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# Race/Ethnicity Differences in Trends of Marijuana, Cigarette, and Alcohol Use Among 8th, 10th, and 12th Graders in Washington State, 2004–2016

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## Abstract

Accurate estimates of substance use in the teenage years by race/ethnicity may help identify when to intervene to prevent long-term substance use disparities. We examined trends in past 30-day use of marijuana, cigarette, and alcohol among 8th, 10th, and 12th graders in Washington State, which passed a recreational marijuana law in 2012 and initiated retail marijuana sales in 2014. Data are from the 2004–2016 Washington Healthy Youth Surveys ($n = 161,992$). We used time series regression models to assess linear and quadratic trends in substance use for the full sample and stratified on race/ethnicity and grade level and examined relative differences in prevalence of use by race/ethnicity. In Washington, across all racial/ethnic groups, marijuana use peaked in 2012. Although there was not a significant overall change in marijuana use for the full sample across the study period, there was a statistically significant increase in use among 12th graders and a statistically significant decrease among 8th graders. Relative to Whites, Asians had a lower prevalence of marijuana use, whereas all other race/ethnicity groups had a higher prevalence of use. Prevalence of marijuana use is particularly high among American Indian/Alaska Native and Black youth and has increased most rapidly among 12th grade Hispanic/Latinx youth. There were large and statistically significant decreases in alcohol and cigarette use across the study period for the full sample, as well as for each race/ethnicity group. These findings highlight the need for continued monitoring of trends in use among these groups and potentially warrant consideration of selective interventions that specifically focus on students of color and that include developmentally-appropriate strategies relevant to each grade.

**Keywords** Adolescent · Substance use · Alcohol · Smoking · Marijuana/cannabis · Policy

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## Introduction

In recent history, alcohol and cigarette use have decreased substantially among US adolescents, whereas marijuana use has declined at a slower pace (Johnson et al. 2015). From 1999 to 2015, past 30-day substance use among US high school students declined by 34% for alcohol (50–33%), 69% for cigarettes (35–11%), and 19% for marijuana (27–22%) (Kann et al. 2016). There have been notable changes in drug policy over this period, with substantial strides in tobacco and alcohol control. The public health sector undertook a comprehensive set of policy initiatives to discourage youth cigarette smoking and alcohol use, including restrictions on advertising and marketing, enforcing minimum-age requirements for purchase, and excise taxes (Hingson and White 2014; Farrelly et al. 2013). On the other hand, several states have loosened restrictions on marijuana use. California was the first state to pass a medical marijuana law (MML) in 1996, and Washington State and Colorado were the first to pass recreational marijuana laws (RMLs) in 2012. As of the November 2016 election, eight states and Washington D.C. have RMLs, and 21 additional states have MMLs (Pacula and Smart 2017; Hanson and Garcia 2017; Smith 2017). Although all US states prohibit recreational use by minors, the gradual loosening of restrictions on adult use may have created a climate of pro-marijuana attitudes and norms conducive to adolescent use.

It is well-established that decreases in use in youth drinking and smoking can be at least partially attributed to tobacco and alcohol control policies (e.g., Farrelly et al. 2013; Hingson and White 2014). Most quasi-experimental studies evaluating the impact of MMLs have not shown an increase in marijuana use (Martins et al. 2016; Sarvet et al. 2018), although additional research on specific provisions of MMLs suggest that they may moderate the effects of subsequent use (Hunt and Miles 2017; Guttmannova et al. 2016; Pacula and Smart 2017; Carliner et al. 2017). The impact of RMLs on adolescent substance use is unknown; evaluations are in the early phases with equivocal results. Cerdá et al. (2017) examined changes in past 30-day marijuana use before (2010–2012) vs. after (2013–2015) enactment of RMLs in Washington and Colorado. Results from a difference-in-difference analysis show a modest but statistically significant increase in use among 8th and 10th graders in Washington relative to those in non-RML states. Increases were not observed among Washington 12th graders nor among students of any grade level in Colorado (Cerdá et al. 2017).

In this study, we apply the first step of the prevention science framework to examine adolescent substance use in Washington State, where marijuana has transitioned from an illicit to a state-regulated substance. This framework includes the following: (1) basic epidemiology research to identify target populations and vulnerable periods, (2) increasingly-rigorous studies to determine the effectiveness and impact of policies and interventions, and (3) timely translation of findings into practice and policy (Holder et al. 1999; Cordova et al. 2014). We provide foundational knowledge about trends in adolescent substance use in an RML state, so as to inform public health planning. Our purpose is to characterize changes in marijuana, cigarette, and alcohol use among 8th, 10th, and 12th graders in Washington State from 2004 to 2016 overall, and also by race/ethnicity. The study period includes passage of the state's RML in 2012 and initiation of retail marijuana sales in 2014 (Cambron et al. 2017; Roffman 2016), as well as ongoing state efforts to reduce underage drinking and smoking. Our primary focus is on marijuana use, but we also describe changes in the prevalence of alcohol and cigarette use because they are widely used, and their use is positively correlated (e.g., Fleming et al. 2016). Importantly, increases in adolescent use of either substance in response to RMLs would have considerable negative public health impact (e.g., Guttmannova et al. 2016; Pacula and Sevigny 2014).

