Differences in patterns of cannabis use among youth: Prevalence, perceptions of harm and driving under the influence in the USA where non-medical cannabis markets have been established, proposed and prohibited

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Abstract

Introduction and Aims. *Cannabis use is the most widely used illicit substance in the USA. Currently, over half of US jurisdictions have legalised medical cannabis and nine US jurisdictions (and Washington DC) have legalised non-medical cannabis. Comparisons across jurisdictions can help to evaluate the impact of these policies. The current study examined patterns of cannabis use among youth in three categories: (i) states that have legalised non-medical cannabis with established markets; (ii) jurisdictions that recently legalised non-medical cannabis without established markets; and (iii) all other jurisdictions where non-medical cannabis is prohibited.* ***Design and Methods.*** *Data come from an online survey conducted among 4097 US youth aged 16–19 recruited through a commercial panel in July/August 2017. Regression models were fitted to examine differences between regulatory categories for cannabis consumption, perceived access to cannabis, modes of use, perceptions of harm and cannabis-impaired driving. All estimates represent weighted data.* ***Results.*** *States that had legalised non-medical cannabis had higher prevalence, easier access and lower driving rates than non-legal states. There were few differences between states with established non-medical cannabis markets and those that had recently legalised.* ***Discussion and Conclusions.*** *Cannabis use among youth was higher in states that have legalised non-medical cannabis, regardless of how long the policy had been implemented or whether markets had been established. This suggests that differences between states with and without legal non-medical cannabis may partly be due to longer-term patterns established prior and highlights the importance of longitudinal evidence to evaluate the impact of cannabis policies.* [Wadsworth E, Hammond D. Differences in patterns of cannabis use among youth: Prevalence, perceptions of harm and driving under the influence in the USA where non-medical cannabis markets have been established, proposed and prohibited. *Drug Alcohol Rev* 2018]

Key words: cannabis, marijuana, drug regulations, legal status, youth.

Introduction

Cannabis is the most popular illicit substance in the USA and youth and young adults are among the highest users of cannabis in the USA [1]. The use of cannabis at a young age is associated with negative outcomes such as poor academic achievement and driving whilst under the influence [2–5].

Cannabis remains an illicit substance in the USA at the federal level. However, various US jurisdictions have liberalised cannabis policies including both medical and non-medical cannabis. At the time of the current study, four states had an established non-medical cannabis market, Alaska, Colorado, Oregon and Washington, and four states had passed legislation for

a new non-medical market yet awaited implementation; California, Maine, Massachusetts and Nevada. The District of Columbia (DC) had legalised cannabis possession and allowed adults to grow their own plants; however, a non-medical market was not permitted. Non-medical cannabis markets in all other states was prohibited.

Public opinion in favour of cannabis legalisation in USA has recently increased [6]. However, implementation of more permissive cannabis regulations have brought concerns of increased use, lower harm perceptions and increased cannabis-impaired driving among youth due to permissive norms and broader access [7,8]. Previous research on the comparison between youth cannabis use before and after medical cannabis

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laws are inconsistent, with some concluding an increase in use and some no change [7,9]. Evidence on the impact of cannabis legalisation remains preliminary given that the regulation changes have only recently been implemented. In addition, the transition to a legal marketplace does not occur immediately upon legalisation; indeed, it typically requires 1 to 2 years to fully establish 'legal' retail stores in states that have legalised non-medical cannabis. For this reason, the first US states to legalise non-medical cannabis—Colorado and Washington State, in 2012—have received particular attention. Data on patterns of cannabis use in Colorado and Washington State have yielded mixed findings to date [10–13]. Both states have seen a decrease in the perceptions of harm from cannabis use; however, this has been an overall trend across the USA in the past few decades [14]. Previous research has shown that perception of harm is a potential indicator of cannabis use, and that a reduction of perceived harm is commonly associated with an increase in cannabis use [15]. Furthermore, this association has been seen to be bidirectional and that cannabis use influences perception of harm [16].

