49.3 (47.4–52.2)	24.7 (18.0–31.3)	9th 29.4 (24.4–34.4) 10th 25.5 (22.3–28.8) 11th 23.0 (19.0–27.1) 12th 22.2 (18.7–24.3)	28.4 (26.5–30.3)	44.9 (43.1–46.7)
New Hampshire	49.5 (47.5–51.5)	6.5 (5.6–7.3)	9th 28.4 (23.9–33.0) 10th 25.7 (21.5–29.9) 11th 23.7 (19.7–27.8) 12th 22.1 (18.3–25.9)	24.4 (22.8–26.1)	39.8 (37.8–41.9)
Maine[a]	48.7 (46.1–51.2)	7.4 (6.0–8.7)	9th 30.7 (27.0–34.4) 10th 27.4 (24.4–30.4) 11th 22.0 (19.5–24.5) 12th 19.8 (17.0–22.7)	22.3 (15.4–20.8)	29.9 (26.7–33.1)[b]
New York	49.7 (47.7–51.8)	39.9 (37.0–42.8)	9th 29.5 (27.3–31.7) 10th 26.9 (24.8–28.9) 11th 22.5 (21.1–23.9) 12th 21.1 (19.3–23.0)	22.3 (20.9–23.6)	39.7 (38.0–41.5)
Vermont[a]	48.6 (48.1–49.2)	6.4 (5.3–7.6)	9th 20.9 (19.2–22.6) 10th 21.8 (21.2–22.5) 11th 20.3 (19.7–21.0) 12th 37.7 (35.9–38.0)	26.5 (25.0–27.9)	28.1 (23.6–32.6)
Utah	48.7 (47.1–50.2)	13.2 (11.7–14.7)	9th 25.8 (21.3–30.3) 10th 27.1 (23.9–30.3) 11th 24.4 (21.7–27.2) 12th 22.6 (20.1–25.2)	9.2 (8.1–10.4)	20.9 (19.0–22.7)
Nevada[a]	48.8 (46.4–51.2)	33.4 (31.6–35.2)	9th 28.6 (24.7–32.5) 10th 26.8 (23.8–29.9) 11th 24.1 (21.2–27.0) 12th 20.5 (17.1–23.9)	24.4 (22.8–25.9)	45.4 (43.5–47.4)
Overall without medical marijuana law	49.4 (48.2–50.6)	30.0 (28.3–31.6)	9th 29.3 (27.1–31.5) 10th 26.8 (25.1–28.5) 11th 23.0 (21.4–24.5) 12th 21.0 (19.4–22.6)	21.6 (20.8–22.4)	38.3 (37.2–39.4)
Overall with medical marijuana law[a]	48.8 (48.0–49.5)	19.2 (17.8–20.5)	9th 26.6 (25.0–28.1) 10th 25.1 (23.9–26.3) 11th 23.0 (21.9–24.2) 12th 25.3 (24.0–26.6)	25.0 (24.3–25.7)	42.3 (41.3–43.4)

[a] States with medical marijuana law.
[b] Lifetime marijuana use for Maine only reported in 1 year (1997) of the 2 pre-legislation years.

associations in the main analysis were artifacts of missing data in those state pairings.

Our findings confirm that adolescent substance use continues to be a significant public health issue among youth, with approximately one third of respondents reporting lifetime marijuana use and one fifth reporting ongoing (past month) marijuana use. Reducing marijuana use among adolescents has remained an important U.S. public health goal. In 2004, the American Academy of Pediatrics issued a statement of opposition to the legalization of marijuana for any purpose [26], stating in an associated report that young adolescents were most susceptible to the deterrent effects of drug laws and that "this deterrent effect could disappear or lessen with legalization of marijuana." [27] At the same time, the beneficial effects of marijuana for certain medical conditions have gained increasing recognition and acceptance. California legalized medical marijuana in 1996 and has provided a 15-year testing ground for the impact of the policy on youth drug use, finding little definitive evidence of detrimental effect on youth attitudes toward marijuana or actual use [28,29]. In one longitudinal study, attitudes about harmful effects of marijuana decreased among Californian youth surveyed in the year after the legislation; however, this was true in other states surveyed as well, and the reported use of marijuana did not increase correspondingly. This suggests that concerns about "sending the wrong message" may have been overblown. Similarly, the Substance Abuse and Mental Health Services