## The Drug Policy Environment in Washington State

Washington can be characterized as a state with permissive marijuana and alcohol policies and strong tobacco control policies. Before passing an RML, the state passed an MML in 1998, with a large expansion of the medical marijuana market following the Ogden memo in 2009, which announced that federal resources would not be used to prosecute medical use of marijuana in compliance with state laws. Washington alcohol sale policies and regulations are among the least restrictive of all the states. There is no prohibition on Sunday sales (Erickson et al. 2014), and privatization of the sale and distribution of distilled spirits was approved in 2011, substantially increasing access to liquor (Ballotpedia 2017; Kerr et al. 2015; Subbaraman and Kerr 2016). Relevantly, Washington undertook a concerted and successful legislative effort to address smoking, particularly among youth. As part of a comprehensive tobacco control program, the state passed cigarette use restriction policies, including a prohibition of tobacco use on school property (Dilley et al. 2012; RCW 28A.210.310 2016).

It is worth noting that Washington state has taken steps to prevent diversion of marijuana, tobacco, and alcohol from the legal market to youth (Langer et al. 2014; Dilley and Becker 2014; Dilley 2016; RCW 70.155.100 1997), and also that purchases of all three substances include taxes structured to discourage use (Kerr et al. 2015; Subbaraman and Kerr 2016; Dilley et al. 2012; Dilley et al. 2007; Roffman 2016). Furthermore, there have been substantial prevention, education, and treatment efforts on behalf of state agencies and other stakeholders to mitigate potential negative consequences of these policies on adolescent use and public health, although the effectiveness of these efforts in the new legal context remains to be seen (e.g., Kosterman et al. 2016; Lemon et al. 2014; Mason et al. 2016; Roffman 2016; Skinner et al. 2017; Walker 2017).

## Rationale for Examining Differences by Race/Ethnicity and Grade Level

A key objective of this study is to characterize differences in substance use by race/ethnicity and grade level, both of which are associated with differential levels of risk for substance use in national samples (Johnson et al. 2015; Kann et al. 2016; Miech et al. 2015; Keyes et al. 2017; Cerdá et al. 2017). Existing literature shows that marijuana use is higher among Black, Hispanic/Latinx, Multi-Racial, and American Indian/Alaska Native youth, and that there have been increases or particularly slow decreases among these groups (Johnson et al. 2015; Keyes et al. 2017). Latinx is the gender-neutral term for Latinos and Latinas. In the current study, we examine trends in use stratified on race/ethnicity and grade level within the unique context of Washington State. Importantly, Washington is racially and ethnically diverse, and our approach is responsive to the changing demographic make-up of state youth. Washington has a higher percentage of people who are Asian, Multi-Racial, American Indian/Alaska Native, and Native Hawaiian or Other Pacific Islander than the USA as whole (US Census Bureau 2010), enabling us to examine substance use among these four groups, which often go unexamined because of small sample sizes.

## Methods

We used data from the Washington "Healthy Youth Survey" (HYS), which is administered in even years to representative samples of students in the state (even grades 6–12). The HYS is a key resource for monitoring and evaluation; data are used to evaluate the impacts of the state drug policy (e.g., Darnell 2015). The HYS data system falls under the auspices of the several state agencies, including the Department of Health, the Office of the Superintendent of Public Instruction, the Department of Social and Health Services, the Department of Commerce, and the Liquor and Cannabis Board (Washington State Dept. of Health 2016, 2017).

We used HYS biennial cross-sectional samples from 2004 to 2016 for 8th, 10th, and 12th grade students. Schools were randomly selected from a frame of Washington public schools. Within participating schools, all students enrolled in the specified grades were invited to participate. Students completed self-administered, machine-readable paper-and-pencil questionnaires during a regular class period. Participation was confidential and voluntary. Informed consent was obtained from all participants included in the study (Washington State Dept. of Health 2016, 2017). Secondary data analysis has been deemed exempt by the Washington State Institutional Review Board. The overall response rates across survey years (i.e., the product of school and student participation rates) ranged from 70 to 80% among 8th graders, 58 to 69% among 10th grade students, and 49 to 54% among 12th grade students (Washington State Dept. of Health 2016, 2017). We restricted the analysis sample to those with complete data on substance use and race/ethnicity, both of which had low levels of missing data (< 3%).

## Measurement

The HYS instrument inquired about frequency of past 30-day marijuana, cigarette, and alcohol use, using items similar to those used in the Monitoring the Future survey (MTF) and the National Youth Risk Behavior Survey (YRBS, Fleming et al. 2016; Kann et al. 2016; Miech et al. 2015). We derived a variable that reflects any past 30-day use of each substance. Because of well-characterized group differences, we included sex, grade level, and race/ethnicity as key classification variables (Johnson et al. 2015; Kann et al. 2016; Miech et al. 2015). The item assessing race/ethnicity asks: "How do you describe yourself?" and students were instructed to select one or more of the following options: American Indian or Alaska Native; Asian or Asian American; Black or African American; Hispanic or Latino/Latina; Native Hawaiian or other Pacific Islander; White or Caucasian; and Other. Based on responses, we created eight categories, seven reflecting those who selected one option, and an eighth—Multi-Racial—for students who selected more than one option.

