Modes of Marijuana Consumption Among Colorado High School Students Before and After the Initiation of Retail Marijuana Sales for Adults

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ABSTRACT. Objective: This study aimed to estimate the prevalence of different modes of marijuana consumption (e.g., smoking, ingesting) overall and by sociodemographic factors, marijuana-related perceptions, and other substance use among adolescents, as well as to characterize differences in the usual mode of consumption before and after the initiation of retail marijuana sales in 2014. **Method:** Data are from the 2013 and 2015 administrations of the Healthy Kids Colorado Survey, a cross-sectional, school-based survey. We included 9th–12th grade students who reported past-30-day marijuana use in 2013 ($n = 2,792$; 44.8% female) or 2015 ($n = 1,664$; 48.9% female). We estimated the prevalence of any past-month use of each mode in 2015 and usual mode of consumption the past month in both years. We tested differences by year, sociodemographics, marijuana-related perceptions, and other substance use using

Rao–Scott chi-square tests and multivariable logistic regression. **Results:** The prevalence of past-month marijuana use was 20.7% in both years. In 2015, 39.8% of students reported using multiple modes in the past month. Use of any mode other than smoking and use of multiple modes differed by sociodemographics, marijuana-related perceptions, and other substance use. Smoking remained the most common usual mode in 2015. The prevalence of usually ingesting significantly decreased from 4.7% to 2.1% between years, whereas “other mode(s)” significantly increased from 4.0% to 6.0%. **Conclusions:** The use of multiple modes of marijuana consumption was prevalent among adolescents in Colorado. The usual mode of consumption changed in years before and after the implementation of retail marijuana sales, suggesting the need for continued surveillance. (*J. Stud. Alcohol Drugs*, 80, 46–55, 2019)

AS STATE MARIJUANA POLICIES have evolved, noncombustible modes of marijuana consumption have proliferated (Krauss et al., 2017; Lee et al., 2016). These modes include ingesting edible products, inhaling vaporized liquid or plant material (“vaping”), or “dabbing” (inhaling vapor from heated cannabis concentrates (“dabs”) containing high concentrations of Δ -9-tetrahydrocannabinol [THC] and other cannabinoids) (Johnson et al., 2016; Loflin & Earleywine, 2014; Russell et al., 2018). Although smoking remains the most common mode, between 30% and 35% of adults who use marijuana report ingesting edibles, dabbing, and/or vaping (Krauss et al., 2017; Lee et al., 2016). Further, adults who live in states with medical marijuana laws (MMLs) are more likely to use noncombustible modes of consumption (Borodovsky et al., 2016; Krauss et al., 2017). Therefore, modes other than smoking may also be increasingly common

among adolescents, particularly in states that have passed MMLs or recreational marijuana laws (RMLs).

The number of different modes of use and legal access for adults introduces an unknown potential for adolescents to use marijuana and experience adverse effects. Smoking is associated with a number of health risks, including respiratory problems (Russell et al., 2018). Vaporizer products may be used to reduce the perceived risk of health problems associated with smoking, although research is limited (Russell et al., 2018). Edibles are smokeless, which may be particularly appealing to youth (Frieze et al., 2016). Some research suggests that edibles may be associated with unintentional overconsumption and early and more frequent marijuana use among adolescents (Frieze et al., 2016, 2017; Hancock-Allen et al., 2015). Dabbing is high potency, reinforcing, and may have higher abuse liability than smoked marijuana (Loflin

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& Earleywine, 2014; Stogner & Miller, 2015). Therefore, traditional use-to-dependence estimates, which have been low for marijuana, could rise (Delker et al., 2015; Flórez-Salamanca et al., 2013). However, little is known about the prevalence, frequency, or trends over time of adolescent uptake of nonsmoking consumption modes, limiting how we approach prevention or contextualize adverse events.

To address this research gap, we examined modes of marijuana consumption among Colorado high school students. Colorado passed an MML in 2000, with medical dispensaries expanding after the Ogen Memo in 2009. The state passed an RML in 2012 and initiated retail marijuana sales for adults ages 21 and older in 2014. A previous study found that 15% of Colorado high school students who reported past-30-day marijuana use in 2013 reported most commonly using a mode other than smoking (Johnson et al., 2016). Results from this study also suggest that the mode of consumption differs by demographic characteristics and marijuana-related perceptions use (Johnson et al., 2016). We sought to extend these findings by exploring how modes of use changed over time, as well as identify potential correlates of different modes. The current study objectives were to (a) describe the 2015 prevalence of past-30-day use of modes of marijuana consumption and examine variations by sociodemographic factors, marijuana-related perceptions, and other substance use; (b) describe the 2015 prevalence of the usual mode of consumption; and (c) assess differences in the usual mode of consumption between 2013 and 2015.

Method

Sample

Data come from two administrations of the Healthy Kids Colorado Survey (HKCS), a biennial survey of Colorado middle and high school students (Colorado Department of Public Health and Environment, 2017). The data collection protocol was consistent with the Centers for Disease Control and Prevention (CDC) Youth Risk Behavior Survey (YRBS) (Brener et al., 2013; Kann et al., 2016). The HKCS uses a two-stage stratified cluster design with a sampling frame including all public middle and high schools in the state. Schools were randomly selected within each of 21 health statistics regions, and then classrooms were sampled within schools. In 2013, alternative schools were sampled from a separate frame, whereas alternative schools were included in the main frame in 2015. All students in randomly selected classrooms were invited to participate. Teachers oversaw administration during a regular class period and were directed to read a script providing instructions and to not walk around the room. The instructions indicated that participation was voluntary and anonymous and explained that students could skip questions or choose not to participate without consequence. Participation in the survey was also approved by

the students' parents. All parents were given written notice of the survey 2 weeks before administration and could opt out by returning a signed form. About 5% of school districts required a signed written parental consent form for the child to participate. The study was approved by the Colorado Multiple Institutional Review Board.

