

Changes in Marijuana Use Across the 2012 Washington State Recreational Legalization: Is Retrospective Assessment of Use Before Legalization More Accurate?

WILLIAM C. KERR, PH.D.,^{a,*} YU YE, M.A.,^a MEENAKSHI SABINA SUBBARAMAN, PH.D.,^a EDWINA WILLIAMS, M.P.H.,^a & THOMAS K. GREENFIELD, PH.D.^a

^aAlcohol Research Group, Public Health Institute, Emeryville, California

ABSTRACT. Objective: The purpose of this study was to evaluate changes in marijuana use prevalence and user characteristics across the 2012 recreational legalization in Washington State. Differences in change estimates between retrospective and contemporaneous pre-legalization measures are compared and considered in relation to potential social acceptability and illegality effects on reporting. **Method:** Four representative surveys of the Washington State population 18 years and older were conducted by telephone, two in 2014 and two in 2015, which are combined by year for analyses ($N = 3,451$). Respondents reported their current past-year use frequency and retrospective frequency of use in 2012 before the election in which legalization was passed. They also provided demographic information and details of alcohol use, including simultaneous use with marijuana. **Results:** A small and not statistically significant increase of 1.2 percentage points in past-year use prevalence, from 24.3% (22.3–26.5) to 25.6% (23.6–27.6), was found when

combining the surveys. No statistically significant change was found in the prevalence of simultaneous use with alcohol, which decreased from 12.9% (11.3–14.7) to 12.6% (11.0–14.4). In contrast, estimates from the National Survey on Drug Use and Health (NSDUH) indicate substantially increased prevalence, from 15.5% (13.8–17.3) in 2010–2012 to 19.1% (16.9–21.4) in 2013–2014, although this change is not statistically significant. Other findings of interest from the Washington State surveys include new users after legalization tending to be older, White, and moderate drinkers who do not use marijuana simultaneously with alcohol. **Conclusions:** A retrospective pre-legalization measure showed only a small increase in marijuana use prevalence in contrast to larger changes found in prospectively assessed use in the NSDUH. Changes in the social acceptability and legal status of marijuana after legalization may have increased reporting of pre-legalization use compared with concurrent assessments. (*J. Stud. Alcohol Drugs*, 79, 495–502, 2018)

MARIJUANA USE PREVALENCE in the United States rose steeply from 2005 to 2015 across all age groups, with more than proportional increases in monthly and weekly use frequencies (Kerr et al., 2018; Wu et al., 2016). For younger users, this contrasts with negative trends in the prevalence of cigarette and alcohol use among underage youth (Lanza et al., 2015). Especially steep increases from very low rates in the past have been seen among those older than 50 years of age as the baby boom generation has moved into these ages (Han et al., 2017; Kerr et al., 2018). Changing perceptions of marijuana with regard to riskiness for health and social problems and social acceptability have played a role (Keyes et al., 2016). The changing legal status of marijuana has been important for these perceptions, with medical marijuana now legal in more than half of the states, decriminalization and reduced penalties in many states, and full recreational legalization now in eight states and the District of Columbia (Fairman, 2016; Freisthler & Gruenewald,

2014; Pacula et al., 2015). However, marijuana remains illegal at the U.S. federal level and is classified as a Schedule 1 drug, the most strictly controlled. Between 1969 and 1973, just 12%–16% of U.S. adults approved of marijuana legalization; from 2013 onward, support has averaged 56%, and by 2016 it was 60% (Jones, 2015; Swift, 2016).

In November 2012, voters in Washington State approved Initiative 502, which legalized marijuana at the state level as of December 6, 2012. The initiative authorized the Washington State Liquor and Cannabis Board (formerly the Washington State Liquor Control Board) to regulate and tax marijuana, restricted sale to those 21 years of age and older, and added a new threshold for driving under the influence. The number of retail licenses was limited initially to 334 licensee applicants selected by lottery, but was increased to 556 with additional store openings in 2016 (Washington State Liquor and Cannabis Board, 2017). The first retail store did not open until July 2014, and stores continued to open through 2015 and 2016, with 361 paying taxes in March 2017. Given a local option in the law, the majority of cities and counties passed some type of local ordinance, including bans on retail sales and home delivery, limits on store numbers, location restrictions, limits on hours of sale, and restrictions on advertising (Dilley et al., 2017). The Washington State Liquor and Cannabis Board was also authorized to regulate most aspects of marijuana production, processing, and sales, including security, location, hours of sale, product

Received: December 5, 2016. Revision: December 1, 2017.

This research was funded by National Institute on Alcohol Abuse and Alcoholism Grant R01 AA021742 and National Alcohol Research Center Grant P50AA005595.

*Correspondence may be sent to William C. Kerr at Alcohol Research Group, Public Health Institute, 6001 Shellmound Ave., Suite 450, Emeryville, CA 94608, or via email at: wkerr@arg.org.

labeling, and advertising. Importantly, marijuana products cannot be used in public. Three levels of excise taxes were initially specified: 25% of the producer price on sales to processors, a 25% excise tax on the wholesale price to retailers, and 25% on the retail selling price (Darnell & Bitney, 2017). In July 2015, excise tax rates were reduced and simplified to 37% of the retail price.