## Analyses

We used time series regression models to characterize trends in adolescent substance use over the study period (2004–2016). A Poisson model was used, and effect estimates were expressed as prevalence ratios (PRs; also referred to as relative risk ratios) and 95% confidence intervals (Zou 2004). Given our large sample size, we determined estimates to be statistically significant if the $p$ value was less than 0.05 and if neither the upper nor lower limits of the confidence interval were equal to 1.00 (Greenland et al. 2016). Linear and quadratic terms for survey year (i.e., year and year-squared) served as predictor variables. Survey year was centered at 2010 and coded so that a unit of 1 represented a 2-year period. Survey years 2004 through 2016 were recoded as $-3, -2, -1,$ 0, 1, 2, and 3, respectively, for the linear term, and as 9, 4, 1, 0, 1, 4, and 9 for the quadratic term. PRs can be interpreted as the average percent change in prevalence associated with a one-unit increase in the predictor (i.e.,

for each 2-year period) for linear trend analyses ($< 1 =$ decrease, $> 1 =$ increase). A statistically significant PR for the quadratic term (year-squared) indicates a shift in the rate of change over the study period ($< 1 =$ deceleration, $> 1 =$ acceleration).

All models testing for a quadratic trend included the linear term for survey year as a covariate. Additionally, all models were adjusted for sex, race/ethnicity, and grade level, except when one of the demographic characteristics was a stratifying variable. Sex, race/ethnicity, and grade level were dummy coded with female, White, and 8th grade, respectively, serving as the referent categories. To account for clustering of students within schools given the school-based sampling design, we adjusted standard errors with the Huber-White/sandwich estimator (White 1996; Wooldridge 2010). This adjustment also addresses non-independence of observations across years (e.g., if a respondent is included as an 8th grader in 2010 and again as a 10th grader in 2012). Using the Poisson time series modeling strategy described above, we assessed linear and quadratic trends in the following: (1) past 30-day use of marijuana, cigarette, and alcohol for all three grades combined and (2) past 30-day marijuana use stratified on grade level. Both sets of analyses were conducted for the full sample and for each individual race/ethnicity group. In a final series of models, we tested the statistical significance of relative differences in linear trends across grade level and race/ethnicity groups by including interaction terms for each race/ethnicity or grade level dummy variable with survey year. All analyses were performed using Stata 12.1.5 (Stata Corporation 2011).

## Results

There were 161,992 students in the sample, including $>$ 20,000 students and $> 500$ schools each survey year. The sample was gender-balanced (51.4% girls, 48.6% boys). More than one-quarter were 12th graders (26.7%), 39% were 8th graders, and 34.8% were 10th graders (available online). Although most respondents were White for all years combined and for each survey year, the proportion decreased from 66.7% in 2004 to 53.2% in 2016; this was coupled with larger proportions of Asian, Multi-Racial, and Hispanic/Latinx respondents in later years. The time series plots show the prevalence of past 30-day marijuana, cigarette, and alcohol use over the study period for the full sample and for each race/ethnicity group (Fig. 1; prevalence estimates available online). For all years combined and for each survey year, the prevalence of use was highest for alcohol

(24.2%), followed by marijuana (16%) and cigarettes (10.9%).

### Trends in Marijuana Use by Race/Ethnicity

Changes in the prevalence of marijuana use over the study period were modest (14.7–16.4%), and use was highest at the midpoint of the time series. The test for a linear trend in past 30-day marijuana use (Table 1, column 1) was not statistically significant (aPR = 1.01, 95% CI: 1.00, 1.02). There was a statistically significant quadratic trend, indicating a modestly decelerating rate of change during the time series (aPR = 0.98, 95% CI: 0.98, 0.99).

In models stratified on race/ethnicity (Table 1, column 1), there was a statistically significant linear increase in marijuana use among Hispanic/Latinx students (15.9–18.3%, aPR = 1.03, 95% CI: 1.01, 1.06), but not among any other group. Tests for quadratic trends were statistically significant for White (aPR = 0.98, 95% CI: 0.98, 0.99) and Hispanic/Latinx students (aPR = 0.98, 95% CI: 0.97, 0.99). Asian students had significantly lower prevalence of past 30-day marijuana use over the study period compared to White students, whereas all other race/ethnicity groups had a comparatively higher prevalence of use (Table 2, column 1). The aPRs for Black and American Indian/Alaska Native students were particularly high, i.e., 1.49 (95% CI: 1.40, 1.58) and 1.58 (95% CI: 1.48, 1.69), respectively.

### Trends in Marijuana Use by Race/Ethnicity and Grade Level

The time series plots show the grade-stratified prevalence of past 30-day marijuana use over the study period for the full sample and for each race/ethnicity group (Fig. 2). Prevalence of marijuana use over time was significantly higher among 10th (aPR = 2.27, 95% CI: 2.11, 2.44) and 12th graders (aPR = 3.04, 95% CI: 2.83, 3.27) relative to 8th graders (data not shown). We observed no change in past 30-day use from 2004 to 2016 among 10th graders (17.0–17.2%, aPR = 1.00, 95% CI: 0.98, 1.00), a significant decrease among 8th graders (9.2–6.4%, aPR = 0.96, 95% CI: 0.94, 0.99), and a significant increase among 12th graders (19.4–26.5%, aPR = 1.05, 95% CI: 1.04, 1.07; Table 3). Quadratic trend analyses indicate a statistically significant decelerating rate of change for all three grade levels.