The current study examined patterns of youth cannabis use across three categories: (i) Established Non-Medical Cannabis Markets (NCM)—states that have legalised non-medical cannabis and have an established market (Colorado, Washington, Alaska, Oregon); (ii) New NCMs—jurisdictions that recently legalised non-medical cannabis without established markets (California, Maine, Massachusetts, Nevada); and (iii) Prohibited NCMs—all other jurisdictions where non-medical cannabis is not legal. This study examined differences between these jurisdictions on five primary outcomes among youth: prevalence of use, perceived access to use, modes of use, perception of harm and cannabis-impaired driving. We hypothesised closer similarities in outcomes in established and new NCMs in comparison to prohibited NCMs.

Methods

Study design

Data are from Wave 1 of the International Tobacco Control Policy Evaluation Project Tobacco and Youth *E*-cigarette Survey, conducted in Canada, England and the USA. Data were collected via self-completed web-based surveys conducted in July/August 2017 with youth aged 16 through 19. Respondents were recruited through Nielsen's Consumer Insights Global Panel and their partners' panels, either directly or through their parents. Email invitations (with a unique link) were sent to a random sample of panelists (after targeting for age criteria); panelists known to be ineligible were not invited. A restriction on small screen size was applied to ensure that images presented in the survey could be viewed with a minimum amount of scrolling. The survey was conducted in English in all countries, as well as French in Canada, and took approximately 15 min to complete. The same survey measures were used in all countries, with the exception of race/ethnicity, region and education questions, which were based on census questions in each country. Respondents provided consent prior to completing the survey. Respondents received remuneration in accordance with their panel's usual incentive structure (e.g. points-based or monetary rewards, chances to win prizes).

Measures

Survey measures were drawn from existing national surveys [17] and adapted for the current study. In all cases, participants had the option of selecting 'Do not Know' or 'Refused'.

Socio-demographic. Socio-demographic measures included state of residency ('Prohibited NCMs'/'New NCMs'/'Established NCMs'), sex at birth ('male'/'female'), and age at time of survey. Ethnicity was recoded into 'white' vs. 'non-white'. Due to the age of participants, education was not included given the multi-collinearity with age. Income was captured by the number of computers in their home [18,19].

Cannabis consumption. All youth were asked: 'When was the last time you used marijuana/cannabis?' ('I have never used cannabis'/'Earlier today'/'Not today but sometime in the past week'/'Not in the past week but sometime in the past month'/'Not in the past month but sometime in the past 6 months'/'Not in the past 6 months but sometime in the past year'/'1 to 4 years ago'/'5 or more years ago'). Responses were recoded into 'Never' versus 'Used, but not in the last month' versus 'Used in the last month'. Do not 'Know' and 'Refused' responses were treated as missing.

Modes of use. All youth who reported to have used cannabis in the last month were asked: 'In the last 30 days, did you…' Answers were a 'Yes' versus 'No' checklist to the following options: Smoke cannabis without tobacco/Smoke cannabis with tobacco/Use a waterpipe or bong to smoke cannabis/Use a vapouriser to heat dried cannabis/use an e-cigarette to vape

cannabis/Eat or drink cannabis in a food or drink/Use cannabis extracts.

Perceived access to cannabis. All youth were asked 'How difficult do you think it would be for you to get cannabis, if you wanted?' ('Very difficult'/'Fairly difficult'/'Fairly easy'/'Very easy'). Answers were collapsed into 'Difficult' versus 'Easy'. 'Do not Know' and 'Refused' responses were treated as missing.

Perceptions of harm. All youth were asked 'How much do you think people harm themselves when they SMOKE marijuana/cannabis?' ('No harm'/'Little harm'/'Some harm'/'A lot of harm'). Answers were collapsed into 'A lot of harm' versus 'Other' (No harm/Little harm/Some harm/Do not know).

Youth who answered that they had used cannabis before were asked 'Are you worried that using marijuana/cannabis will damage your health in the future?' ('Not at all'/'A little'/'Moderately'/'Very'). Answers were collapsed into 'Not at all worried' versus 'Other' (A little/Moderately/Very/Do not know).

All youth were asked 'How much do you think people risk harming their mental health when they use marijuana/cannabis on a regular basis?' ('No'/'Slight'/'Moderate'/'Great'). 'Refused' was removed. Answers recoded into 'Great risk' versus 'Other' (No/Slight/Moderate/Do not know).

