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Cannabis use and driving under the influence: Behaviors and attitudes by state-level legal sale of recreational cannabis

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ABSTRACT

Background: As states continue to legalize the sale of recreational cannabis, there is a need to study attitudes and behaviors regarding driving after cannabis use. The purpose of this study was to describe US adults' attitudes and behaviors regarding driving after cannabis use by state-level legal sale of recreational cannabis, and to determine whether these associations differ by frequency of cannabis use.

Methods: Data were collected from a national sample of 17,112 adults in the United States. Weighted adjusted prevalence ratios and 95% confidence intervals were used to compare the prevalence of behaviors and attitudes by state-level legal sale of recreational cannabis. Analyses were repeated among recent cannabis users, stratifying by cannabis use status.

Results: Driving after cannabis use was more prevalent in legal cannabis sales states; however, so were potentially protective attitudes related to cannabis use and driving. After stratifying by frequency of use, daily/almost daily, weekly/monthly, and past 12-month users from states with legal recreational cannabis sales had significantly lower prevalence of driving after cannabis use and higher prevalence of protective attitudes compared to those from states without legal recreational sales. Risk perceptions were lower for cannabis than alcohol.

Conclusions: Public health messaging campaigns to reduce driving and riding after cannabis use and to improve attitudes regarding driving after cannabis use are warranted across all U.S. states, regardless of legalization status.

1. Introduction

In the past 80 years, the public's understanding of cannabis has evolved from the dangerous drug of "Reefer Madness," to a "natural" product with medicinal properties, to a socially acceptable recreational substance (Pew Research Center, 2019; Simkins and Allen, 2020; Stringer and Maggard, 2016). Forty states and the District of Columbia (D.C.) allow cannabis use in some form. However, as of 2019, only eight states have implemented recreational cannabis sales. As public opinion shifts towards further acceptance of cannabis as a legal drug, cannabis use may become more common, as may the consequences of its use.

A frequent concern associated with recreational cannabis legalization is the potential increase in driving under the influence of cannabis, which may result in higher rates of motor vehicle collisions resulting in fatalities or injuries compared to sober drivers (Ramaekers et al., 2004; Rogeberg and Elvik, 2016). Cannabis has a complex influence on driving behavior, impairing coordination, judgement, divided-attention tasks, lane-position, and reaction times (Hartman and Huestis, 2013). Evidence suggests that driving while high is increasingly common (Azofeifa et al., 2019; Brady and Li, 2014; Center for Behavioral Health Statistics and Quality, 2019; Centers for Disease Control and Prevention (CDC)). Around 5% of US adults aged 16 and older drove under the influence of cannabis in the past year (Azofeifa et al., 2019); among high school youth who drove a vehicle in the past 30 days, roughly 13% drove when they had been using cannabis (Centers for Disease Control and Prevention (CDC)). Moreover, over 40% of past-month cannabis users from Washington and Colorado, both legal recreational cannabis states, reported driving while high in the past year, and nearly 25% reported

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driving after using cannabis on five or more occasions in the past month (Davis et al., 2016). Similar results were reported from an online convenience sample of past-month cannabis users; however, residing in a state with legal recreational cannabis was not associated with driving after cannabis use (Berg et al., 2018).

Attitudes and beliefs about driving under the influence of cannabis may partially explain patterns of behavior and are targets for messaging interventions (Berg et al., 2018). The prevalence of driving under the influence of cannabis is consistently higher than driving under the influence of alcohol among youth and young adults (Earle et al., 2019; Kann et al., 2018; O'Malley and Johnston, 2013), suggesting that participants perceive driving under the influence of alcohol as riskier or less socially acceptable than driving under the influence of cannabis (Berg et al., 2018; Goodman et al., 2019). Older adults generally believe that driving under the influence of cannabis is less risky than driving under the influence of alcohol (Spackman et al., 2017), though the relative amounts of alcohol and cannabis affect responses (Berg et al., 2018; McCarthy et al., 2007). In fact, in a small study of at least monthly cannabis users in England, only 12% believed their driving was "very much impaired" and 24% of actually believed that their driving *improved* (Terry and Wright, 2005).

