

# Recreational Marijuana Legalization and Use Among California Adolescents: Findings From a Statewide Survey

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**ABSTRACT. Objective:** The legalization of recreational marijuana use and retail sales raises concerns about possible effects on marijuana use among adolescents. We evaluated the effects of recreational marijuana legalization (RML) in California in November 2016 on use among adolescents and investigated subgroup differences in these effects. **Method:** We analyzed data from successive cross-sectional samples of 7th, 9th, and 11th grade students ( $N = 3,330,912$ ) who participated in the California Healthy Kids Survey from 2010–2011 to 2018–2019. Participants reported grade, sex, ethnicity, race, and lifetime and past-30-day marijuana use. **Results:** Multilevel analyses showed that RML was associated with increases in the likelihood of lifetime (odds ratio = 1.18, 95% CI [1.15, 1.21],  $p < .01$ ) and past-30-day marijuana use (odds ratio = 1.23, 95% CI [1.20, 1.26],  $p < .01$ ) relative to previous downward trends. RML was more strongly associated with increases in prevalence

of marijuana use among 7th versus 9th and 11th graders, females versus males, non-Hispanic versus Hispanic youth, and White versus African American, American Indian/Native Alaskan, and multiracial youth. Overall, RML was not significantly associated with frequency of past-30-day use among users, although stronger positive associations between RML and frequency of use were found for 11th graders, Asian Americans, and African Americans. The association was weaker for females. **Conclusions:** RML in California was associated with an increase in adolescent marijuana use in 2017–2018 and 2018–2019. Demographic subgroup differences in these associations were observed. Evidence-based prevention programs and greater local control on retail marijuana sales may help to reduce marijuana availability and use among adolescents. (*J. Stud. Alcohol Drugs*, 82, 000–000, 2021)

IN RECENT YEARS there has been a move toward liberalization of marijuana laws in the United States. As of January 2021, recreational marijuana use is legal for adults who are at least 21 years old in 15 states (AK, AZ, CA, CO, IL, OR, MA, ME, MI, MO, NJ, NV, SD, VT, WA) and Washington, D.C., and recreational marijuana sales are legal in 10 of those 15 states (Alcohol Policy Information System, 2020). California legalized adult possession and recreational use of marijuana through ballot Proposition 64 on November 9, 2016, and retail sales of recreational marijuana beginning on January 1, 2018 (California Bureau of Cannabis Control, 2019a). Additional states have bills pending that would legalize adult recreational use of marijuana. This liberalization of marijuana laws raises public health concerns, especially about potential effects on marijuana use by adolescents, as marijuana use during adolescence has been associated with a range of adverse consequences (National Academies of Science, Engineering, and Medicine, 2017).

Research on the effects of recreational marijuana legalization (RML) on marijuana use among adolescents is relatively limited and results are mixed. A recent national study with Youth Risk Behavior Survey data found evi-

dence of an 8% decrease in the likelihood of any past-30-day marijuana use and a 9% decrease in the likelihood of frequent past-30-day use among high school students after RML (Anderson et al., 2019). The authors conjectured that these counter-intuitive effects may, in part, reflect the closer regulation of the legal market, which made it more difficult for teens to obtain marijuana. A study by Cerdá et al. (2017) with national Monitoring the Future data found 2.0% and 4.1% increases in past-30-day marijuana use from pre-RML years (2010–2012) to post-RML years (2013–2015) among 8th and 10th graders, respectively, in Washington State, but decreases in marijuana use among 8th and 10th graders in states that did not legalize recreational marijuana use. However, no significant differences were observed for 12th graders in Washington State or among youth in all three grades in Colorado compared with those in non-RML states from 2010–2012 to 2013–2015. However, in a more recent study with data from the Washington Healthy Youth Survey, legalization of recreational marijuana in Washington State was associated with decreases in use among 8th and 10th graders, and no changes in use among 12th graders (Dilley et al., 2019). Also, in contrast to the study by Cerdá et al. (2017), results of the National Survey on Drug Use and Health indicated a significant increase in the prevalence of past-30-day marijuana use among 12- to 17-year-olds in Colorado, from 7.6% in 2006 to 12.6% in 2014 (after RML in 2012), compared with a smaller increase from 6.7% to 7.2% for adolescents in the United States as a whole (Colorado Department of Public Safety, 2016). A more recent study based on data from the Healthy Kids Colorado Survey

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found no changes in the prevalence of past-30-day marijuana use among high school students after legalization of commercial recreational marijuana sales (Brooks-Russell et al., 2019). However, a recent study in Oregon found significant statewide increases in past-30-day marijuana use and beliefs favorable to marijuana use among adolescents after RML (Paschall & Grube, 2020).