Because marijuana use, sales, and other details were not recorded in Washington State before legalization was fully implemented, surveys are the only source of information on use prevalence, amounts, and user characteristics. However, illegality and social stigma could have substantial impacts on the accuracy of reporting. Social acceptability is important for substance use and pattern measurement, including alcohol (Greenfield & Kerr, 2008). Yet even for legal drugs such as alcohol, surveys typically capture only about 50% of sales, although some of this can be attributed to the quality of questions and interpretation of drink sizes (Kerr & Greenfield, 2007). However, survey estimates of the prevalence for alcohol use are thought to be mostly accurate (Greenfield & Kerr, 2008). Given concerns about legality before passage of I-502, this is unlikely to be the case for marijuana, and the degree of underreporting is not known because there has been no objective source for comparison. Most drug measurement validation studies have relied on drug tests of arrestees and repeated youth surveys, both of which suggest significant misreporting (Fendrich & Rosenbaum, 2003). Biomarkers for marijuana use can also be used to validate consumption reports and are not affected by illegality or social desirability biases (Roulette et al., 2016; Taylor et al., 2017). However, these rely on a willingness to provide samples (VanDerNagel et al., 2017) and would be costly and difficult to implement in general population telephone surveys. Urinalysis of respondents in a validity study of the National Survey on Drug Use and Health (NSDUH) suggested that past-30-day use may have been underreported by about 26% (Harrison et al., 2007). However, there are also accuracy issues with urinalysis, and more than 40% of those reporting use tested negative.

When considering the impact of legalization on marijuana use prevalence, the mismatch between conditions of social and legal stigma could bias comparisons of pre- (illegal use) and post-survey (legal use) prevalence and could result in substantial overestimation of an increase. An alternative to this is a retrospective pre- to current post-event survey design where use at both times is assessed in a survey occurring after legalization (Hill & Betz, 2005; Pratt et al., 2000; Sibthorp et al., 2007). This approach has the advantage that social acceptability and legality concerns are equivalent. This aspect of reporting must be weighed against concerns regarding the validity of retrospective recall. For policy evaluation, the salience of the period before a major policy change such as legalization should increase the accuracy of recall for the retrospective period. Studies of retrospective

measures of alcohol use have found reasonable test-retest validity (Greenfield et al., 2014). One four-wave panel study found higher retrospective drinking volumes compared with volumes concurrently assessed at the earlier time point, possibly reflecting increased social acceptability (Koenig et al., 2009).

The relationship between marijuana and alcohol use is an important aspect of potential impacts on problems of marijuana legalization. A recent review on substitution and complementarity found evidence of both effects, with some youth studies suggesting that substitution played a larger role in more liberalized marijuana environments (Subbaraman, 2016). Among marijuana users, the use of alcohol is common, although most alcohol users do not use marijuana (Subbaraman & Kerr, 2015). A U.S. study of 2005 and 2010 data found that 9.3% of men and 5.5% of women tended to use alcohol and marijuana at the same time, and that these simultaneous users had double the risk of both drunk driving and alcohol-related harms compared with alcohol-only users, controlling for drinking patterns (Subbaraman & Kerr, 2015). These findings indicate the importance of considering co-use.

Little is known about changes in marijuana use across legalization in Washington State. One pre-post legalization study of impaired drivers in Washington State found a 25% increase in positive tetrahydrocannabinol (THC) in blood, suggesting an increase in use (Couper & Peterson, 2014). Some mixed results have been found regarding use among youth. Analyses of the Washington Health Youth Survey found no increases among 6th-, 8th-, 10th-, or 12th-grade students (Darnell & Bitney, 2017), whereas an analysis of data from Monitoring the Future found increased use among 8th and 10th graders in Washington State but no change among 12th graders nor for any grade level in Colorado (Cerdá et al., 2017). The present analyses evaluate changes in marijuana use prevalence across legalization using a retrospective (pre-initiative) and current (post-initiative) measurement design. Changes in the frequency of marijuana use, use with alcohol, and the characteristics of continuing and new users are also addressed.

Method

Sample

The sample consists of four representative surveys of adults (age ≥ 18 years) in Washington State, with sample recruitment taking place separately in January–April 2014 (Wave 1, $N = 1,202$), August–October 2014 (Wave 2, $N = 804$), March–May 2015 (Wave 3, $N = 823$), and August–October 2015 (Wave 4, $N = 662$). Participants were reached via random-digit dial sampling of both landlines and cell phones, with about 40% of respondents recruited from cell phone exchanges at each wave. AAPOR2 (American As-

sociation for Public Opinion Research, 2011) cooperation rates—that is, complete and partial interviews as a percentage of identified eligible respondents (landline, cell)—were as follows: Wave 1 (50.8%, 59.5%), Wave 2 (45.8%, 62.4%), Wave 3 (43.7%, 61.5%), and Wave 4 (41.7%, 59.6%). These rates were about 10 percentage points lower than those achieved by the Behavioral Risk Factor Surveillance System survey in Washington State (Centers for Disease Control and Prevention, 2015). At survey completion, participants were issued \$10 gift cards. Surveys lasted about half an hour on average. The first two waves conducted in 2014 and the last two waves conducted in 2015 were each combined to achieve adequate power for analyses. Protocols were approved by the Public Health Institute Institutional Review Board (#I13-010).

For comparison, we also present marijuana use prevalence estimates for Washington State from two population surveys: the NSDUH and the National Alcohol Survey (NAS). The NSDUH provides U.S. national and state-level data on the use of tobacco, alcohol, and illicit drugs, including marijuana, by pooling observations from multiple years of this clustered household-based sampling frame survey conducted in person in both English and Spanish. In this study, we show the past-year marijuana use prevalence for the Washington State population age 18 years and older from pooled 2010–2012 data (before legalization) and 2013–2014 data (after legalization) from published estimates (Substance Abuse and Mental Health Services Administration, 2014, 2015). The NAS is a series of U.S. representative surveys conducted for the Alcohol Research Group every 5 years starting in 1979 (Kerr et al., 2009). In this study, we used data from Washington State adults from the 2009–2010 NAS and 2014–2015 NAS (Greenfield et al., 2015; Karriker-Jaffe et al., 2017) to derive marijuana use prevalence before and after legalization.