The HKCS collected data from 9th–12th grade students in fall 2013 (114 schools, $N = 26,019$) and fall 2015 (127 schools, $N = 15,970$). The overall response rate (i.e., product of the school and student response rates) was 58% in 2013 (78.1% of schools and 71.3% of students) and 47% in 2015 (64.1% of schools and 72.6% of students). The lower response rate in 2015 reflects decreased willingness of Colorado school administrators to participate in public health surveillance efforts rather than individual students declining to participate. The HKCS was fielded in two modules, each completed by approximately half the respondents. Module A respondents ($n = 12,920$ in 2013; $n = 7,985$ in 2015) were asked supplemental questions about marijuana use, including mode of consumption and marijuana-related perceptions. The current study included data from Module A respondents who reported any past-30-day marijuana use, representing 20.7% of the full sample in both years ($n = 2,792$ in 2013; $n = 1,664$ in 2015).

Measures

Mode of marijuana consumption. On both the 2013 and 2015 surveys, the usual mode of marijuana consumption was asked about with the following question: "During the past 30 days, how did you most often use marijuana?" Response options were (a) I did not use marijuana during the past 30 days, (b) I smoked it, (c) I ate it (in an edible, candy, tincture, or other food), (d) I used a vaporizer, (e) I dabbed it [added in 2015], and (f) I used it in some other way. The following question was added to the 2015 survey: "During the past 30 days, how did you use marijuana? (select all that apply)." This item had the same five response options as the 2015 question for usual mode of use. We created a binary variable for multiple modes of use (only one/two or more).

Frequency of marijuana use. Students were asked, "During the past 30 days, how many times did you use marijuana?" and response options were (a) 0 times, (b) 1–2 times, (c) 3–9 times, (d) 10–19 times, (e) 20–39 times, and (f) 40 times or greater. Similar to the CDC and YRBS threshold for frequent tobacco use, we defined "frequent marijuana use" as having used marijuana 20 times or more in the past month (i.e., daily or near daily use) (Kann et al., 2016).

Other substance use. Students were asked to report any past-30-day cigarette, alcohol, and prescription drug use and lifetime use of other illicit drugs (yes/no).

Marijuana-related perceptions. Students were asked four questions about perceptions of access, wrongfulness, parental disapproval, and harm associated with use, derived from

the Monitoring the Future survey and the National Survey on Drug Use and Health (Johnston et al., 2017). Perceived access to marijuana was defined as low if students reported it would be “very hard or sort of hard” to get marijuana and high if they reported it would be “sort of easy or very easy.” Perceived wrongfulness was defined as high if students believed it was “very wrong or wrong” for someone their age to use marijuana and low if they thought it was “a little bit wrong or not wrong at all.” Students indicated whether their parents would view their marijuana use unfavorably, classified as high versus low parental disapproval. Students specified if they thought regular marijuana use had a high (great or moderate) or low (slight or no) risk of harm.

Sociodemographic characteristics. Individual characteristics included sex (male/female), grade level (9th–12th), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic [any race], and other/multiracial), and sexual orientation (heterosexual/straight, LGB [lesbian, gay, bisexual], and not sure). Sexual orientation responses of “not sure” were omitted from analyses, as we could not determine if the response was based on not understanding the question or questioning their orientation.

Analyses

We applied both design weights and post-stratification weights to represent Colorado public school student enrollment, using demographic information from the Colorado Department of Education. The design weights account for different sampling probabilities, and the post-stratification weights adjust for the differences of the profiles of the sample from the selected population. Post-stratification weights were generated using a raking algorithm, which involves the comparison of target population relative frequencies and achieved, design-weighted sample relative frequencies on sex, grade, and race/ethnicity independently and sequentially. For the current analysis of marijuana use mode, domain analysis was not used because those who did not use marijuana in the past 30 days did not report a mode of marijuana use and had a variance estimation of zero.

We calculated state prevalence estimates and 95% confidence intervals (CIs) for (a) any use of each mode of consumption in 2015 and (b) the usual mode of consumption in 2015, overall and by sociodemographic factors, marijuana-related perceptions, and other substance use behaviors. To test associations between any use of each mode and any use of multiple modes and sociodemographic factors, marijuana-related perceptions, and other substance use behaviors in 2015, we fit a series of logistic regression models adjusted for sex, grade, and race/ethnicity. Results were expressed as prevalence ratios (Zhang & Kai, 1998). To assess the statistical significance ($p < .05$) of group differences in the usual mode of marijuana use in 2015, Rao–Scott chi-square tests were used. The Rao–Scott

TABLE 1. Weighted prevalence of sociodemographic characteristics of Colorado high school students who reported past-30-day marijuana use in 2013 and 2015

Variable	2013 % (<i>n</i> = 2,792)	2015 % (<i>n</i> = 1,664)	<i>p</i>
Sex			
Female	44.8	48.9	.13
Male	55.2	51.1	
Race/ethnicity			
Non-Hispanic White	49.0	51.3	.76
Non-Hispanic Black	5.5	4.8	
Hispanic	40.9	38.1	
Other/multiracial ^a	4.5	5.9	
Grade			
9th	18.2	16.1	.47
10th	24.1	23.2	
11th	27.3	32.0	
12th	30.4	28.7	
Sexual orientation			
Heterosexual	86.0	82.6	.13
Lesbian/gay/bisexual	14.0	17.4	

^a“Other” race/ethnicity includes Asian, American Indian/Alaska Native, Native Hawaiian or other Pacific Islander.

chi-square test is a widely used design-adjusted test that takes into account the complex sample design and provides estimates that can be applied to the entire study population (Rao & Scott, 1984, 1987). Last, to assess differences in the prevalence of the usual mode of marijuana use between 2013 and 2015, we used multivariable logistic regression with maximum likelihood estimation. For this analysis, the “other mode(s)” category included both “other” and “dabbing” in 2015. Results were also expressed as prevalence ratios. For all analyses, estimates were suppressed if the number of subjects in a cell (total number of a particular response) was fewer than 3 and/or if the total number in that category (total number of responses) was fewer than 30 to ensure stability of estimates. Non-responses were excluded from respective analyses. Analyses were performed using the complex survey procedures in SAS Version 9.4 (SAS Institute Inc., Cary, NC).

Results

Table 1 displays sociodemographic characteristics for both years. In both 2013 and 2015, 20.7% of the full sample reported using marijuana in the past 30 days. Sociodemographic characteristics did not differ significantly between survey years. In 2015, 51.1% of the sample were male, 51.3% were non-Hispanic White, and 82.6% were heterosexual. Sixteen percent were in 9th grade, 23.2% in 10th grade, 32.0% in 11th grade, and 28.7% in 12th grade.