### *Marijuana use disparities*

Although RML may reduce social justice harms related to discriminatory law enforcement practices (Carliner et al., 2017), some concern can be raised that legalization may differentially affect marijuana use among adolescents in some age, sex, and racial/ethnic groups, potentially leading to or increasing marijuana-related disparities in health, social, and psychological harms experienced by those groups. Little or no published research has directly addressed such differences in the effects of RML policies on adolescents. However, research on support for RML and on prevalence of use may give some indication of how sex, race, and ethnicity may moderate any effects of RML. In addition, differences in the geographical distribution of recreational marijuana outlets may increase exposures and thus the effects of RML for some groups.

Overall, support for RML by adolescents is substantial, with 48% of high school seniors in the 2018 Monitoring the Future survey indicating that using marijuana should be entirely legal and another 27% indicating that it should be decriminalized (Miech et al., 2019a). Research further suggests that there is greater support for legalization among male than female high school seniors and among African American students compared with Whites (Palamar, 2014). No differences were found between Hispanics and other students. A possibility is that RML may have greater effects on marijuana use for those groups of adolescents who are more supportive of legalization (e.g., males and African Americans).

Although female adolescents have historically used marijuana at lower rates than males, their prevalence rates, particularly for lifetime and annual use, have increased and converged with those of males (Johnston et al., 2019). Data from the 2015–2017 California Healthy Kids Survey (CHKS; Austin et al., 2018) show similar past-30-day prevalence rates for females and males in 7th grade (2.2% vs. 2.4%) and 9th grade (10.2% vs. 8.9%), but slightly higher rates for males in 11th grade (15.4% vs. 17.8%). In terms of race and ethnicity, national studies suggest that marijuana use among African American 12th graders has increased more rapidly than it has among White and Latinx 12th graders and has converged with those groups in recent years (Johnston et al., 2019; Keyes et al., 2017). Unfortunately, these national data sets include too few racial and ethnic minorities to allow detailed comparisons across

groups. The CHKS, however, includes a large and very diverse sample, thus allowing a more detailed consideration of racial and ethnic differences. For example, among 11th graders who participated in the 2015–2017 CHKS, 17% of Latinx students, 21% of American Indian/Alaska Native students, 6% of Asian American students, 21% of African American students, 20% of Native Hawaiian or Pacific Islander students, 18% of White students, and 19% of multiracial students reported using marijuana in the past 30 days (Austin et al., 2018). Some evidence suggests that RML may have a greater effect on adolescents who were marijuana users before the policy change, increasing their intensity of use (Rusby et al., 2018). In contrast, other research with college students found that legalization of recreational marijuana use in Washington, DC, was associated with increases in favorable attitudes toward marijuana and in willingness to use marijuana, but only among those who were nonusers and light users before legalization (Clarke et al., 2018). It is thus unclear whether RML may have a greater effect on adolescents from groups with higher prevalence rates of use or those from groups that historically have had lower prevalence rates.

Greater retail availability of marijuana in disadvantaged urban areas may also contribute to racial/ethnic disparities in marijuana use among adolescents, although research in this area is limited. Recent studies in California, Colorado, and Washington indicate that recreational marijuana outlets and medical marijuana dispensaries are concentrated in neighborhoods with higher levels of poverty, crime, and racial/ethnic minority populations (Morrison et al., 2014; Shi et al., 2016; Tabb et al., 2018). Higher rates of marijuana use and marijuana use disorder have been observed among minority youth in urban neighborhoods with higher levels of poverty, drug-related crime, and social disorder (Furr-Holden et al., 2011; Hasin et al., 2015; Reboussin et al., 2014, 2015). Given the concentration of marijuana retail outlets in neighborhoods that are economically disadvantaged and have higher ethnic and racial minority populations, it is likely that minority adolescents will be more exposed to marijuana marketing and thus RML may have a greater impact on them.

In summary, California's RML for adult use in 2016 and legalization of recreational marijuana sales in 2018 may have promoted norms favorable to marijuana use and increased availability of marijuana to adolescents through social and retail sources. However, no studies have yet examined the possible effects of RML on marijuana use over time with large, representative samples of adolescents in California. The present study focuses on possible effects of RML in California on lifetime and past-30-day marijuana use among adolescents during the 2017–2018 to 2018–2019 school years compared with prior secular trends. This study also examines possible grade, sex, ethnic, and racial differences in RML effects.