Measures

Current marijuana use was determined from the question: “How often have you used marijuana, hash or pot during the last twelve months?” Respondents were coded as dichotomous current (past 12 months) users or not, and for current users, as weekly users or not. Current marijuana users were also asked, “In the past year, how often did you use alcohol and marijuana products at the same time? Was it usually, sometimes or never?” Those who answered “usually” or “sometimes” were defined as simultaneous users.

Retrospective marijuana use before legalization was based on a question asking, “Now, thinking about the year 2012, prior to December 6, 2012, when the state legalized marijuana, how often did you use marijuana, hash or pot in any form during 2012?” Similarly, marijuana users in 2012, before legalization, were asked how often they used marijuana and alcohol at the same time.

The following demographics were included as independent predictors of marijuana use status change: gender, age (18–29, 30–49, ≥50), race/ethnicity (White, Black, Hispanic, other), education (high school graduate or less, some college, college graduate or higher), household income (annual income no more than \$30,000, more than \$30,000 but no more than \$60,000, more than \$60,000, and missing for income), marital status (married or not), and alcohol use status (lifetime abstainers, ex-drinkers and never 5+ during lifetime, ex-drinkers and had 5+ during lifetime, current drinkers but not any 5+/4+ for men/women last month, current drinkers and had at least one day of 5+/4+ last month).

Statistical analyses

For each cross-section wave, the data were weighted to adjust for probability of selection introduced during the sampling design and also to adjust the sample to match the target population, thus to be representative of all adults (18 years of age and older) residing in the Washington State. The weighting process takes three steps. First, base weights were constructed for landline and cell phone samples separately to reflect the probability of selection, the number of phones for each household or individual, and the number of adults living in the household. Second, the landline and cell samples were combined to reflect the population coverage of landline and cell sample frames. Responses were weighted to the benchmarks (National Health Interview Survey state estimate) based on their landline/cell usage status (Blumberg & Luke, 2013). Last, the weighted data were calibrated to reflect population distribution from the American Community Survey, using a raking adjustment for sex by age, age by race/ethnicity and education levels. All analyses were performed in STATA Version 13 (StataCorp LP, College Station, TX), which generates robust standard errors for analyses applying sampling weights.

Results

Table 1 shows the prevalence of marijuana use before and after legalization. For the data collected in 2014 (Waves 1 and 2 combined) and 2015 (Waves 3 and 4 combined), we compare their retrospectively reported use in 2012 and current use in the past year before the interview. For the 2014 surveys, no stores had opened by the end of Wave 1, but 31 stores had opened in the 2 months before the beginning of Wave 2; therefore, some of these respondents had access to retail stores for part of the year before the interview. For the 2015 surveys, 120 stores had opened by the beginning of Wave 3, and most of the past-year window included the period with retail stores; furthermore, 172 stores had opened by the beginning of Wave 4, and the full past-year window was within the period of retail sales. From the 2014 surveys, 23.6% reported any marijuana use during the 12-month

TABLE 1. Percentage of past-year marijuana use for the Washington State population aged 18 and older before and after marijuana legalization from surveys conducted in 2014 and 2015

Variable	Any last year [95% CI]	≥Weekly [95% CI]	<Weekly [95% CI]	Use with alcohol [95% CI]	Not use with alcohol [95% CI]
Use in 2012 (retrospective from 2014 data)	23.6% [21.0%, 26.4%]	12.4% [10.2%, 14.9%]	11.2% [9.4%, 13.2%]	12.2% [10.1%, 14.6%]	11.3% [9.5%, 13.4%]
Current use in 2014	24.9% [22.3%, 27.7%]	13.6% [11.4%, 16.2%]	11.3% [9.6%, 13.3%]	12.1% [10.0%, 14.6%]	12.6% [10.7%, 14.7%]
Difference	1.3%	1.2%	0.1%	-0.1%	1.3%
Use in 2012 (retrospective from 2015 data)	25.1% [22.1%, 28.3%]	14.1% [11.7%, 16.9%]	11.0% [9.0%, 13.4%]	13.6% [11.2%, 16.4%]	11.2% [9.1%, 13.6%]
Current use in 2015	26.2% [23.3%, 29.3%]	14.6% [12.2%, 17.4%]	11.6% [9.7%, 13.8%]	13.1% [10.8%, 15.7%]	13.0% [11.0%, 15.4%]
Difference	1.1%	0.5%	0.6%	-0.5%	1.8%
Use before legalization (retrospective from combined 2014 & 2015 data)	24.3% [22.3%, 26.5%]	13.2% [11.6%, 15.1%]	11.1% [9.7%, 12.6%]	12.9% [11.3%, 14.7%]	11.2% [9.8%, 12.8%]
Use after legalization (current use from combined 2014 & 2015 data)	25.6% [23.6%, 27.6%]	14.1% [12.4%, 16.0%]	11.5% [10.2%, 12.9%]	12.6% [11.0%, 14.4%]	12.8% [11.4%, 14.4%]
Difference	1.2%	0.9%	0.4%	-0.3%	1.6%

period before legalization, compared with 24.9% reporting any use during the 12 months before the interview. For 2015 data, 25.1% reported any marijuana use before legalization, whereas 26.2% reported current use. When both 2014 and 2015 data are combined, the prevalence of use was found to have increased by 1.2 percentage points (from 24.3% to 25.6%) across legalization. None of the pre–post legalization differences were found to be statistically significant, as shown from the large overlapping confidence intervals in Table 1.