2015 prevalence of any use of modes of consumption

Among students who reported using marijuana in the past 30 days, 91.6% reported any smoking, 27.8% reported

TABLE 2. Weighted prevalence estimates [95% CI] of any past-30-day use of modes for consuming marijuana among Colorado high school students reporting past-30-day use, by sociodemographic characteristics, marijuana-related perceptions, and other substance use, 2015 ($n = 1,664$)^{a,b}

Variable	Smoke	Ingest	Vaporize	Dab	Other	1 mode	≥2 modes
Total	91.6 [90.1, 93.1]	27.8 [24.7, 31.0]	21.8 [18.1, 25.5]	28.0 [22.1, 34.0]	7.7 [5.3, 10.0]	60.2 [55.9, 64.5]	39.8 [35.5, 44.1]
Sociodemographic characteristics (%) ^c							
Sex							
Female (48.9)	93.4 [90.8, 95.9]	23.8 [20.5, 27.0]	14.8 [9.6, 20.1]	22.3 [14.7, 29.9]	4.9 [2.8, 7.0]	64.7 [59.8, 69.6]	35.3 [30.4, 40.2]
Male (51.1)	90.2 [87.5, 92.9]	31.6 [27.0, 36.2]	28.4 [23.0, 33.8]	33.4 [27.6, 39.1]	9.9 [7.0, 12.8]	55.8 [51.1, 60.4]	44.2 [39.6, 48.9]
Race/ethnicity							
Non-Hispanic White (51.3)	93.0 [90.9, 95.1]	29.1 [25.2, 33.1]	21.4 [15.5, 27.3]	28.6 [20.1, 37.2]	5.5 [3.1, 7.8]	56.0 [50.4, 61.6]	44.0 [38.4, 49.6]
Non-Hispanic Black (4.8)	94.2 [88.2, 100]	19.1 [2.1, 36.0]	11.3 [3.3, 19.4]	— [0.0, 39.4]	— [6.5, 12.7]	74.7 [54.1, 95.3]	25.3 [4.7, 45.9]
Hispanic (38.1)	89.2 [86.6, 91.8]	24.0 [19.4, 28.6]	22.2 [15.4, 28.9]	26.0 [20.9, 31.1]	9.6 [6.5, 12.7]	66.1 [61.1, 71.1]	33.9 [28.9, 38.9]
Other/multiracial (5.9)	93.9 [89.5, 98.3]	43.9 [31.4, 56.5]	28.5 [13.5, 43.5]	40.9 [28.1, 53.6]	17.7 [6.4, 29.0]	50.2 [39.1, 61.4]	49.8 [38.6, 60.9]
Grade							
9th (16.1)	87.3 [82.8, 91.9]	28.7 [18.7, 38.7]	19.3 [12.9, 25.7]	16.1 [10.7, 21.5]	5.6 [1.7, 9.6]	65.1 [56.5, 73.8]	34.9 [26.2, 43.5]
10th (23.2)	93.2 [90.0, 96.5]	32.5 [27.4, 37.6]	24.8 [19.2, 30.5]	35.7 [29.9, 41.5]	9.2 [4.8, 13.6]	55.6 [49.8, 61.3]	44.4 [38.7, 50.2]
11th (32.0)	90.7 [87.7, 93.7]	21.9 [17.9, 25.8]	20.4 [13.3, 27.4]	26.8 [18.6, 35.0]	6.5 [3.5, 9.4]	61.8 [54.8, 68.9]	38.2 [31.1, 45.2]
12th (28.7)	94.6 [91.8, 97.4]	29.0 [24.1, 33.9]	21.7 [15.1, 28.2]	28.4 [21.0, 35.8]	7.5 [3.5, 11.6]	60.0 [53.2, 66.7]	40.0 [33.3, 46.8]
Sexual orientation							
Heterosexual (82.6)	92.2 [90.4, 94.0]	24.8 [22.0, 27.5]	21.9 [18.0, 25.8]	28.7 [24.1, 33.4]	6.5 [4.7, 8.4]	60.8 [56.6, 64.9]	39.2 [35.1, 43.4]
Lesbian/gay/bisexual (17.4)	90.0 [84.2, 95.7]	33.1 [24.9, 41.3]	18.1 [12.3, 24.0]	23.6 [14.3, 32.8]	6.0 [2.1, 9.8]	62.9 [56.4, 69.4]	37.1 [30.6, 43.6]
Marijuana-related perceptions (%) ^c							
Access to marijuana							
Low (10.9)	75.6 [67.0, 84.2]	17.1 [10.4, 23.7]	20.4 [11.6, 29.2]	7.5 [1.1, 13.8]	1.5 [0.2, 2.8]	81.5 [73.8, 89.2]	18.5 [10.8, 26.2]
High (89.1)	93.5 [92.2, 94.8]	29.1 [26.2, 32.1]	21.8 [18.5, 25.1]	30.5 [25.1, 35.9]	8.3 [6.1, 10.6]	57.7 [53.8, 61.7]	42.3 [38.3, 46.2]
Harmfulness							
Low (85.7)	92.0 [90.4, 93.7]	29.1 [26.3, 31.9]	21.9 [18.5, 25.3]	30.1 [23.1, 37.1]	7.5 [4.6, 10.4]	58.0 [53.3, 62.6]	42.0 [37.4, 46.7]
High (14.3)	88.7 [83.7, 93.8]	18.3 [11.0, 25.6]	17.0 [8.9, 25.0]	11.9 [7.2, 16.7]	5.1 [1.8, 8.3]	76.5 [68.8, 84.2]	23.5 [15.8, 31.2]

Table continued

any ingesting, 21.8% reported any vaporizing, 28.0% reported any dabbing, and 7.7% reported using some other mode in the past 30 days (not mutually exclusive). Forty percent of individuals reported using multiple modes (Table 2).