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## Method

### *Study design and sample*

*California Healthy Kids Survey.* This study is based on annual cross-sectional survey data from 7th, 9th, and 11th grade students who participated in the CHKS from 2010–2011 to 2018–2019. CHKS is the largest statewide self-administered survey of health-related behaviors and attitudes in the nation and has been administered every other year since 1998, with about half of the schools participating in alternate years (California Department of Education, 2019). CHKS is conducted by WestEd, a nonprofit research organization in collaboration with the California Department of Education. School districts were formerly required to participate in CHKS to comply with the No Child Left Behind Act, Title IV, and are now required to participate if they receive funding under the State Tobacco Use Prevention Education Program (California Department of Education, 2019). Otherwise CHKS participation is voluntary. About 75% of all California school districts currently participate in CHKS. Minimum CHKS requirements include participation by students in Grades 7, 9, and 11 and a 60% response rate with passive or active parental consent. Response rates are typically 70% or greater for each participating school. The CHKS questionnaire is administered in either the fall or spring semester at the discretion of each participating school.

*Survey sample.* Because of changes in the formatting of questions about ethnicity and race in 2010–2011, this study is based on annual CHKS data for 2010–2011 to 2018–2019 school years from 3,330,912 students in 3,812 schools, 852 school districts, and all 58 counties in California. This study also examines the association between RML and frequency of marijuana use among 395,268 students who reported any marijuana use in the past 30 days across the 9 school years. This study was deemed exempt by the Pacific Institute for Research and Evaluation Institutional Review Board because it is based on de-identified data that were collected anonymously.

### *Survey measures*

*Marijuana use.* From 2010–2011 to 2016–2017 students were asked, “During your life, how many times have you used marijuana (pot, weed, grass, hash, bud)?” with the six response options ranging from *0 times* to *7 or more times*. Students were then asked, “During the past 30 days, on how many days did you use marijuana (pot, weed, grass, hash, bud)?” with six response options, including *0 days*, *1 day*, *2 days*, *3 to 9 days*, *10 to 19 days*, and *20 to 30 days*. The same two questions were asked in 2017–2018 and 2018–2019 but with “. . . (smoke, vape, eat, or drink)?” instead of “. . . (pot, weed, grass, hash, bud)?” to reflect the increasing variety of marijuana products available. These variables

were dichotomized to represent any lifetime marijuana use and any past-30-day marijuana use. An approximation of an interval measure of past-30-day marijuana use frequency was created using response scale midpoint values (i.e., 6 for *3 to 9 days*, 14.5 for *10 to 19 days*, and 25 for *20 to 30 days*).

*Demographic variables.* Students were asked to report their grade level and gender. In separate questions, students were asked to report their ethnicity (Hispanic or Latinx) and race (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Pacific Islander, White, multiracial). Because a large percentage of students reported their ethnicity but not race, we also created an “unknown” race variable. Survey year was coded 1–9 based on the 9 school years with CHKS data and was included to account for the secular trend in marijuana use from the 2010–2011 to 2018–2019 school years.

*Urban/rural context.* We used the Rural Urban Continuum Code for California counties developed by the U.S. Department of Agriculture Economic Research Services to represent the urban/rural context of school locations in California. The Rural Urban Continuum Code scale ranges from 1 (*metropolitan areas with at least 1 million population*) to 9 (*completely rural or less than 2,500 urban population*). We obtained the most recent 2013 Rural Urban Continuum Code for the 58 counties (U.S. Department of Agriculture, 2013).

*Legalization.* We created an RML variable coded 0 for the 7 school years up to and including the school year when RML went into effect on November 9, 2016 (2010–2011 to 2016–2017) and coded 1 for the two school years after RML (2017–2018 and 2018–2019). We were not able to disaggregate fall 2016 from spring 2017 CHKS data. We considered legalization of recreational marijuana sales on January 1, 2018, as possibly contributing to the effect of RML on marijuana use in the spring of 2018 and the 2018–2019 school year.

### *Data analysis*

We first examined descriptive statistics for study variables and compared student characteristics during pre-RML versus post-RML years. Multilevel logistic regression analyses were conducted to assess changes in marijuana use after RML for the total sample of adolescents, controlling for student demographic variables, the secular trend, and urban/rural context. We conducted multilevel linear regression analyses with past-30-day marijuana users to assess possible effects of RML on marijuana use frequency with the same model covariates. Controlling for the secular trend allowed us to determine whether post-RML levels of marijuana use were higher than would be expected given the overall decline in marijuana use from 2010–2011 to 2018–2019, and to account for possible confounding effects of the secular trend (Bernal et al., 2017). This modeling approach is commonly used in interrupted time series studies to evaluate effects of

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TABLE 1. Sample characteristics, percent