In addition to any marijuana use, Table 1 also presents the prevalence of at least weekly use and less than weekly use, and separately, whether marijuana and alcohol were used simultaneously by the respondent. There appears to have been a larger increase in rates of at least weekly use compared with less frequent use (0.9 vs. 0.4 percentage point increase from the combined data) across legalization. No increase was seen in the prevalence of simultaneous use of marijuana and alcohol across legalization, whereas there was a 1.6 percentage point increase in the prevalence of marijuana use among drinkers who use the substances separately after legalization (11.2% before vs. 12.8% after for combined data). Again, none of these pre–post legalization differences were statistically significant.

To illustrate comparisons with prevalence estimates from repeated cross-sectional surveys, Table 2 shows 12-month marijuana use prevalence estimates for Washington State before and after legalization from two national cross-sectional surveys. The pooled 2013–2014 NSDUH reports 19.1% of Washington State adults had used marijuana at least once during the last 12 months and the 2014–2015 NSDUH estimate indicates a prevalence of 17.7%. Both estimates show

an increase from the 15.3% prevalence before legalization using the pooled 2011–2012 surveys, although overlapping 95% confidence intervals indicate that these differences may not be statistically significant. Combining the postlegalization estimates in consideration of sample variation suggests an increase of about 20% in the prevalence of past-year marijuana use across legalization. Estimates of past-month use for the same period show a similar pattern of change (not shown). Earlier estimates from 2009–2010 and 2010–2011 indicate that reported marijuana use was slowly rising in the pre-legalization period. The 12-month prevalence of marijuana use was 28.6% for the 2014–2015 NAS, compared with 19.5% for the 2009–2010 NAS. The sample size of the NAS from Washington State was quite small (114 for 2014–2015 and 120 for 2009–2010 data), resulting in much larger confidence intervals than those from the NSDUH. However, the survey mode and questions used for the NAS were very similar to the Washington State surveys, and both used the same fieldwork organization (ICF, Inc.).

Using retrospective questions to evaluate pre- and post-legalization marijuana use not only provides marginal prevalence estimates but also allows us to examine the characteristics of those who changed use status. Only a small proportion of respondents became users from nonusers (new users) or changed to nonusers from users (quitters). For the combined 2014 and 2015 data, only 5.8% were new users (4.9% for 2014 and 6.8% for 2015 data) and 4.4% were quitters (3.5% for 2014 and 5.3% for 2015 data). In contrast, 70.1% were nonusers both before and after legalization and 19.7% were users during both periods.

Table 3 shows the demographic and drinking character-

TABLE 2. Prevalence [95% CI] of any past-year marijuana use before and after legalization from National Survey on Drug Use and Health (NSDUH) and National Alcohol Survey (NAS)

NSDUH, Washington State	
2009–2010 combined	13.8% [12.0%, 16.0%]
2010–2011 combined	14.9% [12.9%, 17.1%]
2011–2012 combined	15.3% [13.3%, 17.5%]
December 6, 2012, recreational legalization	
2013–2014 combined	19.1% [16.9%, 21.4%]
2014–2015 combined	17.7% [15.5%, 19.9%]
NAS, Washington State	
2009–2010 survey	19.5% [11.5%, 31.1%]
2014–2015 survey	28.6% [18.7%, 41.2%]

istics by marijuana use status before and after legalization for the 2014 and 2015 data combined. The total sample was classified into four mutually exclusive groups: nonusers both before and after legalization ($n = 2,658$), users during both periods ($n = 509$), new users ($n = 183$), and quitters ($n = 101$). Comparisons were made between the first two groups (nonusers at both periods and users at both periods) and the last two groups (new users and quitters), using both differences in prevalence estimates and multinomial logistic regressions predicting one status versus another. Recognizing that movement between use and non-use occurs for many

reasons, we focused on differences between new users and quitters to identify characteristics of those who may have been influenced to initiate use because of legalization. Comparing consistent users and nonusers, descriptive prevalence comparisons showed that users during both periods were more likely to be male, be younger than 30 years of age, be non-White, have lower education and income levels, and be current heavy drinkers than nonusers during both periods. These characteristics differentiating users and nonusers are not reflected among new users and quitters. As shown in the fourth and fifth data columns of Table 3, new users, compared with quitters, were more likely to be age 50 years or older and current non-heavy drinkers and less likely to be Black and former drinkers. In the multinomial logistic regression, those age 50 years and older compared with those younger than 30 years were more likely to be new users rather than quitters, whereas Blacks compared with Whites and ex-drinkers compared with moderate drinkers were more likely to be quitters rather than new users.