Among 8th graders, there were statistically significant decreases in marijuana use among Black (aPR = 0.93, 95% CI: 0.88, 0.99) and White students over the study period (aPR = 0.95, 95% CI: 0.91, 0.98), with quadratic trend analysis indicating a deceleration in change among White students (aPR = 0.97, 95% CI: 0.95, 0.98;
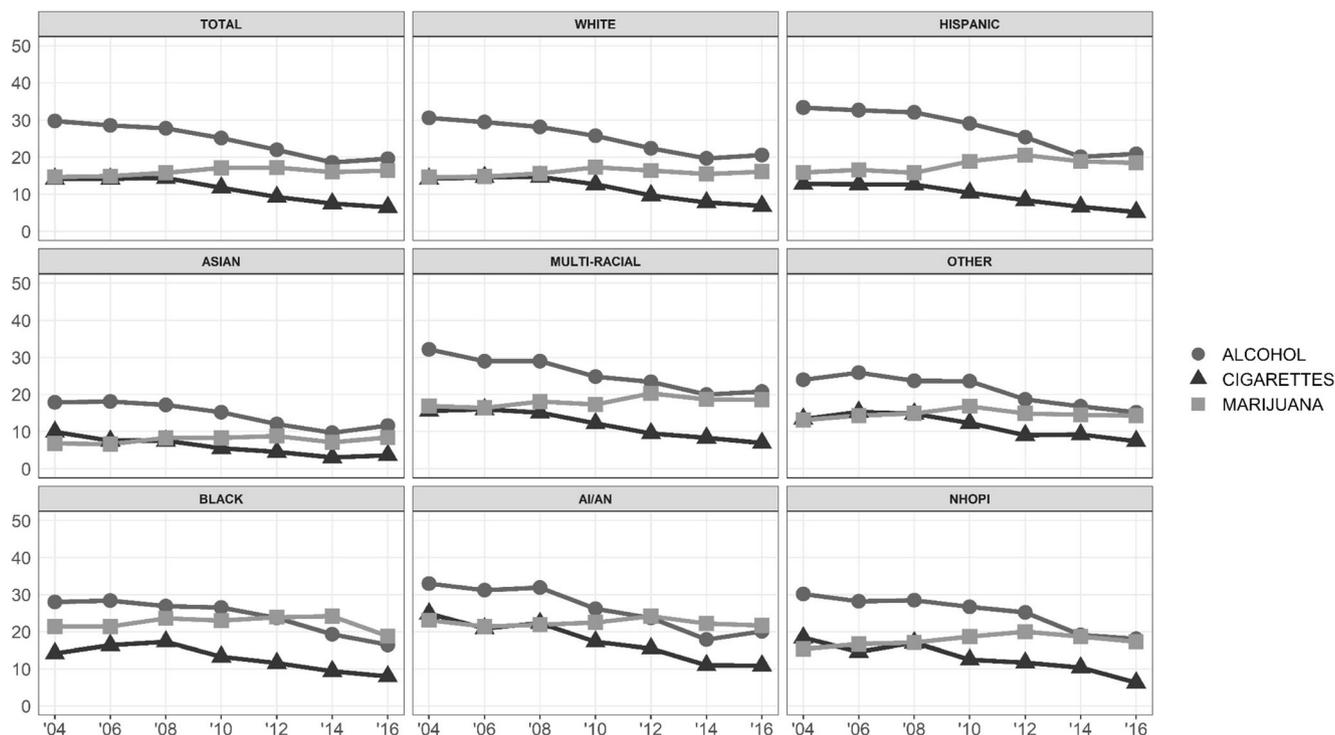
**Fig. 1** Past 30-day marijuana, cigarettes, and alcohol use among 8th, 10th, and 12th grade students combined by year and race/ethnicity—Washington Healthy Youth Surveys 2004–2016 (n = 161,992). Note. AI/AN = American Indian/Alaska Native; NHOPI = Native Hawaiian or Other Pacific Islander

**Table 1** Linear and quadratic trend analysis of past 30-day marijuana, cigarette, and alcohol use among 8th, 10th, and 12th graders combined, by race/ethnicity—Washington Healthy Youth Surveys, 2004–2016 (n = 161,992)