Variable	Total sample ( <i>N</i> = 3,330,912)	Pre-RML years ( <i>n</i> = 2,453,833)	Post-RML years ( <i>n</i> = 877,079)
Grade			
7th	34.0	33.1	36.5**
9th	34.9	35.2	33.9**
11th	31.2	31.7	29.6**
Female	50.6	50.8	50.0**
Hispanic/Latinx	50.3	50.1	51.0**
Asian American	11.2	11.0	11.8**
African American	4.3	4.4	4.0**
American Indian/Alaska Native	3.3	3.4	3.2**
Native Hawaiian/Pacific Islander	1.9	2.0	1.5**
White	28.4	28.3	28.8**
Multiracial	38.2	36.8	42.3**
Unknown race	12.6	14.2	8.4**
Lifetime marijuana use	20.8	22.3	16.7**
Past-30-day marijuana use	11.8	12.5	9.8**

Notes: RML = recreational marijuana legalization. Significance tests compared percentages in pre-RML versus post-RML school years. Pre-RML school years were 2010–2011 to 2016–2017 and post-RML school years were 2017–2018 to 2018–2019.

\*\**p* < .01.

policies or public health interventions on health outcomes of interest (Bernal et al., 2017; Hudson et al., 2019). The regression models had four levels representing students (Level 1), schools (Level 2), school districts (Level 3), and counties (Level 4). The student demographic measures (grade level, gender, ethnicity, race) were coded as dummy variables with the following referent groups: 7th graders, males, non-Hispanic/Latinx, and White students. Initial models were conducted that included only the main effects. Possible moderating effects of grade level, gender, ethnicity, and race were then explored by running models that added interaction terms for each relevant demographic variable and the pre/post RML dummy variable. Analyses were conducted in HLM Version 8.0 software (Raudenbush et al., 2019) to account for the nonindependence of observations nested within schools, school districts, and counties.

## Results

### Sample characteristics

The descriptive statistics shown in Table 1 indicate that about one third of the CHKS respondents were 7th graders, whereas about 35% were 9th graders and 31% were 11th graders. Half of the sample was female, about 50% was Hispanic/Latinx, 11% Asian American, 4% African American, 3% American Indian/Alaska Native, 2% Native Hawaiian/Pacific Islander, 28% White, 38% multiracial, and 12% of unknown race. About 21% of respondents reported any lifetime marijuana use and about 12% reported any past-30-day marijuana use.

There were generally small, although statistically significant, changes in student demographic characteristics from pre- to post-RML years. For example, the percentage of stu-

dents in 7th grade increased from 33.1% to 36.5%, whereas the percentage of students reporting more than one race increased from 36.8% to 42.3%. The percentage of students reporting any lifetime marijuana use decreased from 22.3% to 16.7%, and the percentage reporting any past-30-day marijuana use decreased from 12.5% to 9.8%.

### Multilevel regression analyses

Table 2 shows the results of initial multilevel regression analyses for lifetime and past-30-day marijuana use. When we controlled for urban/rural context, student demographic characteristics, and the secular trend, there was a significantly greater likelihood of both lifetime and past-30-day marijuana use after RML than would be expected. Greater odds of lifetime and past-30-day marijuana use were observed among 9th and 11th graders relative to 7th graders, among Hispanic/Latinx relative to non-Hispanic/Latinx students, and among African American, American Indian/Alaska Native, Native Hawaiian/Pacific Islander, and multiracial students relative to White students. A lower likelihood of lifetime and past-30-day marijuana use was observed among females relative to males, and among Asian American students relative to White students. In addition, there was a greater likelihood of lifetime and past-30-day marijuana use among youth in more rural counties.

The summary results of analyses to assess differential effects of RML on lifetime and past-30-day marijuana use by grade level, sex, ethnicity, and race are shown in Table 3. RML was more strongly associated with increases in lifetime marijuana use among 7th graders relative to 9th and 11th graders. RML was also more strongly associated with increases in both lifetime and past-30-day marijuana use among females relative to males, among non-Hispanic/Latinx relative to Hispanic/Latinx students, and among

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TABLE 2. Results of multilevel logistic regression analyses to assess effects of recreational marijuana legalization (RML) on marijuana use, odds ratio [95% confidence interval]