Driving after cannabis use. Youth who answered that they had used cannabis before were asked, 'Have you ever driven a car or other vehicle within two hours of using marijuana/cannabis?' ('No, never'/'Yes, in the last 30 days'/'Yes, more than 30 days ago'). All youth were also asked, 'To your knowledge, have you ever been a passenger in a car or other vehicle driven by someone who had been using marijuana/cannabis in the last two hours?' ('No, never'/'Yes, in the last 30 days'/'Yes, more than 30 days ago'). Answers to both questions were recoded into 'No, never' versus 'Yes' (In the last 30 days/More than 30 days ago). 'Do not Know' and 'Refused' responses were treated as missing.

All youth were asked, 'Do you think driving a car or other vehicle within two hours of using marijuana/cannabis increases the risk of getting into an accident?' All respondents were also asked 'If someone drives a car or other vehicle within two hours of using marijuana/cannabis, how likely are they to get caught by the police?' Response options for both questions were 'Not at all'/'A little'/'Somewhat'/'A lot', which were recorded into 'A lot' versus 'Other' (Somewhat/A little/Not at all/Do not know).

Statistical analysis

A total of 13 468 youth completed the survey and consented to the use of their data. After removing participants who provided incomplete or invalid data on smoking status, e-cigarette use or other variables used for weighting ($n = 1022$), as well as respondents who provided an incorrect response to a data quality check question ($n = 382$), a total of 12 064 respondents were retained for the analytic sample. A sub-sample of US youth ($n = 4097$) were included in the current analysis. As shown in Tables 1, 3328 youth were from Prohibited NCMs, including eight participants from the District of Columbia; 544 youth were from New NCMs (California, Maine, Massachusetts, Nevada); and 207 youth were from Established NCMs (Alaska, Colorado, Oregon, Washington).

Sample weights were constructed using a raking algorithm. First, respondents were divided into three cigarette smoking categories: never smokers, experimental smokers and current/former smokers. Raking was then performed based on geographic region, language in Canada and the following cross-classifications: sex by smoking, age by smoking and age by race/ethnicity in the USA. Finally, weights were rescaled to sample size within each country/condition, to allow for comparisons between countries with different population sizes.

Estimates reported are weighted unless otherwise specified. All models were adjusted for country, age, sex, ethnicity and number of computers in the home. Respondents were excluded from analyses for measures with missing data. Analyses were conducted with SAS 9.4.

Sample characteristics were examined, and χ^2 tests were used to assess differences across US jurisdictions. Multinomial logistic regression models were fitted to examine differences in the prevalence of cannabis use between regulatory 'conditions' (Established NCMs, New NCMs and Prohibited NCMs). Binary logistic regression were fitted to examine any differences between regulatory conditions for each of four outcomes: modes of use, perceived access to cannabis, perceptions of harm and driving after using cannabis.

Ethics

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#21847) and the King's College London Psychiatry, Nursing and Midwifery Research Ethics Subcommittee (PNM RESC).

Table 1. Unweighted (left) and weighed (right) sample characteristics by cannabis market in the United States (2017)

	Unweighted respondents (n = 4079)				Weighted respondents (n = 4079)			
	Prohibited states, % (n = 3350)	New non-medical states, % (n = 536)	Established non-medical states, % (n = 193)	P value for χ2	Prohibited states, % (n = 3328)	New non-medical states, % (n = 544)	Established non-medical states, % (n = 207)	P value for χ²
Sex				0.353				0.040
Female	60.1 (2012)	60.5 (324)	65.3 (126)		46.2 (1539)	46.3 (252)	55.3 (114)	
Male	39.9 (1338)	39.6 (212)	34.7 (67)		53.8 (1790)	53.7 (292)	44.7 (92)	
Age, years				0.309				0.774
16	21.8 (731)	20.5 (110)	22.3 (43)		22.9 (761)	24.3 (132)	21.5 (45)	
17	22.9 (768)	18.8 (101)	20.7 (40)		24.3 (808)	21.0 (114)	23.5 (49)	
18	30.4 (1018)	34.7 (186)	32.1 (62)		29.7 (987)	30.8 (168)	30.1 (62)	
19	24.9 (833)	25.9 (139)	24.9 (48)		23.2 (772)	24.0 (130)	24.9 (51)	
Ethnicity				<0.001				0.008
White	75.4 (2527)	63.1 (338)	76.2 (147)		79.6 (2650)	75.0 (408)	84.5 (175)	
Non-white	24.6 (823)	36.9 (198)	23.8 (46)		20.4 (678)	25.0 (136)	15.5 (32)	
No. of computers				0.565				0.036
None or one	9.6 (319)	9.6 (51)	6.3 (12)		10.6 (351)	8.9 (48)	4.7 (10)	
Two	19.3 (640)	18.0 (95)	20.3 (39)		21.0 (693)	19.1 (103)	23.7 (49)	
More than two	71.1 (2362)	72.4 (383)	73.4 (141)		68.4 (2253)	72.0 (387)	71.6 (148)	