Discussion

An increased prevalence of past-year marijuana use from before legalization in 2012 to 2014 and 2015 was found

TABLE 3. Differences in demographic and drinking characteristics across groups of marijuana use status change and multinomial logistic regression results predicting marijuana use status change

Variable	Nonusers both periods ($n = 2,658$)	Users both periods ($n = 509$)	Relative risk ratios ^a compare users both periods to nonusers both periods	Change to new users ($n = 183$)	Change to quitters ($n = 101$)	Relative risk ratios ^a compare change to new users with change to quitters
Male	46.50%	56.5%**	1.32 [1.02, 1.73]*	55.80%	55.90%	1.13 [0.61, 2.09]
Age						
18–29	16.90%	34.1%***	ref.	32.10%	38.90%	ref.
30–49	32.90%	36.90%	0.64 [0.44, 0.94]*	33.00%	39.20%	1.13 [0.51, 2.48]
≥50	50.20%	29.0%***	0.43 [0.30, 0.61]***	34.90%	22.0%*	2.41 [1.14, 5.11]*
Race/ethnicity						
White	76.80%	69.9%*	ref.	80.40%	67.20%	ref.
Black	4.00%	6.30%	1.96 [1.04, 3.68]*	0.70%	6.3%**	0.10 [0.02, 0.57]*
Hispanics	8.90%	10.70%	0.81 [0.45, 1.44]	10.20%	11.80%	0.86 [0.25, 2.96]
Others	10.40%	13.20%	1.19 [0.75, 1.88]	8.80%	14.70%	0.52 [0.18, 1.52]
Education						
≤HS grad	31.40%	45.0%***	ref.	30.30%	42.10%	ref.
Some college	33.90%	33.60%	0.71 [0.51, 0.98]*	41.30%	38.20%	1.35 [0.64, 2.85]
College grad	34.60%	21.5%***	0.50 [0.36, 0.71]***	28.40%	19.70%	1.77 [0.78, 4.01]
House income						
≤\$30k	25.10%	48.5%***	ref.	33.00%	30.60%	ref.
\$30–\$60k	22.70%	24.40%	0.55 [0.38, 0.79]**	21.70%	22.60%	0.71 [0.30, 1.66]
>\$60k	38.70%	23.2%***	0.36 [0.24, 0.53]***	36.60%	34.50%	0.60 [0.25, 1.43]
Missing	13.50%	4.0%***	0.15 [0.08, 0.29]***	8.80%	12.30%	0.65 [0.21, 2.00]
Married	58.30%	47.4%***	1.00 [0.74, 1.35]	44.60%	40.90%	0.96 [0.51, 1.79]
Alcohol use						
Life abstainer	10.00%	1.1%***	0.09 [0.04, 0.23]***	3.90%	7.20%	0.52 [0.11, 2.44]
Ex-never 5+	15.50%	4.6%***	0.29 [0.17, 0.51]***	4.50%	18.7%**	0.15 [0.05, 0.47]**
Ex-any 5+	10.00%	9.40%	0.91 [0.58, 1.42]	6.20%	12.80%	0.25 [0.10, 0.66]**
Nonheavy	55.30%	48.3%*	ref.	58.60%	36.7%**	ref.
5+/4+ 1st 30 days	9.20%	36.5%***	3.70 [2.61, 5.22]***	26.80%	24.60%	0.77 [0.37, 1.61]

Notes: ref. = reference; HS = high school; grad = graduate; k = 1,000. ^aRelative risk ratios [95% confidence intervals] from multinomial logistic regression predicting the four-category marijuana change status variable shown. The two sets of RRR estimates are obtained from the same model by changing the reference outcome category.

* $p < .05$; ** $p < .01$; *** $p < .001$.

in our analysis of current and retrospective use from four general population surveys of Washington State. However, the magnitude of increased use was much smaller than the substantial increases found in the repeated cross-sectional waves of the NSDUH and NAS. It should be noted that the NSDUH used household sampling methods and in-person interviews with self-administered drug use questions and also had a Spanish version; therefore, there are differences in sampling and reporting compared with the Washington State surveys. In the Washington State surveys, an increase of only 1.2 percentage points in past-year use, from 24.3% before to 25.6% after, was seen. This might be attributed to more accurate reporting of pre-legalization use due to reduced social stigma and concerns about legality after legalization. Similar conclusions were drawn from a study of changes in self-reported quality of life, in which the retrospective to current assessment was found to have a stronger association with changes in clinical indicators of health status (Nieuwkerk et al., 2007). Quality-of-life measures depend on a reference value that can change with circumstances, and the retrospective measure avoids this bias. A similar situation with potentially large bias from social desirability and legal status suggests that evaluations of drug legalization might be improved by including retrospective pre-legalization to current post-legalization designs, in addition to currently assessed pre-post designs, and the use of routine data that would not be subject to the same biases. The current results indicate that the legalization of marijuana in Washington State did not result in a substantial increase in marijuana prevalence, frequency, or use with alcohol through 2015; however, this period included no or limited retail availability. Therefore, continued tracking is warranted.

Importantly, changes in user characteristics after legalization show that new users tended to be older, White, moderate drinkers and potentially more educated than those who quit use over the same period. Although the increase in use was small, results show that use weekly or more frequently increased more than less frequent use, indicating a shift toward more intensive use in the legal environment. Another important aspect of changing use is that the increase occurred in the prevalence of use without alcohol, and there was no change in use with alcohol. If this is confirmed in further studies it would suggest that although marijuana users tend to be heavier drinkers, legalization in Washington State did not increase the prevalence of simultaneous use of alcohol and marijuana. Simultaneous use has been found to increase the risk for alcohol-related problems both in the general population (Midanik et al., 2007; Subbaraman & Kerr, 2015) and among adolescents, who are particularly vulnerable (Terry-McElrath et al., 2013, 2014). Results from laboratory studies further support that the combined use of alcohol and marijuana increases both subjective (e.g., "feeling sedated") and objective (e.g., heart rate) measurements of impairment (Downey et al., 2013; Ronen et al., 2010).