Variable	Lifetime marijuana use	Past-30-day marijuana use
County level		
Greater rural context (RUCC)	1.08 [1.04, 1.12]**	1.05 [1.01, 1.09]*
Student level		
Grade 7	1 (ref.)	1 (ref.)
Grade 11	6.58 [6.35, 6.81]**	5.03 [4.84, 5.23]**
Grade 9	3.13 [3.02, 3.24]**	2.97 [2.86, 3.09]**
Male	1 (ref.)	1 (ref.)
Female	0.93 [0.92, 0.94]**	0.87 [0.86, 0.88]**
Non-Hispanic/Latinx	1 (ref.)	1 (ref.)
Hispanic/Latinx	1.21 [1.20, 1.22]**	1.17 [1.16, 1.18]**
White	1 (ref.)	1 (ref.)
Asian American	0.41 [0.40, 0.42]**	0.42 [0.41, 0.43]**
African American	1.52 [1.50, 1.54]**	1.57 [1.55, 1.60]**
American Indian/Alaska Native	1.30 [1.28, 1.32]**	1.30 [1.27, 1.33]**
Native Hawaiian/Pacific Islander	1.17 [1.15, 1.19]**	1.15 [1.12, 1.18]**
Multiracial	1.22 [1.21, 1.23]**	1.19 [1.18, 1.20]**
Unknown race	1.04 [1.03, 1.05]**	0.96 [0.95, 0.97]**
Year	0.89 [0.88, 0.90]**	0.90 [0.89, 0.91]**
Pre-RML years	1 (ref.)	1 (ref.)
Post-RML years	1.18 [1.17, 1.19]**	1.23 [1.21, 1.25]**

Notes: Ref. = referent group. Of the 58 counties, 29 (50%) were classified as metropolitan areas with at least 250,000 people (RUCC = 1–2), 8 (13.8%) were metropolitan areas with less than 250,000 people (RUCC = 3), 12 (20.7%) had small cities/towns with 2,500–20,000 people and were adjacent to metropolitan areas (RUCC = 4–6), and 9 (15.5%) were nonmetropolitan or completely rural and not adjacent to a metropolitan area (RUCC = 7–8).

\* $p < .05$ ; \*\* $p < .01$ .

White relative to African American and American Indian/Alaska Native students. Trends and post-RML changes in past-30-day marijuana use in demographic subgroups are shown in Figure 1.

Results of multilevel linear regression analyses with the subgroup of past-30-day marijuana users indicated no overall association between RML and the frequency of past-30-day marijuana use when controlling for urban/rural context, student demographic characteristics, and the secular trend ( $\beta$  [ $SE$ ] = 0.06 [0.05],  $p = .27$ ). However, results of moderation analyses indicated stronger positive associations of RML and increases in marijuana use frequency among 11th graders

relative to 7th graders ( $\beta$  [ $SE$ ] = 0.44 [0.12],  $p < .01$ ), Asian versus White students ( $\beta$  [ $SE$ ] = 0.46 [0.19],  $p < .05$ ), and among African American versus White students ( $\beta$  [ $SE$ ] = 0.51 [0.17],  $p < .01$ ). There was a stronger negative association between RML and marijuana use frequency among females versus males ( $\beta$  [ $SE$ ] = -0.41 (0.07),  $p < .01$ ). Trends in marijuana use frequency in these demographic subgroups are illustrated in Figure 2. Although in Figure 2(a) there also appears to be a stronger positive association between RML and marijuana use frequency among 9th graders versus 7th graders, this difference was not significant for the Pre/Post RML  $\times$  9th Grade interaction term adjusted for other model

TABLE 3. Summary results of multi-level logistic regression analyses to assess differential effects of recreational marijuana legalization (RML) on marijuana use, odds ratio [95% confidence interval]

Variable	Lifetime marijuana use	Past-30-day marijuana use
Post-RML $\times$ Grade 11	0.86 [0.84, 0.88]**	1.00 [0.98, 1.03]
Post-RML $\times$ Grade 9	0.87 [0.85, 0.89]**	0.94 [0.91, 0.97]**
Post-RML $\times$ Female	1.17 [1.15, 1.19]**	1.18 [1.16, 1.20]**
Post-RML $\times$ Hispanic/Latinx	0.88 [0.87, 0.89]**	0.89 [0.88, 0.91]**
Post-RML $\times$ Asian American	1.00 [0.97, 1.03]	0.98 [0.94, 1.02]
Post-RML $\times$ African American	0.83 [0.80, 0.85]**	0.83 [0.80, 0.86]**
Post-RML $\times$ American Indian/Alaska Native	0.86 [0.83, 0.89]**	0.88 [0.84, 0.92]**
Post-RML $\times$ Native Hawaiian/Pacific Islander	0.99 [0.94, 1.04]	1.01 [0.95, 1.07]
Post-RML $\times$ Multiracial	0.96 [0.94, 0.98]**	0.99 [0.97, 1.01]
Post-RML $\times$ Unknown race	0.90 [0.88, 0.92]**	0.93 [0.89, 0.96]**

Notes: Demographic referent groups are 7th graders, males, non-Hispanic students, and White students. All interaction terms were included in the same model for each dependent variable. All models included main effects for interaction terms and year to account for the secular trend.