Medical marijuana laws are associated with increases in driving under the influence of cannabis, suggesting that driving under the influence of cannabis may increase as a result of recreational cannabis legalization, especially among current cannabis users (Fink et al., 2020). However, to date there are no U.S. national estimates of driving under the influence of cannabis or associated attitudes, nor is there a comparison of behaviors and attitudes by state legal recreational cannabis status. The objectives of this study are to: 1) describe behaviors and attitudes regarding driving under the influence of cannabis among U.S. adults by legal sale of recreational cannabis status while accounting for sociodemographic characteristics, and 2) determine whether any of these associations differ by cannabis use frequency.

2. Methods

2.1. Participants

Data are from Wave 1 of the International Cannabis Policy Study (Hammond et al., 2018), conducted in Canada and the United States. Data for these analyses are from US respondents only; thus, only methods concerning the US sample will be discussed below. Respondents aged 16–65 completed web-based surveys between August 27 and October 7, 2018. Respondents were recruited through the Nielsen Consumer Insights Global Panel and their partners' panels. Email invitations containing a unique survey link were sent to a random sample of known eligible panelists who were located in the United States. Surveys were conducted in English, with a median survey time of 19.9 min. Respondents provided consent prior to completing the survey and received remuneration in accordance with their panel's typical incentive structure (e.g., points-based or monetary rewards, chances to win prizes). The study was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 31330). A full description of the study methods and participation rates can be found in the International Cannabis Policy Study: Technical Report – Wave 1 (2018) (Goodman and Hammond, 2019).

A total of 28,471 respondents completed the survey. To generate weights, respondents from the Canada were grouped into age-by-sex-by-province and education groups, while respondents from the U.S. were classified into age-by-sex-by-legal state, education, and region-by-race groups. Population count and proportion estimates for these groups were obtained from Statistics Canada (Canada, 2017; Canada, 2016) and the U.S. Census Bureau (U.S. Census Bureau Population Division, 2018; US Census Bureau, 2013-2017). A raking algorithm was applied to the full analytic sample ($n = 28{,}741$) to generate weights calibrated to these groupings. After removing 1302 respondents with invalid responses to data quality questions (e.g., inability to correctly select the correct month, reported inability to answer honestly), ineligible country of residence, smartphone use (to facilitate image viewing), residence in District of Columbia (due to inadequate sample size) and 10,057 respondents from Canada, a total of 17,112 U.S. respondents were retained in the analytic sample.

3. Measures

3.1. Exposure

The primary exposure variable was legal sale of recreational cannabis at the time of data collection. As of October 2018, nine states had passed legislation to legalize recreational cannabis. However, only 6 of these states (Alaska, California, Colorado, Nevada, Oregon, and Washington) had established a recreational retail market for purchasing legal cannabis products. Participants from these six states were classified as living in a state with legal sale of recreational cannabis (LSRC) while participants from all other states were classified as living in a state with no legal sale of recreational cannabis (NLSRC).

3.2. Outcomes – Cannabis Use and Driving Behaviors

Five cannabis use and driving behavior measures were included in this study. Driving after cannabis use was assessed using the following measure: "Have you ever driven a vehicle (e.g., car, snowmobile, motor boat, or an off-road vehicle (ATV)) within 2 hours of using marijuana?" Potential responses included never, in the past 30 days, in the past 12 months, or more than 12 months ago. Binary past 30-day and past 12-month driving after cannabis use variables were created from this measure. Participants who had ever used cannabis were asked to report whether they had ever planned ahead to avoid driving high or decided not to drive to while high (yes vs. no). Riding with a driver who had been using cannabis was assessed using the following measure: "Have you been a passenger in a vehicle (e.g., car, snowmobile, motor boat, or an off-road vehicle (ATV)) driven by someone who had been using marijuana in the past 2 hours?" Potential responses were identical to the driving after cannabis use item and binary past 30-day and past 12-month riding with a driver who used cannabis variables were created from this measure.