Results

Table 1 shows unweighted and weighted sample characteristics in each US category ($n = 4097$).

Cannabis consumption

Table 2 indicates the prevalence of cannabis use in each US category. Overall, the majority of youth in Prohibited, New and Established NCMs had never used cannabis (70.9%, 65%, 63%, respectively). Youth in Prohibited NCMs were significantly less likely to have used cannabis in the last month (vs. never), than youth in New NCMs (adjusted odds ratio [AOR] = 0.69, 95% confidence interval [CI] 0.53,0.89, $P = 0.005$) or Established NCMs (AOR = 0.59, 95% CI: 0.40,0.86, $P = 0.006$). Findings were inconclusive between all regulatory conditions regarding cannabis use more than a month ago (vs. never).

Modes of use

As Table 2 shows, the most common method of cannabis use across Prohibited, New and Established NCMs was smoking cannabis without tobacco (90%, 93% and 97%, respectively). Youth in Prohibited NCMs were significantly less likely to have used a waterpipe/bong to smoke cannabis in the last 30 days than youth in New NCMs (AOR = 0.53, 95% CI 0.32, 0.87, $P = 0.011$), with no conclusive findings observed between youth in Prohibited and Established NCMs or New and Established NCMs.

Youth in Established NCMs were significantly more likely to have used an e-cigarette to vape cannabis in the last 30 days than youth in Prohibited (AOR = 2.61, 95% CI 1.31, 5.20, $P = 0.007$) or New NCMs (AOR = 2.42, 95% CI 1.07, 5.46, $P = 0.033$). Findings were inconclusive between youth in Prohibited and New NCMs.

Youth in Established NCMs were significantly more likely to have eaten or drank cannabis in a food or beverage in the last 30 days than youth in Prohibited NCMs (AOR = 2.08, 95% CI 1.06, 4.12, $P = 0.034$). Findings were inconclusive between youth in Prohibited and New NCMs or New and Established NCMs.

Youth in Prohibited NCMs were significantly less likely to have used cannabis extracts including oil, wax or shatter in the last 30 days than youth in New (AOR = 0.59, 95% CI 0.35, 0.97, $P = 0.037$) or Established NCMs (AOR = 0.29, 95% CI: 0.15, 0.57, $P < 0.001$). Findings were inconclusive between youth in New and Established NCMs.

In addition, no conclusive findings were observed between youth in all regulatory conditions regarding their use of cannabis with or without tobacco, or their use of a vaporiser to heat cannabis leaves.

Perceived access to cannabis

As Table 2 shows, approximately two-thirds of youth in New (67%) and Established NCMs (68%) reported that it was easy to obtain cannabis if they wanted compared to 58.9% of youth in Prohibited NCMs. Youth in Prohibited NCMs were significantly less likely to report that it was easy to get cannabis than youth in New (AOR = 0.71, 95% CI 0.58, 0.86, $P < 0.001$) or Established NCMs (AOR = 0.67, 95% CI 0.49, 0.92, $P = 0.013$).

Perceptions of harm

Approximately a third of youth in Prohibited, New and Established NCMs reported that people harm themselves 'a lot' when they smoke cannabis (28.5%, 25% and 31%, respectively). A similar proportion of youth reported that regular cannabis use presents a 'great risk' to mental health (29.7%, 26% and 28%, respectively). Of those who had used cannabis, the majority of all youth were 'not at all' worried that cannabis will damage their health in the future, as shown in Table 2. Findings were inconclusive between youth in all regulatory conditions for any perception of cannabis harm questions.