The high prevalence of marijuana use in Washington State before legalization may have been affected by the availability of medical marijuana in 2012. Although the medicinal use of marijuana was legalized in 1998, dispensaries did not open until 2007. The number of dispensaries expanded after the 2009 Ogden memo from the U.S. Justice Department and more than 300 were open in 2015 (Cambron et al., 2017). Neither the number of patients nor dispensaries is known for 2012, but Washington State allows marijuana recommendations for common conditions including anxiety and chronic pain, increasing the potential for wider use of medical marijuana. The privatization of the Washington State liquor monopoly in July 2012 and the substantial reduction in the beer tax in July 2013 are also potentially relevant to changes in marijuana use during this period. Analyses of alcohol use do not indicate major changes in overall use but do show a shift from distilled spirits to beer in response to increased prices for distilled spirits and reduced beer prices (Kerr et al., 2015; Ye & Kerr, 2016).

Analyses of opinions regarding legalization and support for Initiative 502 in the 2014 surveys of Washington State found increased support for the initiative in the years following legalization (Subbaraman & Kerr, 2016a). This is consistent with the current study's findings that marijuana use did not rise steeply following legalization, a key concern of voters. Analyses of support for legalization using surveys from 2014 through 2016 have found continued increases from 64% in 2014 to 78% in 2016 (Subbaraman & Kerr, 2017). This increase in support contrasts with findings of reduced support for Initiative 1183 that privatized sales of distilled spirits in Washington State in 2012 (Subbaraman & Kerr, 2016b).

Study limitations include the use of self-reports and retrospective recall in establishing use prevalence. Although these would generally be expected to bias estimates downward, it is possible that new users could misremember their prior status, inflating retrospective estimates. There were also changes in marijuana regulations and distribution in Washington State during the 2014 and 2015 survey period that may have affected use between the survey waves. The opening of retail stores began just before Wave 2, with the majority of stores opening in 2015 between Waves 2 and 3 and Waves 3 and 4. The reduction in marijuana tax rates noted in the introduction occurred between survey Waves 3 and 4. Further, although we included household income in the estimated models, this measure could not be adjusted for household size, which may affect the comparability across family circumstances. It is also important to note that the high prevalence of marijuana use in Washington State compared with other U.S. states may reduce the generalizability of these results.

These analyses provide a new perspective on the evaluation of changing marijuana use across recreational legalization, suggesting that the currently assessed pre-post design

may overestimate changes in this situation because of differential underreporting. Results based on the retrospective pre- and current post-legalization design indicate only a small increase in use among those who tend to be older, White, more educated, and moderate drinkers. This group may have had less access or perceived access to marijuana under the illegal and medical distribution systems than other groups. A small shift toward more frequent use of marijuana was found after recreational legalization, indicating a change in intensity. Importantly, an increased prevalence of use with alcohol was not found, suggesting that these substances are not complementary in this situation. Certainly more research is needed on details of potentially important aspects of use not captured by prevalence, including frequency, amounts, and routes of administration and on the potential consequences of marijuana use, including dependence, impaired driving, and other health and social problems in Washington State and the other states where legal recreational marijuana is now available. The effects of legalization on use may also take more time to appear, and ongoing monitoring is recommended.