| | | Marijuana | | Cigarettes | | Alcohol | |
|---|---|---|---|---|---|---|---|
| | | aPR | 95% CI | aPR | 95% CI | aPR | 95% CI |
| Total | Linear | 1.01 | (1.00, 1.02) | 0.86 | (0.85, 0.88) | 0.92 | (0.91, 0.93) |
| | Quadratic | 0.98 | (0.98, 0.99) | 0.97 | (0.96, 0.98) | 0.99 | (0.98, 1.00) |
| White | Linear | 1.01 | (1.00, 1.02) | 0.87 | (0.85, 0.88) | 0.92 | (0.91, 0.93) |
| | Quadratic | 0.98 | (0.98, 0.99) | 0.97 | (0.96, 0.98) | 0.99 | (0.99, 1.00) |
| Hispanic/Latinx | Linear | 1.03 | (1.01, 1.06) | 0.85 | (0.82, 0.88) | 0.91 | (0.89, 0.92) |
| | Quadratic | 0.98 | (0.97, 0.99) | 0.97 | (0.95, 0.99) | 0.99 | (0.98, 1.00) |
| Asian | Linear | 1.03 | (0.99, 1.07) | 0.82 | (0.78, 0.87) | 0.90 | (0.87, 0.92) |
| | Quadratic | 0.99 | (0.97, 1.01) | 1.00 | (0.98, 1.03) | 1.00 | (0.98, 1.01) |
| Multi-Racial | Linear | 1.01 | (0.99, 1.04) | 0.85 | (0.82, 0.88) | 0.91 | (0.89, 0.93) |
| | Quadratic | 0.99 | (0.97, 1.00) | 0.97 | (0.96, 0.99) | 0.99 | (0.98, 1.00) |
| Other | Linear | 1.01 | (0.98, 1.04) | 0.89 | (0.86, 0.91) | 0.91 | (0.89, 0.94) |
| | Quadratic | 0.98 | (0.97, 1.00) | 0.98 | (0.96, 0.99) | 0.98 | (0.97, 1.00) |
| Black | Linear | 1.00 | (0.97, 1.02) | 0.88 | (0.85, 0.92) | 0.91 | (0.89, 0.94) |
| | Quadratic | 0.98 | (0.97, 1.00) | 0.97 | (0.94, 0.99) | 0.98 | (0.96, 0.99) |
| American Indian/Alaska Native | Linear | 1.00 | (0.97, 1.03) | 0.87 | (0.83, 0.90) | 0.90 | (0.88, 0.93) |
| | Quadratic | 0.99 | (0.98, 1.01) | 0.99 | (0.97, 1.01) | 0.99 | (0.98, 1.01) |
| Native Hawaiian or Other Pacific Islander | Linear | 1.03 | (0.99, 1.07) | 0.87 | (0.82, 0.91) | 0.92 | (0.89, 0.95) |
| | Quadratic | 0.98 | (0.96, 1.01) | 0.98 | (0.95, 1.01) | 0.98 | (0.96, 1.00) |

*Note.* Italicized values indicate a statistically significant estimate for which the 95% CI does not include 1.00. Models were adjusted for sex, grade level, and—for the full (total) sample models only—race/ethnicity. aPRs can be interpreted as the average percent change in prevalence for each 2-year period for linear trend analyses. A statistically significant aPR for the quadratic term indicates a shift in the rate of change over the study period

**Table 2** Race/ethnicity differences in past 30-day marijuana, cigarette, and alcohol use among 8th, 10th, and 12th graders combined—Washington Healthy Youth Surveys, 2004–2016 (n = 161,992)

| | Marijuana | | Cigarettes | | Alcohol | |
|---|---|---|---|---|---|---|
| | aPR | (95 CI) | aPR | (95 CI) | aPR | (95 CI) |
| White (reference) | | | | | | |
| Hispanic/Latinx | 1.21 | (1.15, 1.27) | 0.89 | (0.80, 0.98) | 1.14 | (1.10, 1.19) |
| Asian | 0.52 | (0.48, 0.57) | 0.53 | (0.48, 0.59) | 0.61 | (0.57, 0.64) |
| Multi-Racial | 1.26 | (1.19, 1.32) | 1.14 | (1.08, 1.21) | 1.10 | (1.06, 1.15) |
| Other | 1.10 | (1.04, 1.16) | 1.19 | (1.12, 1.26) | 0.99 | (0.95, 1.03) |
| Black | 1.49 | (1.40, 1.58) | 1.18 | (1.08, 1.30) | 1.02 | (0.96, 1.08) |
| American Indian/Alaska Native | 1.58 | (1.48, 1.69) | 1.69 | (1.56, 1.82) | 1.16 | (1.09, 1.23) |
| Native Hawaiian/ Pacific Islander | 1.16 | (1.08, 1.25) | 1.16 | (1.05, 1.29) | 1.04 | (0.97, 1.10) |

*Note.* Italicized values indicate a statistically significant estimate for which the 95% CI does not include 1.00. These estimates are for main effects of race/ethnicity in models that adjust for sex, grade level, and linear and quadratic trends across time

Table 3). There were no statistically significant linear trends in use among 10th graders of any race/ethnicity group, although there was evidence of a deceleration in the rate of change among Multi-Racial and Black students. Among 12th graders, there were statistically significant linear increases in prevalence among White, Hispanic/Latinx, and Asian students, and evidence of deceleration in the rate of change for youth who are Hispanic/Latinx or in the 'Other' race/ethnicity group.