Driving after cannabis use

As Table 2 shows, approximately a quarter of youth in Prohibited (29%) and Established NCMs (26%) reported they had 'ever' driven a car within 2 h of using cannabis, compared to 19% of youth in New NCMs. Youth in Prohibited NCMs were significantly more likely to report having driven a car within 2 h of using cannabis than youth in New NCMs (AOR = 1.78, 95% CI 1.19, 2.67, $P = 0.005$). Findings were inconclusive between youth in Prohibited and Established NCMs or youth in New and Established NCMs.

Approximately a quarter of youth in Prohibited (24.2%), and New NCMs (29%) had been a passenger in a car driven by someone who had been using cannabis in the last 2 h, compared to 30% of youth in Established NCMs. Youth in Prohibited NCMs were significantly less likely to have been a passenger in a

car within 2 h of the driver using cannabis than youth in New NCMs (AOR = 0.78, 95% CI 0.63, 0.98, $P = 0.029$). Findings were inconclusive between youth in Prohibited and Established NCMs or youth in New and Established NCMs.

Approximately half of youth in Prohibited, New and Established NCMs reported that driving a car within 2 h of using cannabis increases the risk of an accident by 'a lot' (43.8%, 44% and 42%, respectively). Findings were inconclusive between youth in all regulatory conditions.

Approximately half of youth in all regulatory conditions reported that they would be 'a lot' or 'somewhat' likely to be caught by the police if they were driving a car within 2 h of using cannabis. Youth in Prohibited NCMs reported a higher likelihood of getting caught (AOR = 1.28, 95% CI 1.06, 1.54, $P = 0.009$) than youth in New NCMs, with no conclusive findings observed between youth in Prohibited and Established NCMs or in New and Established NCMs.

Discussion

Consistent differences in perceptions and patterns of cannabis use were observed between jurisdictions with and without legal non-medical cannabis. Overall, youth were more likely to report using cannabis in states that have legalised non-medical cannabis, similar to prevalence from national surveys. Data from a US survey conducted in 2013–2014 found that the highest rates of youth use were in states that had a 'new' or 'established' non-medical cannabis market [20]. This survey was conducted before states with a newly legalised market had passed their laws in 2014, suggesting that these states already had higher levels of use than non-legal states. Longitudinal studies conducted on pre and post legalisation in established non-medical cannabis markets have generally shown few changes in cannabis use among youth, which suggests that differences between states with and without legalised non-medical cannabis may be due to pre-existing trends rather than policy changes [10,11,21]. This is similar to what was found pre and post medical cannabis laws [22–24]. The lack of conclusive findings between states with new and established non-medical cannabis markets is consistent with this prior research.

In addition to higher rates of overall use, cannabis users living in legal states were more likely to report consuming cannabis edibles and extracts. These findings are consistent with the proliferation of commercially prepared edibles and extracts that are available in non-medical cannabis retail outlets in states such as Colorado and Washington State. Although the

Table 2. *Weighted outcome variables by cannabis market in the United States (2017)*