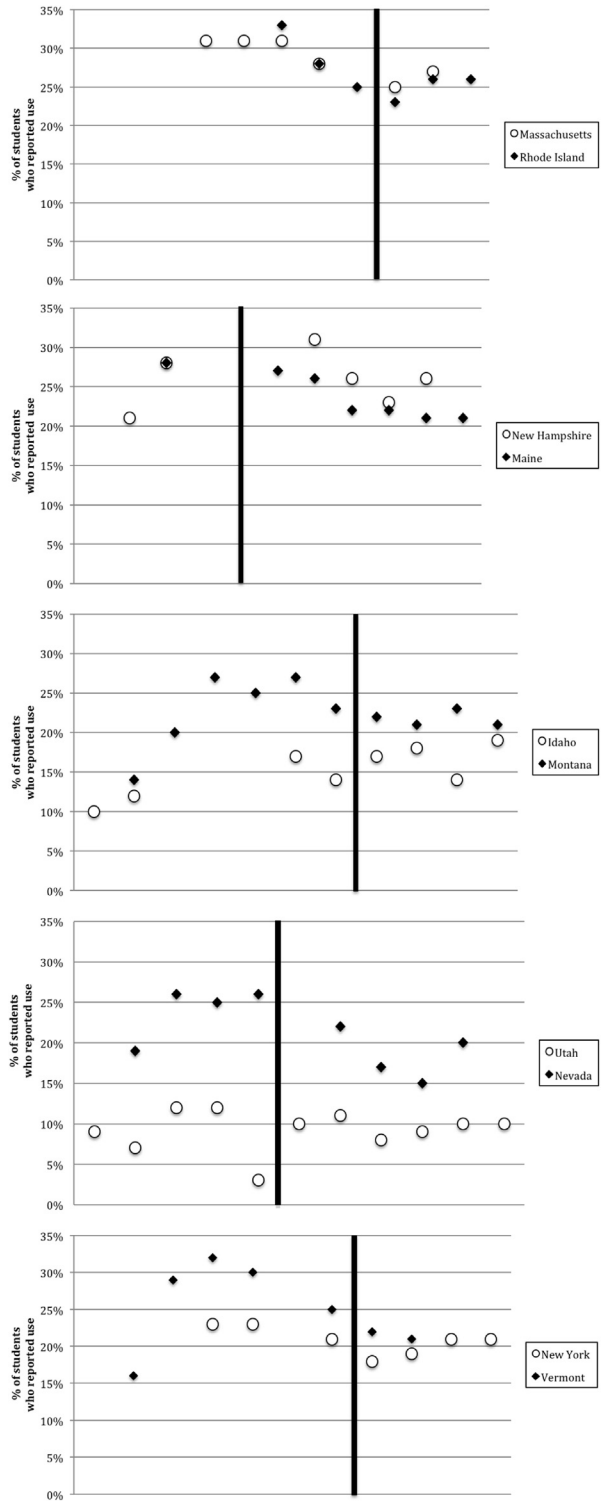

Figure 1. Marijuana use trends in states with (diamond) and without (open circle) medical marijuana laws, paired by region. The solid vertical line indicates the date of medical marijuana legalization.

Administration reported a 200% increase in admissions for marijuana treatment in California between 1992 and 2002 [28]; however, 31 other states at least doubled their admission rates during the same period, and overall youth marijuana use trends in California have not demonstrated significant increase [29].

Concerns about laws and policy measures that may inadvertently affect youth drug use merit careful consideration. Our study does not show evidence of a clear relationship between legalization of marijuana for medical purposes and youth drug use for any age group, which may provide some reassurance to policymakers who wish to balance compassion for individuals who have been unable to find relief from conventional medical therapies with the safety and well-being of youth. Further research is required to track the trends in marijuana use among adolescents, particularly with respect to different types of marijuana laws and implementation of laws in each state.

This study has several important limitations. As with all survey data, there is the possibility of reporting bias. There may be limited concordance of self-report and objective measures of drug use among adolescents [30]. In particular, with questions relating to substance use, there is the possibility that social desirability effect or fear of consequences led to under-reporting of drug use. The anonymous nature of YRBS, however, minimizes these biases, and the reliability of the YRBS for high-risk behaviors has been demonstrated [31].