In a final series of models for marijuana, we used time-by-race/ethnicity interactions to compare the relative average difference in linear trends over time. There were no group significant differences in change in prevalence of marijuana use over the study period for 8th and 10th graders. Among 12th graders, however, we observed that Hispanic/Latinx students had a greater increase in the prevalence of use relative to White students (aPR = 1.07, 95% CI: 1.03, 1.12).
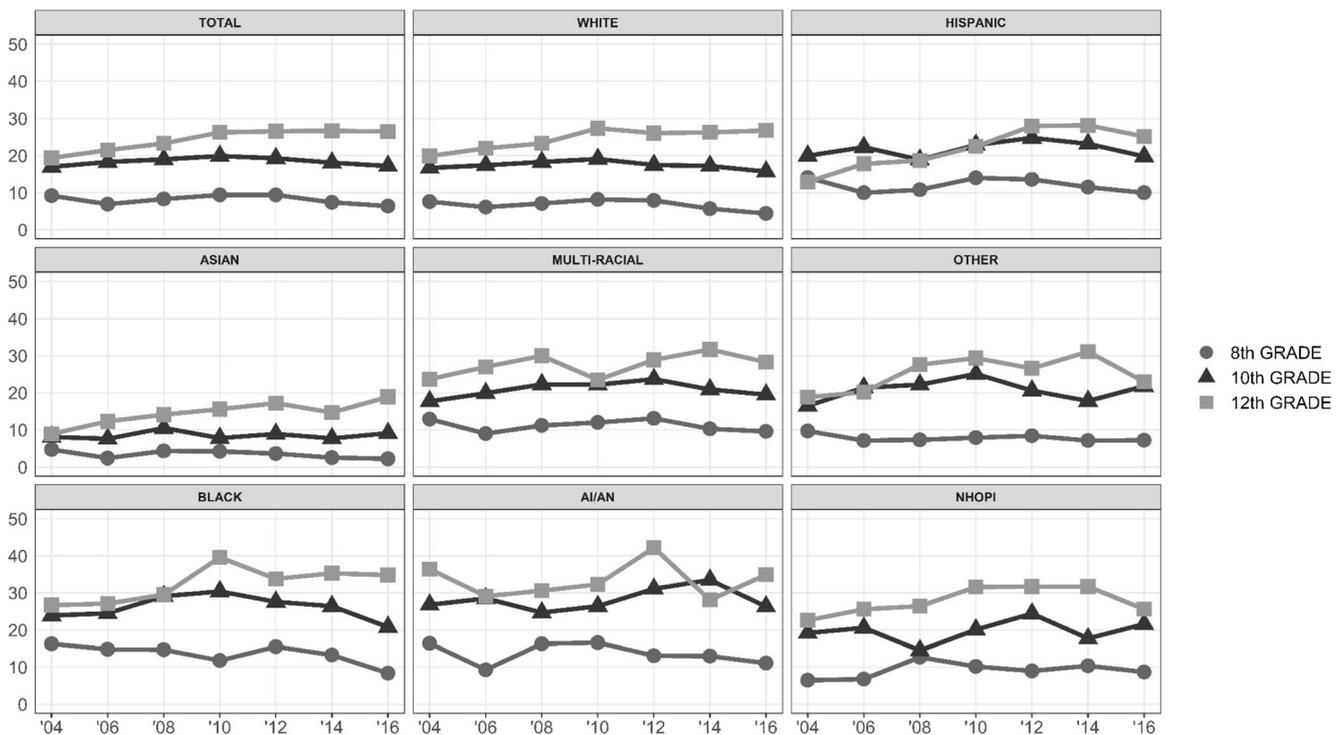


**Fig. 2** Past 30-day marijuana use by grade level, by year, and race/ethnicity—Washington Healthy Youth Surveys 2004–2016 (n = 161,992). Note. AI/AN = American Indian/Alaska Native; NHOPI = Native Hawaiian or Other Pacific Islander

**Table 3** Linear and quadratic trend analysis of past 30-day marijuana use, by grade level and race/ethnicity—Washington Healthy Youth Surveys, 2004–2016 ($n = 161{,}992$)

| | 8th Grade | | 10th Grade | | 12th Grade | |
|---|---|---|---|---|---|---|
| | aPR | (95% CI) | aPR | (95% CI) | aPR | (95% CI) |
| **Total** | | | | | | |
| Linear | *0.96* | *(0.94, 0.99)* | 1.00 | (0.98, 1.01) | *1.05* | *(1.04, 1.07)* |
| Quadratic | *0.98* | *(0.97, 0.99)* | *0.98* | *(0.98, 0.99)* | *0.99* | *(0.98, 0.99)* |
| **White** | | | | | | |
| Linear | *0.95* | *(0.91, 0.98)* | 0.99 | (0.97, 1.01) | *1.05* | *(1.03, 1.07)* |
| Quadratic | *0.97* | *(0.95, 0.98)* | 0.99 | (0.97, 1.00) | 0.99 | (0.98, 1.00) |
| **Hispanic/Latinx** | | | | | | |
| Linear | 0.98 | (0.94, 1.02) | 1.01 | (0.98, 1.04) | *1.12* | *(1.08, 1.17)* |
| Quadratic | 0.98 | (0.96, 1.00) | 0.98 | (0.97, 1.00) | *0.97* | *(0.95, 0.99)* |
| **Asian** | | | | | | |
| Linear | 0.92 | (0.84, 1.00) | 1.01 | (0.94, 1.08) | *1.10* | *(1.04, 1.16)* |
| Quadratic | 0.97 | (0.93, 1.02) | 1.00 | (0.97, 1.03) | 0.98 | (0.95, 1.01) |
| **Multi-Racial** | | | | | | |
| Linear | 0.99 | (0.94, 1.05) | 1.02 | (0.98, 1.05) | 1.03 | (0.99, 1.07) |
| Quadratic | 0.99 | (0.95, 1.02) | *0.98* | *(0.96, 0.99)* | 0.99 | (0.98, 1.01) |
| **Other** | | | | | | |
| Linear | 0.97 | (0.92, 1.03) | 1.01 | (0.97, 1.05) | 1.06 | (1.00, 1.12) |
| Quadratic | 1.01 | (0.98, 1.04) | 0.98 | (0.96, 1.00) | *0.96* | *(0.94, 0.99)* |
| **Black** | | | | | | |
| Linear | *0.93* | *(0.88, 0.99)* | 0.99 | (0.94, 1.04) | 1.05 | (1.00, 1.10) |
| Quadratic | 0.99 | (0.95, 1.02) | *0.97* | *(0.95, 0.99)* | 0.99 | (0.96, 1.01) |
| **American Indian/Alaska Native** | | | | | | |
| Linear | 0.97 | (0.91, 1.02) | 1.02 | (0.97, 1.07) | 1.01 | (0.96, 1.06) |
| Quadratic | 0.99 | (0.95, 1.02) | 0.99 | (0.97, 1.02) | 1.00 | (0.97, 1.03) |
| **Native Hawaiian/ Other Pacific Islander** | | | | | | |
| Linear | 1.05 | (0.93, 1.17) | 1.01 | (0.96, 1.07) | 1.04 | (0.98, 1.09) |
| Quadratic | 0.96 | (0.90, 1.02) | 1.00 | (0.96, 1.05) | 0.98 | (0.94, 1.01) |