	Respondents used in analysis (n = 4079)			
	Prohibited states, % (n = 3328)	New non-medical states, % (n = 544)	Established non-medical states, % (n = 207)	P value for χ^{2a}
Consumption measures				
When was the last time you used cannabis?				0.003
Never	70.9 (2294)	64.9 (348)	63.2 (129)	
Used, but not in the last month	15.8 (510)	17.5 (94)	16.5 (34)	
Used in the last month	13.3 (431)	17.6 (94)	20.3 (42)	
Modes of use (In the last 30 days, did you…)[b]				
Smoke cannabis WITHOUT tobacco?				0.249
Yes	89.9 (383)	92.5 (85)	97.1 (40)	
No	10.2 (43)	7.5 (7)	2.9 (1)	
Smoke cannabis WITH tobacco in a joint or blunt?				0.273
Yes	32.7 (138)	30.6 (28)	20.5 (8)	
No	67.3 (285)	69.4 (64)	79.5 (33)	
Use a waterpipe/bong to smoke cannabis?				0.041
Yes	52.9 (227)	66.9 (62)	59.7 (25)	
No	47.1 (202)	33.1 (31)	40.3 (17)	
Use a vapouriser to heat dried cannabis leaves or herb?				0.717
Yes	22.4 (96)	18.6 (17)	22.8 (9)	
No	77.6 (331)	81.4 (75)	77.2 (30)	
Use an e-cigarette to vape cannabis oil or liquid?				0.032
Yes	24.2 (103)	27.8 (26)	43.1 (17)	
No	75.8 (324)	72.2 (67)	56.9 (22)	
Eat or drink cannabis in a food or a beverage?				0.099
Yes	26.2 (112)	32.2 (30)	40.4 (17)	
No	73.8 (316)	67.8 (63)	59.7 (25)	
Use cannabis extracts, including oil, wax or shatter?				<0.001
Yes	23.9 (103)	34.8 (32)	48.0 (20)	
No	76.1 (327)	65.3 (60)	52.0 (23)	
Access				
How difficult do you think it would be for you to get cannabis, if you wanted?				<0.001
Difficult	41.1 (1230)	33.1 (167)	32.1 (61)	
Easy	58.9 (1764)	66.9 (337)	67.9 (130)	
Perceptions of harm				
How much do you think people harm themselves when they SMOKE cannabis?				0.188
A lot of harm	28.5 (947)	25.2 (137)	30.9 (64)	
Otherwise (Some/Little/No harm/do not know)	71.5 (2378)	74.8 (407)	69.1 (143)	
How much do you think people risk harming their mental health when they use cannabis on a regular basis?				0.189
Great risk	29.7 (987)	26.0 (141)	27.8 (58)	
Otherwise (Moderate/Slight/No/Do not know)	70.3 (2333)	74.0 (402)	72.2 (149)	
Are you worried that using cannabis will damage your health in the future?[b]				0.102
Not at all worried	67.4 (290)	55.9 (53)	63.8 (27)	
Otherwise (Little/Moderately/Very/Do not know)	32.6 (140)	44.1 (42)	36.2 (15)	
Cannabis and driving				
Have you ever driven a car or other vehicle within 2 h of using cannabis?[b]				0.017
No, never	70.7 (650)	81.0 (148)	73.9 (54)	
Yes	29.3 (270)	19.1 (35)	26.1 (19)	

(Continues)

Table 2. (Continued)

	Respondents used in analysis (n = 4079)			
	Prohibited states, % (n = 3328)	New non-medical states, % (n = 544)	Established non-medical states, % (n = 207)	P value for χ^{2a}
Have you ever been a passenger in a car or other vehicle driven by someone who had been using cannabis in the last 2 h?				0.031
No, never	75.8 (2294)	71.4 (350)	69.9 (130)	
Yes	24.2 (731)	28.6 (140)	30.1 (56)	
Do you think driving a car or other vehicle within 2 h of using cannabis increases the risk of getting into an accident?				0.845
A lot	43.8 (1454)	43.7 (237)	41.8 (86)	
Otherwise (Somewhat/Little/Not at all/Do not know)	56.2 (1865)	56.3 (306)	58.2 (120)	
If someone drives a car or other vehicle within 2 h of using cannabis, how likely are they to get caught by the police?				0.020
Not at all/A little/Do not know	50.1 (1663)	56.6 (308)	52.1 (108)	
A lot/Somewhat	49.9 (1656)	43.4 (236)	47.9 (99)	

[a]Unadjusted bivariate analyses. [b]Participants are those who had answered 'Yes' to using cannabis in the last month.

differences between these new and established legal markets were not conclusive, this was largely due to a lack of power due to smaller sample sizes in these regulatory conditions, and the pattern of data is consistent with greater consumption of edibles and extracts in states with established markets [25,26]. However, it is worth noting that, among all jurisdictions, smoking cannabis remains the dominant form of consumption among youth [27].

Youth in states with prohibited markets were less likely to report it was easy to obtain cannabis than youth in legalised states. One could predict that the legalisation of non-medical cannabis would increase youth access by providing more visible and alternate methods, such as storefronts, via advertising or through cultivation in the home [28,29]. Due to the age of participants, youth would not have direct access to the non-medical market; however, in states with established markets, youth have reported increased access [30]. Future research should examine the impact of home cultivation on youth access.