Differences by sociodemographic characteristics. Males were more likely to report ingesting (adjusted prevalence ratio [aPR] = 1.3, 95% CI [1.1, 1.6]), vaporizing (aPR = 1.9, 95% CI [1.3, 2.7]), dabbing (aPR = 1.5, 95% CI [1.1, 2.0]), or other modes (aPR = 1.9, 95% CI [1.1, 3.0]) than females (Table 3). The prevalence of using multiple modes was also higher among males (aPR = 1.3, 95% CI [1.1, 1.4]). Other/multiracial students had a higher prevalence of any ingestion (aPR = 1.5, 95% CI [1.1, 1.8]) or using an unspecified mode (aPR = 3.1, 95% CI [1.5, 5.9]) compared with White students. Hispanic students were less likely than White students to use multiple modes (aPR = 0.8, 95% CI [0.6, 0.9]). Compared with 9th grade students, higher grade students were more likely to report any dab-

bing (10th grade: aPR = 2.2, 95% CI [1.6, 2.9]; 11th grade: aPR = 1.7, 95% CI [1.2, 2.4]; 12th grade: aPR = 1.8, 95% CI [1.2, 2.5]). LGB students were more likely to have ingested marijuana compared with heterosexual students (aPR = 1.5, 95% CI [1.1, 2.0]).

Differences by marijuana-related perceptions and other substance use. High perceived parental disapproval, high perceived wrongfulness, and high perceived harm were associated with less prevalent use of modes other than smoking or using multiple modes (Table 3). High perceived access to marijuana was associated with using modes other than smoking and using multiple modes. Frequent marijuana use, as well as past-30-day use of cigarettes, alcohol, or prescription drugs and lifetime use of other illicit drugs were all associated with an increased likelihood of using modes other than smoking and using multiple modes (Table 3). However, cell sizes for the “other” category were small, leading to larger confidence intervals; thus, results should be interpreted with caution.

TABLE 2. *Continued*

Variable	Smoke	Ingest	Vaporize	Dab	Other	1 mode	≥2 modes
Parental disapproval							
Low (40.8)	93.7 [90.9, 96.4]	33.5 [28.0, 39.0]	24.3 [20.1, 28.5]	36.6 [28.0, 45.3]	12.0 [8.2, 15.8]	52.6 [46.9, 58.3]	47.4 [41.7, 53.1]
High (59.2)	90.5 [88.4, 92.6]	24.0 [20.4, 27.6]	20.3 [16.2, 24.4]	22.2 [17.6, 26.7]	4.1 [2.2, 6.0]	65.1 [60.6, 69.6]	34.9 [30.4, 39.4]
Wrongfulness							
Low (82.2)	92.1 [90.6, 93.5]	29.1 [26.1, 32.1]	22.9 [19.5, 26.2]	30.8 [23.8, 37.7]	8.1 [5.5, 10.7]	57.2 [53.1, 61.3]	42.8 [38.7, 46.9]
High (17.8)	89.4 [84.8, 94.1]	22.1 [14.5, 29.7]	16.9 [10.3, 23.4]	14.9 [8.5, 21.2]	5.5 [1.4, 9.6]	74.1 [67.0, 81.2]	25.9 [18.8, 33.0]
Other substance use variables (%) ^c							
Frequent marijuana use							
No (72.8)	90.3 [88.7, 92.0]	21.6 [17.8, 25.5]	16.1 [12.1, 20.1]	16.4 [12.2, 20.6]	2.9 [1.5, 4.4]	70.1 [66.1, 74.1]	29.9 [25.9, 33.9]
Yes (27.2)	95.1 [92.9, 97.2]	44.2 [38.5, 50.0]	37.1 [31.3, 43.0]	58.7 [50.2, 67.2]	20.2 [14.3, 26.0]	33.9 [27.8, 40.0]	66.1 [60.0, 72.2]
Past-30-day cigarette use							
No (69.7)	90.5 [88.7, 92.3]	25.0 [21.8, 28.3]	19.3 [15.4, 23.3]	21.4 [16.6, 26.2]	5.0 [2.8, 7.1]	66.2 [62.4, 70.0]	33.8 [30.0, 37.6]
Yes (30.3)	94.4 [91.5, 97.3]	33.5 [27.5, 39.4]	28.1 [21.5, 34.8]	42.0 [32.5, 51.5]	12.8 [8.5, 17.2]	49.2 [42.3, 56.0]	50.8 [44.0, 57.7]
Past-30-day alcohol use							
No (28.1)	91.6 [87.1, 96.0]	21.0 [16.0, 26.0]	17.3 [12.1, 22.4]	18.9 [14.5, 23.2]	5.3 [2.1, 8.6]	71.1 [66.3, 75.8]	28.9 [24.2, 33.7]
Yes (71.9)	93.2 [91.0, 95.3]	31.5 [28.2, 34.8]	25.4 [20.7, 30.2]	32.9 [26.7, 39.1]	7.7 [5.2, 10.2]	53.7 [49.0, 58.4]	46.3 [41.6, 51.0]
Past-30-day prescription drug use							
No (76.2)	91.5 [89.9, 93.1]	24.0 [20.7, 27.3]	16.6 [12.8, 20.3]	22.2 [17.7, 26.7]	4.4 [2.7, 6.2]	65.2 [61.2, 69.3]	34.8 [30.7, 38.8]
Yes (23.8)	92.6 [88.9, 96.3]	41.2 [34.1, 48.3]	37.2 [29.0, 45.5]	45.9 [33.2, 58.6]	17.1 [10.2, 24.1]	44.7 [35.7, 53.6]	55.3 [46.4, 64.3]
Lifetime illicit drug use							
No (67.8)	92.5 [90.7, 94.2]	22.8 [18.8, 26.8]	16.7 [13.1, 20.4]	19.8 [15.1, 24.4]	3.0 [1.3, 4.7]	66.3 [62.9, 69.7]	33.7 [30.3, 37.1]
Yes (32.2)	90.4 [86.7, 94.1]	38.9 [32.5, 45.4]	32.7 [26.8, 38.6]	45.9 [36.3, 55.6]	16.8 [11.1, 22.4]	46.8 [38.0, 55.7]	53.2 [44.3, 62.0]

Notes: CI = confidence interval. ^aFor all analyses, estimates were suppressed if the number of subjects was fewer than 3 and/or if the total number in that category was fewer than 30. A dash (–) indicates that there were too few subjects to report estimates. ^bAny use of mode categories are not mutually exclusive; therefore, prevalence estimates do not add up to 100. ^cPercentages are weighted and therefore do not produce original cell sample sizes.