\* $p < .05$ ; \*\* $p < .01$ .

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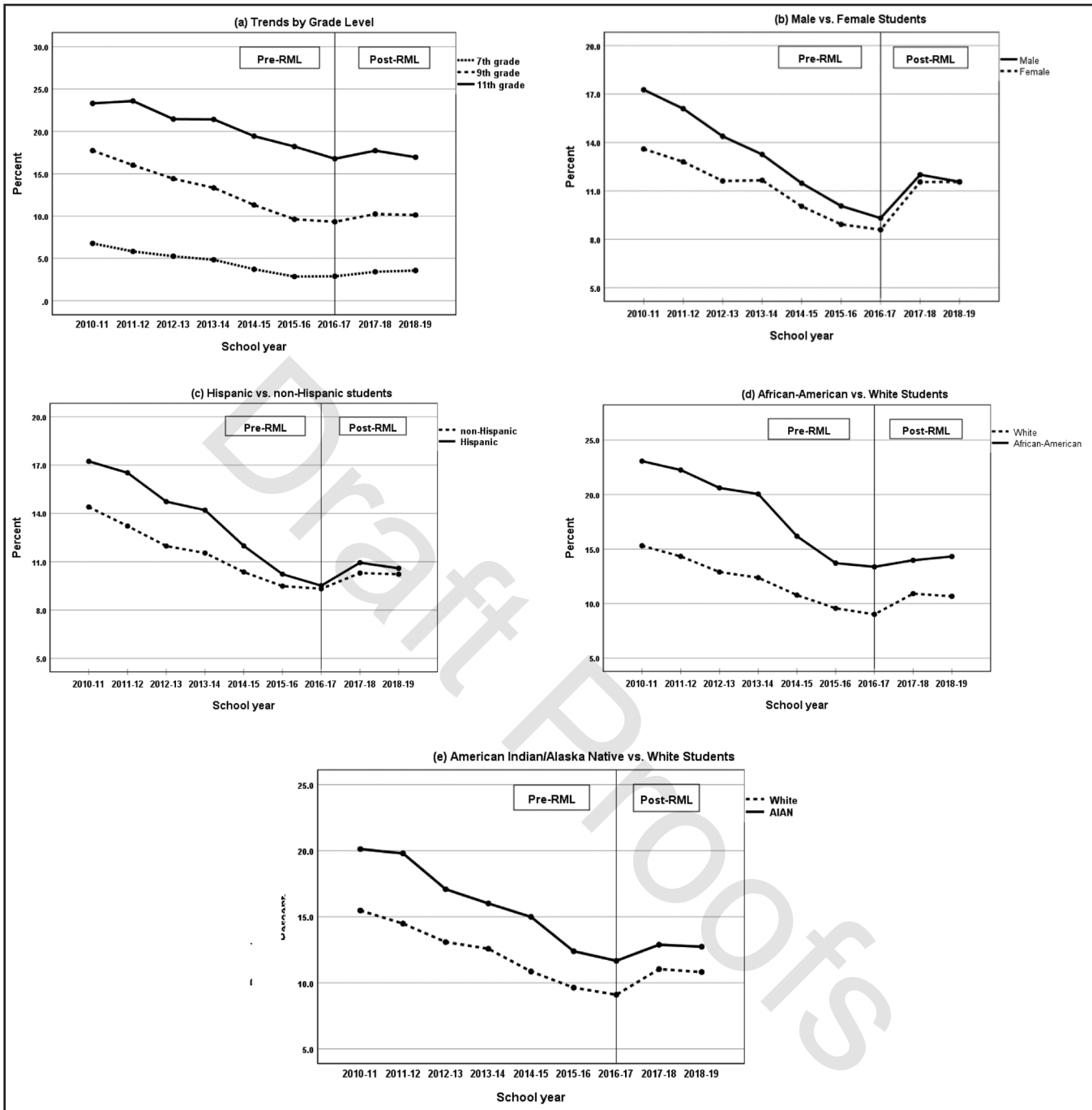


FIGURE 1. Trends in the prevalence of past-30-day marijuana use in demographic subgroups. Percentages are predicted values from regression models. RML = recreational marijuana legalization; AIAN = American Indian/Alaska Native.

covariates. We noted that across almost all demographic subgroups, there was an apparent increase in marijuana use frequency in the 2018–2019 school year. The results for the main effects of student and county demographic characteristics and the secular trend were consistent with results for any past-30-day marijuana use. Complete results for these analyses are available on request from the authors.