3.3. Outcomes – driving attitudes

Six attitudes related to impaired driving were included in this study. Participants self-reported whether they thought driving drunk or driving high increases the risk of an accident using the following two measures: 1) "Does driving drunk increase the risk of getting into an accident?", and 2) "Does driving high increase the risk of getting into an accident?" Possible responses included: "not at all," "a little," "somewhat," "a lot," and "don't know." Two binary outcome variables were created that grouped "a lot" vs. all other responses, given that any responses other than "a lot" may represent a concern for public safety.

Participants also reported whether it was easy or difficult to tell if someone had too much alcohol or cannabis to drive using the following two measures: 1) "Is it easy or difficult to tell if someone has had too much alcohol to drive safely?", and 2) "Is it easy or difficult to tell if someone has had too much marijuana to drive safely?" Possible responses included: "very easy", "easy", "neither easy nor difficult", "difficult", "very difficult", or "don't know". Two binary outcome variables were created that grouped "very easy" and "easy" vs. all other responses.

Participants self-reported whether they would try to stop a friend from driving drunk or high using the following two measures: 1) "If a friend was drunk and was going to drive, would you try to stop them?", and 2) "If a friend was high and was going to drive, would you try to stop them?" Possible responses for both measures included: "I wouldn't do

anything," "I would tell them not to drive, but I wouldn't try to stop them," "I would try a little bit to stop them from driving," "I would try very hard to stop them from driving," and "I don't know." Binary outcome variables were created for both measures where participants were classified as "I would try very hard to stop them from driving" vs. all other responses.

3.4. Cannabis use

Recent cannabis use was grouped into the following mutually exclusive categories: daily/almost daily use, weekly/monthly use, and past 12-month use.

3.5. Confounders

Participants self-reported age, sex at birth, race (American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Pacific Islander, white, or other/multiple racial/ethnic groups), and educational attainment (less than high school, high school or equivalent, some college, or bachelor's degree or higher), and sexual identity (heterosexual, gay or lesbian, bisexual, or other).

3.6. Data analysis

First, weighted chi-square tests were used to compare the characteristics of participants in LSRC and NLSRC states. For the full analytic sample, behaviors and attitudes regarding cannabis use and driving in LSRC and NLSRC states were compared using weighted adjusted prevalence ratios (APR) and 95% confidence intervals (95% CI), which is appropriate when estimating risk in a cross sectional study (Spiegelman and Hertzmark, 2005). Next, we repeated the analyses among participants who used cannabis in the past 12 months. Results were stratified by level of use: 1) daily/almost daily; 2) weekly/monthly use; and 3) past 12-month use. All models and estimates were weighted and adjusted for age, sex, education, race, and sexual identity. The percentage of participants who had missing data was less than 1% for all outcome variables Therefore, we did not perform imputation and participants with missing data for a given outcome were not included in that model. Analyses were conducted using SAS Version 9.4 (SAS Institute, Cary NC).

4. Results

As shown in Table 1, a greater proportion of participants in LSRC states were daily/almost daily cannabis users (10.9% vs. 8.0%), weekly/monthly cannabis users (13.7% vs. 9.7%), and past 12-month cannabis users (9.4% vs. 7.1%) compared to those in NLSRC states. Further, the prevalence of driving after using cannabis during the past 30 days (7.3% vs. 5.5%), planning ahead or deciding not to drive while high (52.1% vs. 39.7%), riding with a driver who had recently used cannabis in the past 30 days (10.1% vs. 8.4%) and the past 12 months (18.5% vs. 14.7%), believing that driving high increases the risk of accident a lot (57.1% vs. 52.2%) and that it is easy or very easy to tell if someone has had too much marijuana to drive safely (36.2% vs. 33.6%) were significantly higher in LSRC states compared to NLSRC states.