2015 prevalence of usual mode of consumption

In 2015, smoking was the most prevalent usual mode (86.8%), followed by vaporizing (5.1%), dabbing (4.3%), ingesting (2.1%), and other (1.7%) (Table 4). The usual mode of use did not differ by sociodemographic characteristics or marijuana-related perceptions. Differences in the usual mode were present among those who reported frequent marijuana use, past-30-day cigarette use, past-30-day prescription drug use, and lifetime use of other illicit drugs (Table 4).

Changes in the usual mode of consumption

Among students who reported past-30-day use, smoking was the most common usual mode of marijuana use in both 2013 and 2015, and its prevalence did not change between years (84.9 vs. 86.8, aPR = 1.0, 95% CI [1.0, 1.0]) (Table 5). The prevalence of ingesting as the usual mode decreased from 2013 to 2015 (4.7 vs. 2.1, aPR = 0.4, 95% CI [0.3,

0.7]). The prevalence of “other mode(s)” as the usual mode increased between years (4.0 vs. 6.0, aPR = 1.7, 95% CI [1.1, 2.5]). In 2015, of the 6.0% reporting “other mode(s),” dabbing accounted for 4.3%. Among students who reported frequent use, the prevalence of ingesting and vaporizing as the usual mode decreased from 2013 to 2015 (4.0 vs. 0.6, aPR = 0.1, 95% CI [0.0, 0.5]; 7.5 vs. 1.3, aPR = 0.2, 95% CI [0.0, 0.6]) (Table 5). The prevalence of “other mode(s)” as the usual mode increased among those who used marijuana frequently (9.6 vs. 13.7, aPR = 1.8 95% CI [1.1, 2.8]). In 2015, of the 13.7% reporting “other mode(s),” dabbing accounted for 9.4%.

Discussion

This study sought to understand how high school students in Colorado use marijuana and how modes of use have changed as the policy landscape in the state has evolved. Smoking remains the most common mode of use among

TABLE 3. Adjusted prevalence ratios [95% CI] of any past-30-day use of modes for consuming marijuana among Colorado high school students reporting past 30-day use, by sociodemographic characteristics, marijuana-related perceptions, and other substance use, 2015 ($n = 1,664$)^{a,b}

Variable	Smoke	Ingest	Vaporize	Dab	Other	1 mode	≥2 modes
Sociodemographic characteristics							
Sex							
Female	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Male	1.0 [0.9, 1.0]	1.3 [1.1, 1.6] ^c	1.9 [1.3, 2.7] ^c	1.5 [1.1, 2.0] ^c	1.9 [1.1, 3.0] ^c	0.9 [0.8, 0.9] ^c	1.3 [1.1, 1.4] ^c
Race/ethnicity							
Non-Hispanic White	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Non-Hispanic Black	1.0 [0.9, 1.1]	0.6 [0.2, 1.4]	0.5 [0.2, 1.0]	0.7 [0.2, 1.5]	—	1.3 [0.9, 1.6]	0.6 [0.2, 1.1]
Hispanic	1.0 [0.9, 1.0]	0.8 [0.6, 1.0]	1.0 [0.6, 1.6]	0.9 [0.6, 1.2]	1.5 [1.0, 2.4]	1.2 [1.1, 1.3] ^c	0.8 [0.6, 0.9] ^c
Other/multiracial	1.0 [0.9, 1.0]	1.5 [1.1, 1.8] ^c	1.3 [0.6, 2.2]	1.4 [0.8, 2.0]	3.1 [1.5, 5.9] ^c	0.9 [0.7, 1.1]	1.1 [0.8, 1.4]
Grade							
9th	ref.	ref.	ref.	ref.	ref.	ref.	ref.
10th	1.1 [1.0, 1.1]	1.1 [0.8, 1.5]	1.3 [0.8, 1.8]	2.2 [1.6, 2.9] ^c	1.5 [0.5, 3.8]	0.9 [0.7, 1.0]	1.2 [1.0, 1.5]
11th	1.0 [1.0, 1.1]	0.7 [0.5, 1.1]	1.1 [0.7, 1.6]	1.7 [1.2, 2.4] ^c	1.3 [0.5, 2.9]	1.0 [0.8, 1.1]	1.1 [0.8, 1.4]
12th	1.1 [1.0, 1.1]	1.0 [0.7, 1.4]	1.1 [0.7, 1.7]	1.8 [1.2, 2.5] ^c	1.4 [0.6, 3.1]	0.9 [0.8, 1.1]	1.1 [0.8, 1.5]
Sexual orientation							
Heterosexual/straight	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Lesbian/gay/bisexual	1.0 [0.9, 1.0]	1.5 [1.1, 2.0] ^c	1.1 [0.7, 1.5]	0.8 [0.6, 1.1]	0.9 [0.5, 1.7]	1.0 [0.8, 1.1]	1.0 [0.8, 1.3]
Marijuana-related perceptions							
High access ^d	1.2 [1.2, 1.3] ^c	1.7 [1.3, 2.3] ^c	1.1 [0.7, 1.6]	4.0 [1.9, 7.0] ^c	5.1 [2.2, 11.4] ^c	0.7 [0.5, 0.9] ^c	2.3 [1.6, 3.0] ^c
High harmfulness ^d	1.0 [0.9, 1.0]	0.6 [0.4, 0.9] ^c	0.8 [0.5, 1.3]	0.4 [0.3, 0.6] ^c	0.7 [0.4, 1.5]	1.3 [1.2, 1.4] ^c	0.5 [0.4, 0.7] ^c
High parental disapproval ^d	1.0 [0.9, 1.0]	0.7 [0.6, 1.0]	0.8 [0.6, 1.1]	0.6 [0.5, 0.8] ^c	0.3 [0.2, 0.5] ^c	1.2 [1.1, 1.4] ^c	0.7 [0.6, 0.9] ^c
High wrongfulness ^d	1.0 [0.9, 1.0]	0.8 [0.5, 1.1]	0.7 [0.5, 1.0]	0.5 [0.3, 0.8] ^c	0.7 [0.3, 1.7]	1.3 [1.1, 1.4] ^c	0.6 [0.5, 0.8] ^c
Other substance use variables							
Frequent marijuana use ^e	1.1 [1.0, 1.1]	2.0 [1.5, 2.4] ^c	2.1 [1.5, 2.7] ^c	3.5 [2.8, 4.1] ^c	5.8 [3.3, 9.7] ^c	0.5 [0.4, 0.6] ^c	2.2 [1.9, 2.4] ^c
Past-30-day cigarette use ^e	1.0 [1.0, 1.1]	1.2 [1.0, 1.6]	1.4 [1.1, 1.8] ^c	1.9 [1.6, 2.3] ^c	2.2 [1.4, 3.2] ^c	0.8 [0.6, 0.9] ^c	1.5 [1.2, 1.7] ^c
Past-30-day alcohol use ^e	1.0 [0.9, 1.0]	1.5 [1.2, 1.9] ^c	1.6 [1.2, 2.0] ^c	1.8 [1.4, 2.2] ^c	1.3 [0.6, 2.6]	0.8 [0.7, 0.9] ^c	1.6 [1.3, 1.8] ^c
Past-30-day prescription drug use ^e	1.0 [1.0, 1.1]	1.7 [1.4, 2.1] ^c	2.2 [1.6, 2.9] ^c	2.0 [1.5, 2.5] ^c	3.5 [2.1, 5.8] ^c	0.7 [0.6, 0.8] ^c	1.6 [1.3, 1.8] ^c
Lifetime illicit drug use ^e	1.0 [0.9, 1.0]	1.6 [1.3, 2.1] ^c	1.9 [1.4, 2.3] ^c	2.3 [1.8, 2.8] ^c	4.7 [2.4, 8.6] ^c	0.7 [0.6, 0.9] ^c	1.6 [1.3, 1.9] ^c