References

- American Association for Public Opinion Research. (2011). *Standard definitions: Final dispositions of case codes and outcome rates for surveys* (Revised 2011, 7th ed.). Oakbrook Terrace, IL: Author. Archived by WebCite at <http://www.webcitation.org/5ymByeIL>.
- Blumberg, S. J., & Luke, J. V. (2013). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January–June 2013*. Retrieved from <https://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201312.pdf>
- Cambron, C., Guttmannova, K., & Fleming, C. B. (2017). State and national contexts in evaluating cannabis laws: A case study of Washington State. *Journal of Drug Issues, 47*, 74–90. doi:10.1177/0022042616678607
- Centers for Disease Control and Prevention. (2015). *Behavioral Risk Factor Surveillance System: 2015 Summary Data Quality Report, July 29, 2015*. Retrieved https://www.cdc.gov/brfss/annual_data/2015/pdf/2015-sdqr.pdf
- Cerdá, M., Wall, M., Feng, T., Keyes, K. M., Sarvet, A., Schulenberg, J., . . . Hasin, D. S. (2017). Association of state recreational marijuana laws with adolescent marijuana use. *JAMA Pediatrics, 171*, 142–149. doi:10.1001/jamapediatrics.2016.3624
- Couper, F. J., & Peterson, B. L. (2014). The prevalence of marijuana in suspected impaired driving cases in Washington State. *Journal of Analytical Toxicology, 38*, 569–574. doi:10.1093/jat/bku090
- Darnell, A. J., & Bitney, K. (2017). *I-502 evaluation and benefit-cost analysis: Second required report* (Document no. 17-09-3201). Olympia, WA: Washington State Institute for Public Policy. Retrieved from http://www.wsipp.wa.gov/ReportFile/1670/Wsipp_I-502-Evaluation-and-Benefit-Cost-Analysis-Second-Required-Report_Report.pdf
- Dilley, J. A., Hitchcock, L., McGroder, N., Greto, L. A., & Richardson, S. M. (2017). Community-level policy responses to state marijuana legalization in Washington State. *International Journal on Drug Policy, 42*, 102–108. doi:10.1016/j.drugpo.2017.02.010
- Downey, L. A., King, R., Papafotiou, K., Swann, P., Ogden, E., Boorman, M., & Stough, C. (2013). The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. *Accident Analysis and Prevention, 50*, 879–886. doi:10.1016/j.aap.2012.07.016
- Fairman, B. J. (2016). Trends in registered medical marijuana participation across 13 US states and District of Columbia. *Drug and Alcohol Dependence, 159*, 72–79. doi:10.1016/j.drugalcdep.2015.11.015
- Fendrich, M., & Rosenbaum, D. P. (2003). Recanting of substance use reports in a longitudinal prevention study. *Drug and Alcohol Dependence, 70*, 241–253. doi:10.1016/S0376-8716(03)00010-3
- Freisthler, B., & Gruenewald, P. J. (2014). Examining the relationship between the physical availability of medical marijuana and marijuana use across fifty California cities. *Drug and Alcohol Dependence, 143*, 244–250. doi:10.1016/j.drugalcdep.2014.07.036
- Greenfield, T. K., Karriker-Jaffe, K. J., Kaplan, L. M., Kerr, W. C., & Wil-snack, S. C. (2015). Trends in Alcohol's Harms to Others (AHTO) and Co-occurrence of Family-Related AHTO: The Four US National Alcohol Surveys, 2000–2015. *Substance Abuse: Research and Treatment, 9, Supplement 2*, 23–31. doi:10.4137/SART.S23505
- Greenfield, T. K., & Kerr, W. C. (2008). Alcohol measurement methodology in epidemiology: Recent advances and opportunities. *Addiction, 103*, 1082–1099. doi:10.1111/j.1360-0443.2008.02197.x
- Greenfield, T. K., Nayak, M. B., Bond, J., Kerr, W. C., & Ye, Y. (2014). Test-retest reliability and validity of life-course alcohol consumption measures: The 2005 National Alcohol Survey follow-up. *Alcoholism: Clinical and Experimental Research, 38*, 2479–2487. doi:10.1111/acer.12480
- Han, B. H., Sherman, S., Mauro, P. M., Martins, S. S., Rotenberg, J., & Palamar, J. J. (2017). Demographic trends among older cannabis users in the United States, 2006–13. *Addiction, 112*, 516–525. doi:10.1111/add.13670
- Harrison, L. D., Martin, S. S., Enev, T., & Harrington, D. (2007). Comparing drug testing and self-report of drug use among youths and young adults in the general population. Rockville, MD: Substance Abuse and Mental Health Services Administration. Retrieved from <http://buckleysrenewal-center.com/wp-content/uploads/2012/02/drugtest.pdf>
- Hill, L. G., & Betz, D. L. (2005). Revisiting the retrospective pretest. *American Journal of Evaluation, 26*, 501–517. doi:10.1177/1098214005281356
- Jones, J. M. (2015, October 21). *In U.S., 58% back legal marijuana use*. Retrieved from <http://news.gallup.com/poll/186260/back-legal-marijuana.aspx>
- Karriker-Jaffe, K. J., Greenfield, T. K., & Kaplan, L. M. (2017). Distress and alcohol-related harms from intimates, friends, and strangers. *Journal of Substance Use, 22*, 434–441. doi:10.1080/14659891.2016.1232761
- Kerr, W. C., & Greenfield, T. K. (2007). Distribution of alcohol consumption and expenditures and the impact of improved measurement on coverage of alcohol sales in the 2000 National Alcohol Survey. *Alcoholism: Clinical and Experimental Research, 31*, 1714–1722. doi:10.1111/j.1530-0277.2007.00467.x
- Kerr, W. C., Greenfield, T. K., Bond, J., Ye, Y., & Rehm, J. (2009). Age-period-cohort modelling of alcohol volume and heavy drinking days in the US National Alcohol Surveys: Divergence in younger and older adult trends. *Addiction, 104*, 27–37. doi:10.1111/j.1360-0443.2008.02391.x
- Kerr, W. C., Lui, C., & Ye, Y. (2018). Trends and age, period and cohort effects for marijuana use prevalence in the 1984–2015 US National Alcohol Surveys. *Addiction, 113*, 473–481. doi:10.1111/add.14031
- Kerr, W. C., Williams, E., & Greenfield, T. K. (2015). Analysis of price changes in Washington following the 2012 liquor privatization. *Alcohol and Alcoholism, 50*, 654–660. doi:10.1093/alc/alcv067
- Keyes, K. M., Wall, M., Cerdá, M., Schulenberg, J., O'Malley, P. M., Galea, S., . . . Hasin, D. S. (2016). How does state marijuana policy affect US youth? Medical marijuana laws, marijuana use and perceived harmfulness: 1991–2014. *Addiction, 111*, 2187–2195. doi:10.1111/add.13523
- Koenig, L. B., Jacob, T., & Haber, J. R. (2009). Validity of the lifetime drinking history: A comparison of retrospective and prospective quantity-frequency measures. *Journal of Studies on Alcohol and Drugs, 70*, 296–303. doi:10.15288/jsad.2009.70.296