Table 2 shows weighted APRs comparing the prevalence of driving behaviors and attitudes in LSRC states and NLSRC states. After adjusting for demographics, LSRC states had a significantly higher prevalence of driving after cannabis use during the past 30 days (APR: 1.34; 95% CI: 1.19, 1.51) and past 12 months (APR: 1.16; 95% CI: 1.06, 1.28), and riding with a driver who used cannabis in the past 30 days (APR: 1.22; 95% CI: 1.11, 1.35) and past 12 months (APR: 1.23; 95% CI: 1.15, 1.32) compared to NLSRC states. Among participants who ever used cannabis, a higher proportion in LSRC states planned ahead or decided not to drive while high (APR: 1.28; 95% CI: 1.22, 1.33). Further, LSRC states had significantly higher prevalence of participants stating that driving high

Table 1
Demographic characteristics, driving behaviors, and driving attitudes, by state-level legal sale of recreational marijuana (N = 17,112).

	Legal			Illegal		
	N	%[a][b]	(95% C. I.)	N	%[a]	(95% C. I.)
Total N	5548	37.7	(36.6, 38.9)	11,564	62.3	(61.1, 63.4)
Demographics						
Age						
Mean (SD)	–	39.8	16.0	–	40.1	14.5
Sex						
Female	3624	49.5	(47.1, 51.7)	7231	50.3	(49.2, 51.5)
Male	1924	50.5	(48.3, 52.6)	4333	49.7	(48.5, 50.8)
Race[b]						
White	4623	75.2	(73.3, 77.2)	9982	77.0	(75.8, 78.2)
American Indian or Alaska native	67	1.8	(1.2, 2.4)	56	0.6	(0.4, 0.8)
Asian	335	9.1	(7.8, 10.5)	266	2.6	(2.2, 2.9)
Black or African American	175	6.0	(4.9, 7.2)	758	15.0	(13.9, 16.0)
Native Hawaiian or Pacific islander	17	0.4	(0.1, 0.6)	14	0.2	(0.1, 0.2)
Other/multiple races	331	7.4	(6.2, 8.6)	488	4.7	(4.2, 5.2)
Education						
Less than high school	291	12.6	(11.0, 14.2)	1713	14.4	(13.7, 15.2)
High school	683	14.8	(13.3, 16.4)	1887	19.9	(18.8, 20.8)
Some college	2016	42.2	(40.1, 44.4)	3476	38.7	(37.6, 39.9)
Bachelor's degree or higher	2546	30.3	(28.4, 32.2)	4461	27.0	(26.1, 27.9)
Sexual identity						
Heterosexual	4988	89.2	(87.9, 90.6)	10,572	91.3	(90.6, 92.0)
Gay/lesbian	173	3.8	(2.9, 4.6)	335	3.4	(3.0, 3.9)
Bisexual	243	5.0	(4.0, 5.9)	454	4.2	(3.8, 4.7)
Other	77	2.0	(1.4, 2.7)	119	1.0	(0.8, 1.2)
Cannabis use status						
Daily/almost daily	583	10.9	(9.6, 12.2)	770	8.0	(7.3, 8.7)
Weekly/monthly	639	13.7	(12.5, 14.9)	936	10.7	(10.0, 11.4)
Past 12 months	569	9.4	(8.2, 10.7)	844	7.1	(6.6, 7.7)
More than 12 months ago	1830	26.5	(24.7, 28.4)	3860	31.0	(30.0, 32.1)
Never	1927	39.5	(37.4, 41.6)	5154	44.2	(43.0, 45.3)
Behaviors						
Drove after cannabis use in past 30 days						
Yes	298	7.3	(6.1, 8.4)	504	5.5	(4.9, 6.1)
No	5224	92.7	(91.6, 93.9)	11,023	94.5	(93.9, 95.1)
Drove after cannabis use in past 12 months						
Yes	454	10.4	(9.0, 11.7)	826	9.0	(8.3, 9.7)
No	5068	89.3	(88.3, 91.0)	10,701	91.0	(90.3, 91.7)
Passenger w/ driver who used cannabis in the past 30 days						
Yes	469	10.1	(8.7, 11.4)	830	8.4	(7.7, 9.1)
No	5058	89.9		10,688	91.6	