Notes: Ref. = reference. ^aAdjusted for race/ethnicity, sex, and grade. ^bEstimates were suppressed if the number of subjects was fewer than 3 and/or if the total number in that category was fewer than 30 (indicated by —). ^c $p < .05$ for coefficient in multivariable logistic regression model. ^dReference category is “low.” ^eReference category is “no.”

high school students who use marijuana. The prevalence of using multiple modes in the past month was 39.8%. Students reported a small but significant shift toward dabbing and other modes of use after the state implemented retail marijuana sales for adults. This increase in dabbing, together with the prevalence of using multiple modes, may foreshadow an increase of marijuana-related harms among adolescents. Continued monitoring of trends and further study of the effects that noncombustible modes may have on adolescents is essential for effective public health responses to emerging problems.

Forty percent of students used multiple modes, and more than 20% reported any vaporizing, ingesting, and dabbing in the past month. Although we could not assess the frequency

of use of each mode, this finding suggests that adolescents may be experimenting with noncombustible modes. The risk of harm may be higher among those who have less experience with various modes (Hall & Degenhardt, 2009). This further argues for increased surveillance of how modes of marijuana use are changing in the era of marijuana legalization. Although we did not see an increase in the prevalence of overall marijuana use, policies surrounding legalization and retail marijuana sales could influence experimentation with different modes of consumption, and possible progression to regular use of high-potency modes has the potential to proliferate unintentional marijuana-related injuries and other harms.

TABLE 4. Weighted prevalence estimates [95% CI] of usual modes of consuming marijuana by sociodemographic characteristics, marijuana-related perceptions, and other substance use, 2015 ($n = 1,467$)^{a,b}