The YRBS survey also provides limited information about any single substance; our primary outcome measure, for example, was derived from a single survey item. We do not know how this item performs compared with fully validated, multiple-question substance use instruments. Further, past 30-day use does not capture frequency of use or negative health and social consequences of use that would allow us to distinguish between occasional use and heavy marijuana use. It is possible that policy changes such as the one we examined impact marijuana use among a specific subset of adolescents with particular patterns of drug use and acquisition.

YRBS is voluntary for states, and the success with which it is implemented is variable from year to year. Therefore, some states did not collect data in all consecutive years, or in given years, the data collected were incomplete and did not meet CDC requirements for sampling. As noted, for the state of VT, race was not collected in the first three cycles of that state's participation in YRBS.

Implementation of marijuana policies takes time. Dispensaries must be opened, providers trained, the public made aware, therapeutic relationships developed, processes established for approving registered medical marijuana users, and growth of the program must occur before a medical marijuana program is truly in effect. Any downstream effect on adolescents would be unlikely to occur immediately after a state law is passed. For this reason, we did provide a lead-in period of two data cycles to allow a medical marijuana program to take full effect and to have the potential to impact adolescent marijuana use. Nevertheless, for states in our study that adopted these policies more recently, the full effect on adolescents may not yet have been apparent.

Finally, our analysis has to do with legalization of medical marijuana, not the legalization of marijuana for recreational use. The distinction is important, for with legalization of marijuana for medical reasons, use is regulated by public health departments and made available through a small number of physicians and dispensaries. The risks to adolescents from legalization of marijuana for recreational use at the discretion of the user are surely similar in some ways but different in others, including the extent of availability, the demographic of the users directly affected, and the

Table 2
Logistic regression models for the effect of medical marijuana laws on past-month adolescent marijuana use

Model[a]	Marginal probability[b]
Idaho versus Montana	−.03 (−.06, −.003)
Grade 9	−.02 (−.06, .02)
Grade 10	−.03 (−.07, .02)
Grade 11	.04 (−.01, .09)
Grade 12	−.04 (−.10, .01)
Massachusetts versus Rhode Island	−.01 (−.05, .02)
Grade 9	.005 (−.06, .07)
Grade 10	−.02 (−.08, .05)
Grade 11	−.009 (−.08, .06)
Grade 12	−.04 (−.12, .04)
New Hampshire versus Maine	−.04 (−.09, .01)
Grade 9	−.07 (−.14, .004)
Grade 10	−.05 (−.11, .03)
Grade 11	−.008 (−.11, .10)
Grade 12	−.01 (−.13, .10)
Utah versus Nevada	−.04 (−.06, −.01)
Grade 9	−.01 (−.06, .03)
Grade 10	−.05 (−.09, −.008)
Grade 11	−.03 (−.07, .01)
Grade 12	−.05 (−.10, −.005)
New York versus Vermont	−.02 (−.05, .01)
Grade 9	−.04 (−.08, −.01)
Grade 10	−.02 (−.07, .02)
Grade 11	−.03 (−.07, .02)
Grade 12	−.03 (−.09, .03)
All states[c]	.007 (−.007, .02)
Grade 9	.0006 (−.02, .02)
Grade 10	−.003 (−.02, .02)
Grade 11	.02 (−.003, .05)
Grade 12	.007 (−.02, .03)

[a] Models adjust for grade, gender, and race.
[b] The mean expected probably of marijuana use, if policy is changed from "not present" to "present."
[c] The "all states" model is the combined data from all states and years included in the study.

resulting change in the social image of marijuana use. This means that the findings of our study should not be used to make generalizations about other types of state-level marijuana laws.

In conclusion, our study of self-reported marijuana use by adolescents in states with a medical marijuana policy compared with a sample of geographically similar states without a policy does not demonstrate increases in marijuana use among high school students that may be attributed to the policies. Future research may examine further longitudinal trends following state policy change and include other states where similar policy changes have occurred.

Table 3
Linear regression models for effect of medical marijuana laws on past-month adolescent marijuana use using imputed data

Model[a]	β coefficient
Idaho versus Montana	−.01 (−.14, .11)
Massachusetts versus Rhode Island	−.05 (−1.13, 1.02)
New Hampshire versus Maine	−.003 (−.55, .55)
Utah versus Nevada	−.05 (−.30, .21)
New York versus Vermont	−.03 (−.25, .20)
All states[b]	.03 (−.007, .07)

[a] Models adjust for grade, gender, and race.
[b] Combined data from all states and years included in the study.

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