(continued on next page)

Table 1 (*continued*)

	Legal			Illegal		
	N	%[a][b]	(95% C. I.)	N	%[a]	(95% C. I.)
			(88.6, 91.3)			(90.9, 92.3)
Passenger w/ driver who used cannabis during the past 12 months						
Yes	850	18.5	(16.8, 20.2)	1473	14.7	(13.9, 15.6)
No	4677	81.5	(79.8, 83.2)	10,045	85.3	(84.4, 86.1)
Planned ahead or decided not to drive while high[c]						
Yes	1658	52.1	(49.3, 55.0)	2290	39.7	(38.1, 41.3)
No	1728	47.9	(45.0, 55.7)	3700	60.3	(58.7, 61.9)
Attitudes						
Driving high increases risk of accident "A lot"						
Yes	3299	57.1	(54.9, 59.2)	6423	52.2	(51.1, 53.4)
No	2233	42.9	(40.8, 45.1)	5121	47.8	(46.6, 48.9)
Driving drunk increases risk of accident "A lot"						
Yes	5078	88.4	(87.0, 89.9)	10,536	89.1	(88.3, 89.9)
No	458	11.6	(10.1, 13.0)	1005	10.9	(10.1, 11.7)
Easy or very easy to tell if someone has had too much cannabis to drive safely						
Yes	1868	36.2	(34.1, 38.3)	3684	33.6	(32.6, 34.7)
No	3666	63.8	(61.7, 65.9)	7852	66.4	(65.3, 67.4)
Easy or very easy to tell if someone has had too much alcohol to drive safely						
Yes	3768	66.1	(64.0, 68.1)	7817	67.7	(66.7, 68.8)
No	1764	33.9	(31.9, 36.0)	3720	32.3	(31.2, 33.3)
Would try very hard to stop friend from driving high						
Yes	3858	64.4	(62.3, 65.5)	7883	63.6	(62.5, 64.8)
No	1665	35.6	(33.5, 37.7)	3642	36.4	(35.2, 37.5)
Would try very hard to stop friend from driving drunk						
Yes	4826	82.3	(80.6, 84.0)	10,117	84.4	(83.5, 85.4)
No	698	17.7	(16.0, 19.4)	1420	15.6	(14.6, 16.5)

[a] Weighted column percent
[b] Ethnicity was not incorporated into the weighting algorithm and thus is not included in this table
[c] Among lifetime cannabis users

increases the risk of an accident "a lot" (APR: 1.10; 95% CI: 1.07, 1.13), that it is "easy" or "very easy" to tell if someone has had too much cannabis to drive safely (APR: 1.08; 95% CI: 1.04, 1.13), and that they would try very hard to stop a friend from driving high (APR: 1.02; 95% CI: 1.00, 1.05) compared to NLSRC states.

Table 3 restricts the analyses to those who had used cannabis in the past 12 months. Daily/almost daily users from LSRC states were less likely to report driving after cannabis use in the past 12 months (APR: 0.84, 95% CI: 0.73, 0.99) and riding with a driver who used cannabis in the past 30 days (APR: 0.83, 95% CI: 0.70, 0.99) and were more likely to plan ahead or decide not to drive while high (APR: 1.25, 95% CI: 1.16, 1.34) compared to daily/almost daily users from NLSRC states. Daily/almost daily users from LSRC states were also more likely to state that driving high increases risk of an accident "a lot" (APR: 1.48, 95% CI: 1.22, 1.80) and that they would try very hard to stop a friend from driving high (APR: 1.56, 95% CI: 1.34, 1.81) compared to from NLSRC states. A similar pattern was observed when comparing monthly/weekly users and past 12 month users from LSRC states and NLSRC states, but monthly/weekly users in LSRC states were also more likely to state it is "easy" or "very easy" to tell if someone has had too much cannabis to drive safely (APR: 1.26, 95% CI: 1.13, 1.40).