## Discussion

This study suggests that after a 7-year decline in marijuana use prevalence from 2010–2011 to 2016–2017, recreational marijuana legalization for adult use and retail sales in California may be contributing to an increase in marijuana use among adolescents in that state. This pat-

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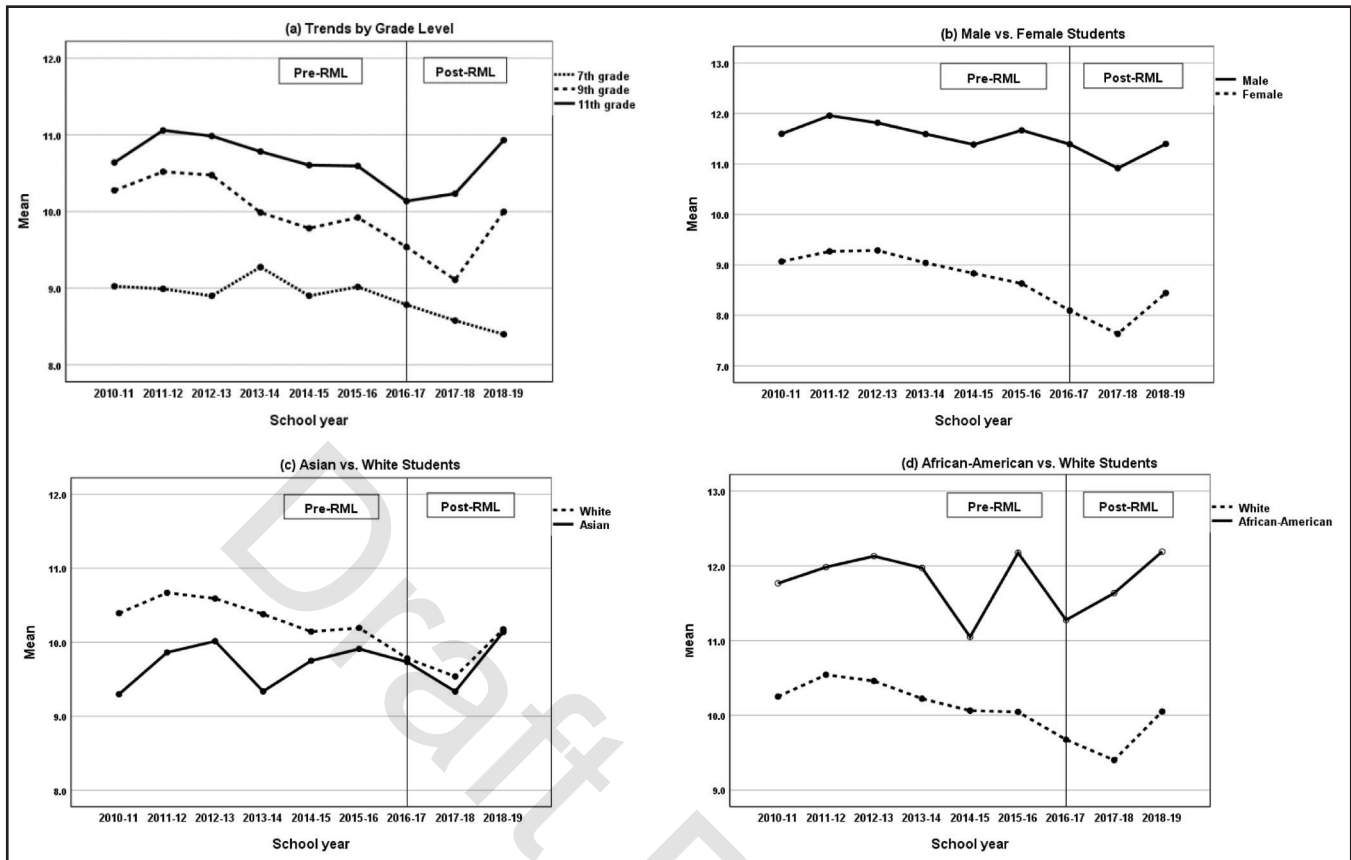


FIGURE 2. Trends in the frequency of past-30-day marijuana use among students who reported any past-30-day use in demographic subgroups. Means are predicted values from regression models. RML = recreational marijuana legalization.

tern can be contrasted with national data from the Youth Risk Behavior Survey that show continued declines in current marijuana use among high school students from 2011 through 2017 (Centers for Disease Control and Prevention, 2020). The post-RML increases observed in California may portend continued increases in adolescent marijuana use in future years if marijuana use becomes more popular among legal age adults and more normative in California. Findings of this study differ from several recent studies on effects of RML and legalization of retail marijuana sales on marijuana use among adolescents, including the national study by Anderson et al. (2019) indicating decreases in any past-30-day marijuana use and frequent marijuana use after RML based on results of the Youth Risk Behavior Survey and studies in Washington State (Dilley et al., 2019) and Colorado (Brooks-Russell et al., 2019). However, our findings are consistent with a recent study in Oregon indicating statewide increases in past-30-day marijuana use after RML and legalization of retail marijuana sales (Paschall & Grube, 2020).