*Note.* Italicized values for the trend analyses indicate a statistically significant estimate for which the 95% CI does not include 1.00. Models were adjusted for sex and—for the full (total) sample models only—race/ethnicity. aPRs can be interpreted as the average percent change in prevalence for each 2-year period for linear trend analyses. A statistically significant aPR for the quadratic term indicates a shift in the rate of change over the study period

### Trends in Cigarette and Alcohol Use by Race/Ethnicity

In contrast to patterns of marijuana use, there were large, steady decreases in use of cigarettes (14.2–6.5%) and alcohol (29.8–19.6%) from 2004 to 2016 (Fig. 1). The results from the time series regression models (Table 1, columns 2 and 3) indicate that linear decreases were statistically significant for both cigarettes (aPR for = 0.86, 95% CI: 0.85, 0.88) and alcohol (aPR = 0.92, 95% CI: 0.91, 0.93). The models testing a quadratic trend indicate a deceleration in the prevalence of smoking over the study period (aPR = 0.97, 95% CI: 0.96,

0.98), but not alcohol use. All tests for linear trends stratified on race/ethnicity were statistically significant, showing that there was an estimated average biennial decrease of at least 8% for both cigarette and alcohol use for each group. Tests for quadratic trends in cigarette use showed that White, Hispanic/Latinx, Multi-Racial, Other, and Black students had a statistically significant decelerating rate of decrease. There were statistically significant quadratic trends in alcohol use among Black students (aPR = 0.98, 95% CI: 0.96, 0.99), but not among any other group.

Relative to White students, Asian and Hispanic/Latinx students had significantly lower prevalence of cigarette use, whereas all other groups had significantly higher prevalence of use (Table 2, column 2). Asian students reported significantly lower prevalence of alcohol use compared to White students, whereas Hispanic/Latinx, American Indian/Alaska Native, and Multi-Racial students reported higher prevalence (Table 2, column 3).

## Discussion

### Summary of Findings

We examined trends in past 30-day marijuana, cigarette, and alcohol use by race/ethnicity among 8th, 10th, and 12th grade students in Washington State from 2004 to 2016, which corresponds to a period of unprecedented changes in substance use policies and regulations. There was a modest increase in marijuana use from 2004 to 2012 (14.7–17.2%), which leveled off thereafter (~ 16% in 2014 and 2016). The increase in adolescent marijuana use occurred during the period of the so-called "green rush," marked by a proliferation of medical marijuana market following the Ogden memo (Cambron et al. 2017), as well as the lead-up to the vote for recreational marijuana. Therefore, it could be a consequence of youths' exposure to a high volume of media messages about opening dispensaries and legalizing marijuana.

Marijuana use from 2004 to 2016 among Washington adolescents varied by grade level and—to a lesser extent—by race/ethnicity. There was an estimated 4% decrease in use among 8th graders, no change in use among 10th graders, and a 5% increase in use among 12th graders. Our findings do not suggest that there were increases in use among 8th and 10th graders following passage of an RML, as was the conclusion drawn by Cerdá et al. (2017). The 2010 and 2012 prevalence estimates for Washington 8th, 10th, and 12th graders reported by Cerdá et al. (2017) were lower than ours for those years, whereas their 2014 estimates were higher than ours. The discrepancy could be due to differences in study design; MTF was not designed to be representative at the state level and has a smaller sample size (~ 30 schools in

Washington), whereas HYS does not include private and alternative schools.

Although substance use has historically been higher among older vs. younger adolescents, our finding that the direction and magnitude of change in marijuana use differs by grade level is important, and we offer a few plausible explanations. First, diversion of marijuana to youth from the legal market may be more common among 12th graders, as they could be more likely than younger adolescents to have access through family or friends who are able to legally obtain marijuana (e.g., Williams Jr et al. 2017). Second, the decrease in use among 8th graders is consistent with "slow development" theory, which suggests that initiation of risk behaviors is happening later than in previous generations. The theory suggests that cultural transitions—such as the tendency to have fewer children per family—yields a social context characterized by more resources for youth, higher levels of supervision, and subsequent changes in normative behavior for early adolescents (Twenge and Park 2017).

From 2004 to 2016, there were statistically significant increases in marijuana use among White, Hispanic/Latinx, and Asian 12th grade students, of about 5, 12, and 10%, respectively. Although Black and American Indian/Alaska Native students did not have increases during the study period, these groups had the highest levels of past 30-day marijuana use (~ 35% for both groups in 2016); Asian students had the lowest (8.4%). These findings are consistent with national research showing that Asian youth have low levels of substance use, and that American Indian/Alaska Native have high levels of use (Wu et al. 2013; Keyes et al. 2017). The patterns of marijuana use among Black, American Indian/Alaska Native, and Hispanic/Latinx youth are particularly concerning given that, as marginalized populations, youth in these race/ethnicity groups may be more likely to experience substance use-related harms in the future (e.g., Godette et al. 2006).