Table 2
Weighted adjusted prevalence ratios (APRs) of attitudes and behaviors regarding cannabis use and driving in states with legal sale of recreational cannabis (LSRC) and states with no legal sale of recreational cannabis (NLSRC) (unweighted $N = 17{,}112$).

	LSRC states vs. NLSRC states (ref)
	APR (95% CI)[a]
Behaviors	
Drove after cannabis use during past 30 days	1.34 (1.19–1.51)
Drove after cannabis use during past 12 months	1.16 (1.06–1.28)
Passenger w/ driver who used cannabis during the past 30 days	1.22 (1.11–1.35)
Passenger w/ driver who used cannabis during the past 12 months	1.23 (1.15–1.32)
Planned ahead or decided not to drive while high[b]	1.28 (1.22–1.33)
Attitudes	
Driving high increases risk of accident "a lot"	1.10 (1.07–1.13)
Driving drunk increases risk of accident "a lot"	1.00 (0.99–1.01)
"Easy" or "very easy" to tell if someone has had too much cannabis to drive safely	1.08 (1.04–1.13)
"Easy" or "very easy" to tell if someone has had too much alcohol to drive safely	0.99 (0.96–1.01)
Would try "very hard" to stop friend from driving high	1.02 (1.00–1.05)
Would try "very hard" to stop friend from driving drunk	0.99 (0.98–1.01)

Note. APR = adjusted prevalence ratio; CI = confidence interval. Reference group = NLSRC states.
[a] Adjusted for age, sex, education, race, and sexual identity.
[b] Among lifetime cannabis users.

5. Discussion

The primary objectives of this study were to describe behaviors and attitudes regarding cannabis use and driving among U.S. adults by state-level sale of recreational cannabis and to determine whether any of these associations differed by cannabis use frequency. At the population level, the findings suggest that sale of recreational cannabis is associated with a higher prevalence of risky behaviors related to cannabis use and driving but is also associated with potentially protective attitudes on this topic. For example, the adjusted prevalence of driving after cannabis use during the past 30 days and past 12 months was significantly higher in LSRC states compared to NLSRC states, yet so was the prevalence of believing driving while high increases the risk of an accident "a lot.". Other research has shown that LSRC states have more cannabis users (Goodman et al., 2020) and this may result in a higher prevalence of driving under the influence of cannabis at the population level. It is also possible that LSRC states have populations that are more aware of the potential negative outcomes associated with driving after cannabis use, perhaps due to state/local education campaigns or personal experience. Given the cross sectional nature of this study, we are unable to ascertain whether a state-level change in recreational cannabis policy is the driver

Table 3
Weighted adjusted prevalence ratios (APRs) of behaviors and attitudes regarding cannabis use and driving in states with legal sale of recreational cannabis (LSRC) and states with no legal sale of recreational cannabis (NLSRC), by state-level legal sale of recreational marijuana among daily/almost daily, weekly/monthly, and past 12-month cannabis users (unweighted $N = 4341$).