- Lanza, S. T., Vasilenko, S. A., Dziak, J. J., & Butera, N. M. (2015). Trends among U.S. high school seniors in recent marijuana use and associations with other substances: 1976–2013. *Journal of Adolescent Health, 57*, 198–204. doi:10.1016/j.jadohealth.2015.04.006
- Midanik, L. T., Tam, T. W., & Weisner, C. (2007). Concurrent and simultaneous drug and alcohol use: Results of the 2000 National Alcohol Survey. *Drug and Alcohol Dependence, 90*, 72–80. doi:10.1016/j.drugalcdep.2007.02.024
- Nieuwkerk, P. T., Tollenaar, M. S., Oort, F. J., & Sprangers, M. A. (2007). Are retrospective measures of change in quality of life more valid than prospective measures? *Medical Care, 45*, 199–205. doi:10.1097/01.mlr.0000246613.49214.46
- Pacula, R. L., Powell, D., Heaton, P., & Sevigny, E. L. (2015). Assessing the effects of medical marijuana laws on marijuana use: The devil is in the details. *Journal of Policy Analysis and Management, 34*, 7–31. doi:10.1002/pam.21804
- Pratt, C. C., McGuigan, W. M., & Katzev, A. R. (2000). Measuring program outcomes: Using retrospective pretest methodology. *American Journal of Evaluation, 21*, 341–349. doi:10.1177/109821400002100305
- Ronen, A., Chassidim, H. S., Gershon, P., Parmet, Y., Rabinovich, A., Bar-Hamburger, R., . . . Shinar, D. (2010). The effect of alcohol, THC and their combination on perceived effects, willingness to drive and performance of driving and non-driving tasks. *Accident Analysis and Prevention, 42*, 1855–1865. doi:10.1016/j.aap.2010.05.006
- Roulette, C. J., Kazanji, M., Breurec, S., & Hagen, E. H. (2016). High prevalence of cannabis use among Aka foragers of the Congo Basin and its possible relationship to helminthiasis. *American Journal of Human Biology, 28*, 5–15. doi:10.1002/ajhb.22740
- Sibthorp, J., Paisley, K., Gookin, J., & Ward, P. (2007). Addressing response-shift bias: Retrospective pretests in recreation research and evaluation. *Journal of Leisure Research, 39*, 295–315. doi:10.1080/00222216.2007.11950109
- Subbaraman, M. S. (2016). Substitution and complementarity of alcohol and cannabis: A review of the literature. *Substance Use & Misuse, 51*, 1399–1414. doi:10.3109/10826084.2016.1170145
- Subbaraman, M. S., & Kerr, W. C. (2015). Simultaneous versus concurrent use of alcohol and cannabis in the National Alcohol Survey. *Alcoholism: Clinical and Experimental Research, 39*, 872–879. doi:10.1111/acer.12698
- Subbaraman, M. S., & Kerr, W. C. (2016a). Marijuana policy opinions in Washington State since legalization: Would voters vote the same way? *Contemporary Drug Problems, 43*, 369–380. doi:10.1177/0091450916667081
- Subbaraman, M. S., & Kerr, W. C. (2016b). Opinions on the privatization of distilled-spirits sales in Washington State: Did voters change their minds? *Journal of Studies on Alcohol and Drugs, 77*, 568–576. doi:10.15288/jsad.2016.77.568
- Subbaraman, M. S., & Kerr, W. C. (2017). Support for marijuana legalization in the US state of Washington has continued to increase through 2016. *Drug and Alcohol Dependence, 175*, 205–209. doi:10.1016/j.drugalcdep.2017.02.015
- Substance Abuse and Mental Health Services Administration. (2014). *2010–2012 National Survey on Drug Use and Health Substate Age Group Tables*. Retrieved from <https://www.samhsa.gov/data/sites/default/files/substate2k12-AgeGroupTabs/NSDUHsubstateAgeGroupTabs2012.pdf>
- Substance Abuse and Mental Health Services Administration. (2015). *National Survey on Drug Use and Health: Comparison of 2002–2003 and 2013–2014 Population Percentages (50 States and the District of Columbia)*. Retrieved from <https://www.samhsa.gov/data/sites/default/files/NSDUHsaeLongTermCHG2014/NSDUHsaeLongTermCHG2014.htm>
- Swift, A. (2016). *Support for legal marijuana use up to 60% in U.S.* Retrieved from <http://news.gallup.com/poll/196550/support-legal-marijuana.aspx>
- Taylor, M., Lees, R., Henderson, G., Lingford-Hughes, A., Macleod, J., Sullivan, J., & Hickman, M. (2017). Comparison of cannabinoids in hair with self-reported cannabis consumption in heavy, light and non-cannabis users. *Drug and Alcohol Review, 36*, 220–226. doi:10.1111/dar.12412
- Terry-McElrath, Y. M., O'Malley, P. M., & Johnston, L. D. (2013). Simultaneous alcohol and marijuana use among U.S. high school seniors from 1976 to 2011: Trends, reasons, and situations. *Drug and Alcohol Dependence, 133*, 71–79. doi:10.1016/j.drugalcdep.2013.05.031
- Terry-McElrath, Y. M., O'Malley, P. M., & Johnston, L. D. (2014). Alcohol and marijuana use patterns associated with unsafe driving among U.S. high school seniors: High use frequency, concurrent use, and simultaneous use. *Journal of Studies on Alcohol and Drugs, 75*, 378–389. doi:10.15288/jsad.2014.75.378
- VanDerNagel, J. E. L., Kiewik, M., van Dijk, M., Didden, R., Korzilius, H. P. L. M., van der Palen, J., . . . de Jong, C. A. J. (2017). Substance use in individuals with mild to borderline intellectual disability: A comparison between self-report, collateral-report and biomarker analysis. *Research in Developmental Disabilities, 63*, 151–159. doi:10.1016/j.ridd.2016.04.006
- Washington State Liquor and Cannabis Board. (2017). *Frequently requested lists: Marijuana*. Archived by WebCite at <http://www.webcitation.org/6tTpUUzge>.
- Wu, L.-T., Zhu, H., & Swartz, M. S. (2016). Trends in cannabis use disorders among racial/ethnic population groups in the United States. *Drug and Alcohol Dependence, 165*, 181–190. doi:10.1016/j.drugalcdep.2016.06.002
- Ye, Y., & Kerr, W. C. (2016). Estimated increase in cross-border purchases by Washington residents following liquor privatization and implications for alcohol consumption trends. *Addiction, 111*, 1948–1953. doi:10.1111/add.13481