We found no overall statistically significant association between RML and frequency of marijuana use among youth who reported any past-30-day use. However, marked increases

in marijuana use frequency were observed in 2018–2019 across almost all demographic subgroups. This may reflect the recent substantial increases in vaping of tobacco and marijuana products among adolescents in the United States (Miech et al., 2019b).

The expanding retail market and diversity of marijuana products may increase both opportunities for adolescents to obtain marijuana from commercial or social sources and the appeal of marijuana products like edibles. By April 2018, there were about 320 stores licensed to sell marijuana for adult recreational use, which increased to about 560 stores in August 2019 (California Bureau of Cannabis Control, 2019b). Growth in the legal retail market is expected to continue and this will add to the already substantial illegal marijuana retail market in California, which continues to thrive (Schroyer & McVey, 2020).

Our findings also indicate differential effects of RML on marijuana use prevalence among demographic subgroups of adolescents in California, notably having greater effects for those groups with historically lower prevalence rates of marijuana use. For example, stronger associations between RML and lifetime and past-30-day marijuana use were observed among females relative to males, and past-30-day marijuana

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prevalence use rates have converged in these two subgroups since 2010. Similarly, stronger RML effects on marijuana use were observed among non-Hispanic/Latinx relative to Hispanic/Latinx students, and marijuana use prevalence rates have converged in these two subgroups. Stronger associations between RML and marijuana use were also observed among White youth relative to African American and American Indian/Alaska Native youth, although somewhat higher prevalence rates persisted for these two groups.

A different pattern of demographic subgroup differences in effects of RML on past-30-day marijuana use frequency among regular users was observed. Relatively greater increases in marijuana use frequency after RML were observed among 11th graders versus 7th graders, and among Asian and African American versus White students. Conversely, a greater decrease in marijuana use frequency after RML was observed among females relative to males. The pattern of these findings suggests that RML may have greater effects on some demographic subgroups of adolescents who are regular users.

Findings of this study should be considered in light of some limitations. Although the majority of public middle and high schools in California participate in the CHKS and response rates are typically 70% or greater, the survey samples may not be representative of all 7th, 9th, and 11th graders or California adolescents in general. Responses to survey questions may be subject to social desirability and recall bias, which may contribute to underreporting of marijuana use. Although changes in student demographic characteristics from pre- to post-RML years were controlled for in the analyses, other unmeasured characteristics (e.g., socioeconomic status) may have influenced changes in marijuana use. It also may be the case that other policy changes could have confounded our findings. For example, the 2018 Agricultural Improvement Act or Farm Bill (Congressional Research Service, 2019), which declassified hemp with low levels of tetrahydrocannabinol (THC) as a controlled substance, may have affected adolescents' perceptions of cannabis products. We were not able to disaggregate the fall 2016 and spring 2017 CHKS data. As a result, we could not determine if RML in November 2016 influenced adolescent marijuana use before the 2017–2018 school year. Last, this study is based on only 2 years of post-RML data, which limits our ability to draw conclusions about long-term RML effects on marijuana use.

Additional research is needed to assess effects of RML on marijuana use and related harms among adolescents in California and other states and the mechanisms through which adolescents may be influenced by RML. Local marijuana policies and retail availability vary considerably within California cities, indicating the need for community-level research to better understand how adolescents are influenced by RML. Youth living in disadvantaged communities and neighborhoods where retail marijuana outlets are more

highly concentrated may be at elevated risk for marijuana use and related harms (Furr-Holden et al., 2011; Reboussin et al., 2014, 2015).

This study also highlights the need for additional efforts to prevent or reduce marijuana use among adolescents in states and communities where adult recreational marijuana use and retail sales are legal. In addition to evidence-based prevention programming (e.g., school-based programs), policies such as greater restrictions on numbers and locations of licensed marijuana retail outlets, hours of operation, and advertising, and higher taxes on marijuana products may help to reduce both retail and social availability of marijuana. These strategies have been effective in reducing alcohol and tobacco availability and use among adolescents, but additional research is needed to assess their effectiveness for reducing marijuana availability and use (Paschall et al., 2019).

### Conflict-of-Interest Statement

The authors declare no conflict of interest related to this study.

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