	Daily/almost daily users ($N = 1353$)	Monthly/weekly users ($N = 1575$)	Past 12-month users ($N = 1413$)
	APR (95% CI)[a]	APR (95% CI)[a]	APR (95% CI)[a]
Behaviors			
Drove after cannabis use during past 30 days	0.92 (0.78–1.10)	0.91 (0.75–1.11)	–
Drove after cannabis use during past 12 months	0.84 (0.73–0.99)	0.82 (0.71–0.93)	0.62 (0.43–0.0.88)
Passenger with driver who used cannabis during the past 30 days	0.83 (0.70–0.99)	0.83 (0.70–0.98)	1.33 (0.94–1.87)
Passenger w/ driver who used cannabis during the past 12 months	0.93 (0.81–1.08)	0.92 (0.83–1.03)	0.69 (0.56–0.83)
Planned ahead or decided not to drive while high	1.25 (1.16–1.34)	1.06 (1.01–1.12)	1.20 (1.08–1.34)
Attitudes			
Driving high increases risk of accident "a lot"	1.48 (1.22–1.80)	1.42 (1.26–1.61)	1.29 (1.14–1.48)
Driving drunk increases risk of accident "a lot"	0.99 (0.96–1.04)	0.99 (0.96–1.03)	0.99 (0.88–1.11)
Easy or very easy to tell if someone has had too much cannabis to drive safely	1.06 (0.90–1.25)	1.26 (1.13–1.40)	0.97 (0.84–1.13)
Easy or very easy to tell if someone has had too much alcohol to drive safely	0.99 (0.94–1.06)	0.96 (0.90–1.01)	0.97 (0.86–1.10)
Would try "very hard" to stop friend from driving high	1.56 (1.34–1.81)	1.27 (1.15–1.41)	1.22 (1.10–1.34)
Would try "very hard" to stop friend from driving drunk	1.02 (0.91–1.14)	1.03 (0.92–1.14)	1.00 (0.96–1.04)

Note. APR = adjusted prevalence ratio; CI = confidence interval. Reference group = NLSRC states.
[a] Adjusted for age, sex, education, race, and sexual identity.

behind these associations, or if they existed before the policy change was enacted.

Interestingly, when we repeated these analyses among subgroups of past 12-month cannabis users (daily/almost daily, weekly/monthly, and past 12-month users), we found that recent cannabis users from LSRC states had a lower prevalence of risky driving and riding behaviors, while also having a higher prevalence of potentially protective attitudes related to cannabis use and driving. While previous studies have examined the prevalence of driving after cannabis use in states with legal sales of recreational cannabis (Berg et al., 2018; Davis et al., 2016), our study is the first to provide national estimates of behaviors and attitudes related to cannabis use and driving in the general population and among those who used cannabis in the past 12 months by state-level legal sale of recreational cannabis. Contrary to our study, Berg et al. concluded that that the legal cannabis sales status of a state was not associated with likelihood of cannabis users to drive under the influence (Berg et al., 2018); however, the study reported data from an online convenience sample of young adult cannabis users ages 18–34. Given that our sample includes wider age range of participants (16–65) and used a different sampling technique, it is not surprising that our estimates differ from those reported in the prior study.

6. Public health implications

These findings have clear implications for prevention. First, widespread messaging to the general population about the dangers of driving or riding with a driver who may be impaired by cannabis is warranted. Consistent with previous research from the US (Berg et al., 2018) and Canada (Goodman et al., 2019), participants from both LSRC and NLSRC states perceived driving after cannabis use as less risky than driving after alcohol use. For example, while nearly 90% of participants in both LSRC and NLSRC states believed that driving after alcohol use increases the risk of an accident "a lot", under 60% of participants in LSRC and NLSRC states believed that driving after cannabis use increases the risk of an accident "a lot". Further, our findings suggest that there is a particular need to target current cannabis users in states without legal recreational cannabis sales. In our study, current cannabis users from LSRC states generally engaged less in risky driving and riding behaviors and had more potentially protective attitudes related to cannabis use and driving compared to cannabis users in NLSRC states. Given these results and the increasing prevalence of driving under the influence of cannabis among adults in the US (Azofeifa et al., 2019; Brady and Li, 2014; Center for Behavioral Health Statistics and Quality, 2019; Centers for Disease Control and Prevention (CDC), n.d C) states should consider public education about driving while high regardless of whether cannabis sales have recently been legalized.