Variable	Smoke	Ingest	Vaporize	Dab	Other	p^c
Total	86.8 [84.2, 89.3]	2.1 [1.2, 3.0]	5.1 [3.2, 7.0]	4.3 [2.8, 5.9]	1.7 [0.5, 2.8]	
Sociodemographic characteristics (%) ^d						
Sex						
Female (48.9)	90.4 [86.4, 94.3]	2.6 [1.2, 4.1]	3.2 [1.0, 5.5]	2.6 [1.2, 4.0]	1.2 [0.0, 2.6]	.15
Male (51.1)	84.1 [80.3, 87.8]	1.5 [0.5, 2.5]	7.0 [3.4, 10.6]	5.7 [3.2, 8.2]	1.7 [0.3, 3.1]	
Race/ethnicity						
Non-Hispanic White (51.3)	87.1 [83.3, 90.8]	2.3 [1.0, 3.7]	6.1 [3.4, 8.9]	3.8 [2.1, 5.4]	0.7 [0.0, 1.4]	—
Non-Hispanic Black (4.8)	94.5 [86.3, 100]	—	—	—	—	
Hispanic (38.1)	86.2 [83.3, 89.1]	1.3 [0.4, 2.1]	4.5 [1.7, 7.3]	5.8 [3.2, 8.5]	2.3 [0.5, 4.0]	
Other/multiracial (5.9)	84.7 [74.5, 94.9]	4.9 [0.2, 9.5]	1.8 [0.0, 4.2]	2.1 [1.0, 3.2]	6.6 [0.0, 16.1]	
Grade						
9th (16.1)	85.3 [80.8, 89.9]	2.5 [0.6, 4.4]	7.9 [3.0, 12.8]	3.9 [1.2, 6.5]	0.4 [0.0, 0.7]	.72
10th (23.2)	88.8 [83.7, 93.9]	2.6 [0.6, 4.5]	2.7 [0.1, 5.2]	4.8 [1.7, 8.0]	1.1 [0.0, 2.2]	
11th (32.0)	86.3 [82.6, 90.1]	2.7 [0.8, 4.6]	5.0 [1.6, 8.3]	4.5 [2.2, 6.7]	1.6 [0.0, 3.6]	
12th (28.7)	87.8 [82.5, 93.1]	0.8 [0.4, 1.2]	5.8 [2.0, 9.7]	3.0 [0.9, 5.2]	2.5 [0.0, 5.1]	
Sexual orientation						
Heterosexual (82.6)	87.3 [84.6, 90.0]	1.5 [0.8, 2.3]	5.5 [2.8, 8.2]	4.7 [2.9, 6.4]	1.0 [0.3, 1.7]	.07
Lesbian/gay/bisexual (17.4)	89.1 [83.0, 95.1]	5.0 [1.3, 8.7]	2.9 [0.4, 5.5]	2.4 [0.0, 5.1]	0.5 [0.1, 0.8]	
Marijuana-related perceptions (%) ^d						
Access to marijuana						
Low (10.9)	75.1 [66.7, 83.6]	3.3 [0.7, 6.0]	15.2 [7.4, 23.0]	6.0 [1.1, 11.0]	—	—
High (89.1)	88.2 [85.3, 91.1]	2.0 [1.1, 2.8]	3.8 [2.0, 5.7]	4.1 [2.6, 5.7]	1.8 [0.6, 3.1]	
Harmfulness						
Low (85.7)	87.0 [84.4, 89.5]	1.8 [1.0, 2.6]	5.0 [2.9, 7.0]	4.8 [3.0, 6.5]	1.5 [0.2, 2.8]	.32
High (14.3)	85.3 [78.8, 91.8]	4.1 [1.0, 7.2]	5.8 [1.6, 10.1]	2.0 [0.3, 3.8]	2.7 [0.2, 5.2]	
Parental disapproval						
Low (40.8)	88.1 [82.6, 93.6]	1.4 [0.4, 2.3]	3.0 [0.8, 5.2]	4.9 [2.4, 7.3]	2.7 [0.3, 5.1]	.24
High (59.2)	85.8 [83.2, 88.3]	2.7 [1.4, 4.0]	6.5 [3.4, 9.7]	4.0 [2.1, 5.9]	1.0 [0.0, 2.1]	
Wrongfulness						
Low (82.2)	86.9 [84.6, 89.2]	1.8 [0.9, 2.6]	5.3 [3.2, 7.4]	4.5 [2.8, 6.2]	1.5 [0.2, 2.8]	.62
High (17.8)	86.3 [79.6, 92.9]	3.9 [0.9, 6.9]	4.0 [0.1, 7.9]	3.5 [1.0, 6.0]	2.4 [0.0, 4.7]	
Other substance use variables (%) ^d						
Frequent marijuana use						
No (72.8)	87.6 [85.1, 90.1]	2.7 [1.5, 3.9]	6.4 [4.1, 8.7]	2.6 [1.2, 4.0]	0.7 [0.0, 1.6]	<.01
Yes (27.2)	84.4 [78.5, 90.3]	0.6 [0.0, 1.2]	1.3 [0.0, 3.0]	9.4 [5.3, 13.4]	4.3 [1.0, 7.7]	
Past-30-day cigarette use						
No (69.7)	86.2 [83.3, 89.2]	2.7 [1.4, 3.9]	6.7 [4.0, 9.5]	3.5 [1.8, 5.3]	0.8 [0.1, 1.6]	<.01
Yes (30.3)	87.8 [81.8, 93.9]	0.7 [0.0, 1.3]	1.9 [0.5, 3.2]	6.0 [2.9, 9.0]	3.7 [0.4, 7.0]	
Past-30-day alcohol use						
No (28.1)	89.7 [85.8, 93.6]	1.4 [0.5, 2.3]	5.4 [1.8, 8.9]	3.3 [0.3, 6.2]	0.3 [0.0, 0.5]	.57
Yes (71.9)	86.6 [82.4, 90.8]	2.4 [1.1, 3.6]	4.8 [2.3, 7.2]	4.7 [3.1, 6.3]	1.6 [0.2, 3.0]	
Past-30-day prescription drug use						
No (76.2)	87.1 [84.7, 89.6]	2.4 [1.3, 3.5]	5.9 [3.5, 8.3]	3.7 [2.0, 5.4]	0.8 [0.2, 1.4]	<.01
Yes (23.8)	85.8 [78.9, 92.8]	1.2 [0.3, 2.2]	1.9 [0.0, 3.8]	6.5 [3.0, 10.0]	4.5 [0.5, 8.5]	
Any lifetime illicit drug use						
No (67.8)	88.2 [85.4, 91.0]	1.9 [0.9, 2.9]	5.8 [3.1, 8.5]	3.4 [1.6, 5.2]	0.7 [0.1, 1.3]	<.01
Yes (32.2)	83.2 [77.5, 88.9]	2.7 [1.2, 4.1]	3.7 [1.5, 5.9]	6.5 [3.5, 9.4]	4.0 [1.0, 6.9]	

Notes: CI = confidence interval. ^aEstimates were suppressed if the number of subjects was fewer than 3 and/or if the total number in that category was fewer than 30 (indicated by —). ^bSample excluded those who did not answer the usual mode of consumption question. ^cRao-Scott chi-square test. ^dPercentages are weighted and therefore do not produce original cell sample sizes.

We found a number of noteworthy differences by sociodemographic characteristics. The prevalence of use of multiple modes was higher among males compared with females, and older students were more likely to report dabbing compared with younger students. These findings extend previous work that found older boys less likely to report smoking as their usual mode of consumption (Johnson et al., 2015). LGB students were more likely to have ingested marijuana compared with heterosexual students. These subgroups may warrant increased attention as potential early adopters of nonsmoking modes of marijuana use.

Students who reported high perceived harmfulness of marijuana were less likely to report any dabbing or report using multiple modes. Students who disapproved of marijuana or had parents with high perceived disapproval were also less likely to report using non-smoking modes. These findings are consistent with previous research that suggests the perceived harmfulness and wrongfulness of marijuana is correlated with the frequency and mode of marijuana use among adolescents (Cerdá et al., 2017; Fleming et al., 2016; Johnson et al., 2015; Miech et al., 2015). However, less is known about perceptions of harm specific to different modes of consumption.