Among 12th graders, Hispanic/Latinx students were the only group with higher levels of marijuana use relative to White students, and the reasons for this finding are not clear. One explanation is that the proportion of Hispanic/Latinx youth in Washington State who are second generation or higher increased over the study period. Because immigrant youth tend to adopt the behaviors of US youth with each successive generation (Almeida et al. 2012; Lopez-Class et al. 2011; Riosmena et al. 2015), increasing numbers of second and third generation youth could result in overall increases in the prevalence of use. Bolstering this premise, the growing proportion of people of Hispanic origin in Washington State is largely attributable to US births (Brown 2014; Office of Financial Management, Washington State 2010).

Patterns of change in alcohol and cigarette use were quite different from those for marijuana. Consistent with national trends (Johnson et al. 2015; Miech et al. 2015), there were large decreases in alcohol and cigarette use for the total sample and for each race/ethnicity group; use of both substances was at historical lows at the end of the time series. The decreases in alcohol use are particularly noteworthy given the recent change in Washington State's alcohol regulation, i.e., the privatization of liquor sales in 2012. It may be that alcohol and tobacco control and prevention efforts have indirectly affected trends in marijuana use. Given that alcohol and tobacco use may precede and lead to marijuana use for many youth, decreases in prevalence of alcohol and tobacco use may have prevented larger increases in marijuana use than would have been observed otherwise (Fleming et al. 2016).

## Strengths and Limitations

An advantage of the HYS data used in the present study is that it has a large sample size, particularly as compared to state samples of national datasets. The large sample size enabled us to conduct detailed subgroup analyses and provides foundational knowledge about adolescent marijuana use within the context of Washington State, leading up to and following passage of an RML. Limitations to our findings relate mainly to external validity. The samples are selected from youth attending public schools, which represents 91% of Washington adolescents (Washington State Legislature 2015). Results cannot be generalized to youth in private schools or home school programs nor to those who have temporarily or permanently stopped attending school. Because response rates were lowest in the 12th grade samples, those data may be less representative than data from 8th or 10th grade samples. Additionally, HYS surveys do not inquire about nativity or family socioeconomic status, both of which may be important sources of variation in substance use prevalence. Finally, we did not examine use of alternative forms of tobacco and nicotine delivery, which are increasingly common (Harrell et al. 2017).

Although we describe changes in adolescent substance use over a period marked by significant drug policy changes, this study is not designed to evaluate the effects of any specific policy. Rather, our examination of trends provides additional context for results of quasi-experimental studies, which collapse years into discrete categories representing pre- and post-policy periods. Our approach recognizes that passage of an RML was not a discrete intervention, particularly for adolescents who cannot legally purchase marijuana even post-RML.

## Implications for Prevention Science Practice and Research

There are several implications for prevention science research and practice stemming from our findings, as well as from the larger body of research. Foremost, it is important to prioritize marijuana use in prevention science research and practice. Prevention programs have historically focused on tobacco and alcohol, and an additional emphasis should be placed on

marijuana use given changes in patterns of substance use and in the policy landscape. Health promotion strategies that were effective in bringing about decreases in underage cigarette and alcohol use should be applied to preventing marijuana use, such as those addressing the social climate or attitudes toward substance use through mass media (Allen et al. 2015) and social media campaigns (Moodie et al. 2009). Emerging evidence further suggests that parental education and training that focuses on diverse messages including risk communication (e.g., Skinner et al. 2017) as well as providing factual information about the law (e.g., Kosterman et al. 2016; Mason et al. 2015; Skinner et al. 2017) is needed and may play an important role in preventing youth marijuana use in the new legal context. Future studies should assess the degree to which such efforts have been adopted and evaluate their effects.

Our findings underscore that programs and policy development should consider the unique impacts on 12th graders as well as on Black, American Indian/Alaska Native, and Hispanic/Latinx youth. This study points unambiguously to the importance of developmentally appropriate prevention and intervention efforts, and prevention science research is needed to determine which strategies are needed at which stage. Further, we recommend research to identify how to increase the effectiveness of marijuana use prevention approaches across race/ethnicity groups.

Finally, there should be an increased emphasis on regulatory science in retail marijuana; again, applying strategies that proved successful in tobacco and alcohol control to marijuana in Washington State and beyond. Pacula and Sevigny (2014) summarized recommendations for regulatory approaches to marijuana based on the lessons learned from decades of alcohol and tobacco control research, including recommendations such as limits the type of products sold and marketing of such products, and restrictions on public consumption. Ongoing policy and public health evaluations should examine the extent to which their recommendations have been adopted and monitor their impact on marijuana-related perceptions (e.g., perceived access, risk, and parental disapproval) and adolescent marijuana use.

## Conclusions

We observed modest increases in marijuana use among Washington adolescents following the Ogden memo and leading up to passage of the state's RML, particularly among 12th graders. Ongoing monitoring is needed to further characterize the trend in use among youth across grades and ethnic/racial groups over time. Lessons from tobacco and alcohol control, their victories as well as challenges, can inform program and policy development aimed at curbing adolescent substance use.

## Compliance with Ethical Standards

**Conflicts of Interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards (World Medical Association 2013).

**Informed Consent** This was a secondary data analysis. Informed consent was obtained from all participants included in the parent study.

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