Several national and state-level media campaigns and educational efforts, including the National Highway Traffic Safety Administration's "If you feel different, you drive different" campaign (US Department of Transportation, n.d) and the Colorado Department of Transportation's "The Cannabis Conversation" project (Colorado Department of Transportation, n.d), aim to change norms concerning cannabis use and driving. The "If you feel different, you drive different" national media campaign is part of the NHTSA's larger effort to expand the public's understanding of impaired driving from alcohol to other substances, including cannabis and prescription medication, and focuses on periods such as Labor Day weekend when the risk of fatality due to car accidents increases dramatically (National Highway Traffic Safety Administration, 2005). In contrast, "The Cannabis Conversation" was a public engagement and education campaign with the goal to inform a larger behavior change ad campaign with salient and trustworthy messages for cannabis users. States considering legalizing the sale of recreational cannabis may learn from these and similar campaigns' as well as the effective campaigns that changed social perception and acceptance of alcohol consumption and driving (Young et al., 2018). However, further research is needed to evaluate whether these campaigns actually change attitudes and behaviors about driving under the influence of cannabis.

7. Limitations and strengths

This study has several limitations. First, the study is cross-sectional and thus, causality cannot be inferred from these associations. As mentioned earlier, it is possible that associations between legal sale of recreational cannabis and the outcomes in this study may have predated legalization. First, given that a non-probability online sampling methodology was used, the sample of U.S. adults may not be entirely representative of the general U.S. population. Survey weights were generated for participants using a raking algorithm that utilized age-by-sex, education, and region-by-race information from the U.S. Census for LSRC and NLSRC states. However, the study sample was somewhat more highly educated than the national population in the US. The ICPS sample had poorer self-reported general health compared to the national population, which is a feature of many non-probability samples (Fahimi et al., 2018) and may be partly due to the use of web surveys, which provide greater perceived anonymity than in-person or telephone-assisted interviews often used in national surveys (Dodou and de Winter, 2014; Hays et al., 2015). The rates of cannabis use were also somewhat higher than some national estimates; however, this is likely due to the fact that the ICPS sampled individuals aged 16–65 whereas the national surveys included older adults, who may have lower rates of cannabis use. The ICPS is also conducted online, whereas most national

surveys are conducted in person. Compared to interviewer-assisted survey modes, self-administered surveys can reduce social desirability bias by providing greater anonymity for sensitive topics, including substance use (Dodou and de Winter, 2014; Krumpal, 2013). Second, although we adjusted for important sociodemographic factors in our analyses, there is potential for residual confounding from unmeasured characteristics such as income or employment status. Despite these limitations, this study fills an important gap in the existing literature. There are also several strengths worth noting, including the large sample size, detailed survey items, weighted analyses, and stratification of the main analyses by cannabis use status.

8. Conclusion

The findings suggest that risky driving and riding behaviors were higher in LSRC states compared to NLSRC states; however, so were protective attitudes about driving after cannabis use. Interestingly, risky driving and riding behaviors were lower among recent cannabis users in states with legal sales of recreational cannabis compared to NLSRC states, as were protective attitudes about driving after cannabis use. These findings highlight the need for public health interventions and awareness campaigns to reduce driving and riding after cannabis use and to improve attitudes regarding driving after cannabis use across all U.S. states, regardless of legalization status. Further, targeted messaging to current cannabis users may reduce the burden of impaired driving on public health and safety in the U.S.

Author statement

Dr. Pearson and Clements-Nolle conceptualized the aims for the paper, reviewed and edited the manuscript, and supervised the writing and analysis team. Dr. Pearson also obtained funding for the analysis. Dr. Lensch conducted data analyses. Ms. Sloan, Ms. Ausmus, and Dr. Lensch wrote the original draft and edited the manuscript. Drs. Goodman and Hammond implemented the ICPS study and developed study resources. Dr. Hammond also obtained funding for the ICPS.

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