TABLE 5. Changes in usual mode of marijuana among Colorado high school students reporting past-30-day marijuana use in 2013 and 2015

Variable	2013 prevalence [95% CI]	2015 prevalence [95% CI]	Crude PR [95% CI] ^{a,b}	<i>p</i>	Adjusted PR [95% CI] ^{a,c}	<i>p</i>
Students with any past-30-day use						
Smoke	84.9 [82.3, 87.4]	86.8 [84.2, 89.3]	1.0 [1.0, 1.1]	.29	1.0 [1.0, 1.0]	.30
Ingest	4.7 [3.8, 5.6]	2.1 [1.2, 3.0]	0.5 [0.3, 0.7]	<.001	0.4 [0.3, 0.7]	<.001
Vaporize	6.5 [4.4, 8.5]	5.1 [3.2, 7.0]	0.8 [0.5, 1.3]	.33	0.8 [0.5, 1.3]	.35
Other ^d	4.0 [2.9, 5.0]	6.0 [3.9, 8.0]	1.5 [1.0, 2.3]	.06	1.7 [1.1, 2.5]	.01
Students with frequent past-30-day use ^e						
Smoke	79.0 [74.5, 83.4]	84.4 [78.5, 90.4]	1.1 [1.0, 1.1]	.17	1.1 [0.9, 1.1]	.29
Ingest	4.0 [2.3, 5.7]	0.6 [0.0, 1.2]	0.1 [0.0, 0.4]	<.001	0.1 [0.0, 0.5]	<.01
Vaporize	7.5 [4.5, 10.4]	1.3 [0.0, 3.0]	0.2 [0.0, 0.7]	<.01	0.2 [0.0, 0.6]	<.01
Other ^d	9.6 [6.4, 12.7]	13.7 [8.5, 18.8]	1.4 [0.9, 2.3]	.16	1.8 [1.1, 2.8]	.02

Notes: CI = confidence interval; PR = prevalence ratio. ^a2013 is the reference category. ^bUnadjusted logistic regression with maximum likelihood estimation. ^cAdjusted logistic regression with maximum likelihood estimation. ^dIn 2015, other is a combined category with dabbing. ^eFrequent defined as 20 or more times.

This evidence that perceived harmfulness can influence the use of dabbing is relevant for public health messaging and prevention efforts, as it suggests that communicating possible risks associated with specific modes of consumption could influence the choice of mode of consumption among youth.

The perceived ease of access was also associated with using multiple modes. Because previous research suggests that adolescents have greater perceived access to marijuana in states with MMLs, we would expect legal recreational marijuana and retail sales to have similar effects (Schuermeyer et al., 2014). Although recreational marijuana remains illegal for individuals younger than 21, increased availability of marijuana via more dispensaries and reduced barriers to access for adults might increase access for youth and affect modes of consumption.

Smoking was the most common usual mode of consumption before and after Colorado implemented marijuana retail sales. There was a small but significant decline in those reporting ingesting and an increase in those reporting “other” as usual modes. Among students who reported using marijuana frequently, the prevalence of both ingesting and vaporizing as the usual mode decreased from 2013 to 2015, whereas “other mode(s)” increased. We were surprised by the decline in use of edibles. Edibles may be attractive to youth given that they may be easier to conceal and do not involve inhaling smoke, and there has been a proliferation of edible marijuana products available in retail marijuana stores (Monte et al., 2015). This presumably made these products more widely available to adults, and perhaps to adolescents. There are growing concerns that the attractiveness of both the product and its packaging may encourage use among adolescents, as well as possible inaccurate labeling of THC/cannabidiol content (MacCoun & Mello, 2015; Monte et al., 2015; Vandrey et al., 2015). Although we did not see an increase, it is important to continue monitoring as years pass since the implementation of retail marijuana sales. Further evaluation of policy regula-

tion of product design and labeling is necessary to ensure that accurate product information is disseminated to consumers, in turn helping inform choices about marijuana use among both adults and adolescents. More information on how these factors influence use among adolescents is also needed since access to retail marijuana is illegal for those under age 21.

The increase in “other mode(s)” as the usual mode of use is concerning, as it includes dabbing, a high-potency mode of use. In 2015, dabbing accounted for approximately 72% of this category among all students in the sample and 69% among those who reported frequent use. This increase is consistent with findings from studies using data from social media platforms that suggest dabbing has increased in popularity in the United States (Russell et al., 2018). Some research suggests that acute adverse mental health effects, including anxiety, panic, and other psychotic symptoms, as well as physiological tolerance and withdrawal, are associated with higher potency products (Di Forti et al., 2015; Hall & Degenhardt, 2009; Leung et al., 2018; Loflin & Earleywine, 2014; Murray et al., 2017; Pierre et al., 2016; Russell et al., 2018). This is particularly important for adolescents, as heavy/frequent use in adolescence is a risk factor for later development of a use disorder (Hall & Degenhardt, 2009; Volkow et al., 2014). Although we cannot evaluate trends specific to dabbing, the potential harms associated with it necessitate continued surveillance. Public health prevention efforts, including informing adolescents of THC levels and how these differ between modes, is necessary to avert serious health consequences related to high-potency products.

Limitations

Although our study makes important contributions to understanding how adolescent marijuana use is changing, it does have some limitations. Because students were asked

to self-report an illegal behavior, respondents may have underreported their marijuana use. However, we expect that underreporting was similar across years and subgroups, and thus we do not believe it had an effect on the differences we observed. Survey administration strategies were also designed to mitigate misreporting. Dabbing was added as a response option in 2015, and the “other” category in the analysis is a combined grouping with dabbing for that year. This addition could have affected the usual mode of consumption reported in both survey years. These data are the best available on dabbing among adolescents and, although limited, are still meaningful. We intend to study dabbing in future HKCS waves. Some analyses had relatively small sample sizes, leading to larger confidence intervals, which should be considered when interpreting findings. Our survey includes a sample of high school students who attend public schools and may not represent those attending private schools or those not in school. The response rate in both years was relatively low, but previous literature suggests that nonparticipation of schools does not lead to major bias of substance use prevalence estimates (Thrul et al., 2016). Last, causal relationships could not be assessed because of the cross-sectional study design.

Conclusions

We examined adolescent use of various modes of marijuana consumption and assessed differences in the usual mode of consumption before and after the initiation of retail marijuana sales. Given the high prevalence of using multiple modes and the possible increase in dabbing among high school students, more surveillance of high-potency products and potential harms associated with experimenting with new modes is needed. Future research should focus on assessing the short- and long-term impacts of the different modes of use and examining how different policies affect the routes of marijuana consumption adolescents use across states.

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