Although it has been suggested that cannabis legalisation will reduce perceptions of risk, no conclusive findings were observed between regulatory conditions for perceptions of physical and mental harm from cannabis use. Most states that have legalised non-medical cannabis have increased public education and mass media campaigns, as one component of their broader cannabis legalisation policy. For example, Washington State and Colorado launched prevention campaigns targeted at youth where they promoted alternative activities to pursue instead of using cannabis [31,32]. While legalisation may have the potential to soften perception of risk among young people, the communication campaigns that have accompanied cannabis legalisation may have attenuated or counteracted any such effect.

Few differences in driving after cannabis use were observed between regulatory conditions. Youth in prohibited states were almost twice as likely to report driving a car within 2 h of using cannabis but less likely to have been a passenger than youth in newly legalised states. However, findings were inconclusive between youth in states with a prohibited and established market or with a new and established market. The pattern of findings is similar to the data on perceptions of risk, and may reflect greater public education and enforcement activities in states that have legalised non-medical cannabis. As states have legalised non-medical cannabis, they have also prohibited cannabis-impaired driving with a 5 ng/mL threshold of THC in the blood, whereas cannabis-impaired laws are inconsistent across prohibited states [33,34]. Most states with prohibited markets have 'effect-based DUI' laws which requires proof of recent ingestion. However, proving recent ingestion is not straightforward due to a current lack of a reliable equivalent to the breathalyser for alcohol [34]. Youth in prohibited states were somewhat more likely to report that using cannabis within 2 h of driving increases your chances to be caught by the police, than youth in newly legalised states but not in states with an established market, with no conclusive findings

between youth in new and established markets. The underlying reason for this pattern of results is unclear. It is possible that the transition to more permissive non-medical cannabis regulations promotes a perception that cannabis is no longer of law enforcement priority, including impaired driving; whereas, this message perception is corrected after the cannabis market has been established and communication campaigns have been implemented [35,36]. Future research should examine changes during this key transition period to examine this possibility.

It should be noted that there are other, larger studies that track cannabis trends, such as Monitoring the Future (MTF) and the National Survey on Drug Use and Health (NSDUH) [37,38]. However, unlike MTF or NSDUH, the current study includes more comprehensive measures of cannabis use that allows us to explore potential differences on a greater number of policy-relevant outcomes.

Limitations

This study has several limitations. Self-report data are subject to memory recall and social desirability biases. Non-medical cannabis remains illegal at the federal level, which may result in underreporting. The sample sizes differ substantially; however, the proportions could be expected from the number and size of the states within each category. Another limitation is that in November 2014, DC had legalised the personal use of non-medical cannabis. However, DC does not have a non-medical retail market in which consumers can lawfully buy non-medical cannabis. Therefore, consumers can only grow cannabis at home or receive it as a gift (where there is no monetary exchange). As such, it was categorised with states that had prohibited markets rather than established legal markets. Supplementary analyses were conducted with DC included with established markets, and conclusions remained the same. Finally, non-probability methods were used to recruit the sample; however, the sample was weighted on region, age, sex and smoking status to established population benchmarks.

Conclusion

Overall, prevalence of use was somewhat higher in states that had legalised non-medical cannabis, with similar levels of risk perceptions and driving after cannabis use. Relatively few differences were observed between states with an established market and those that only recently legalised, which suggests that

differences between legal and non-legal states may be partly due to pre-established trends and a type of 'self-selection' effect, in that states that legalise non-medical cannabis typically have higher rates of cannabis use anyway. The findings provide preliminary support for the importance of public education campaigns that typically accompany cannabis legalisation to help shape risk perception. Future research that compares different regulatory conditions using pre-post longitudinal data will help to elucidate the extent to which regulatory changes influence cannabis use among young people.

Conflict of Interest

The authors have no conflicts of interest to declare.

References

[1] Center for Behavioral Health Statistics and Quality. Key substance use and mental health indicators in the United States: results from the 2015 national survey on drug use and health. HHS Publication No. SMA 16–4984, NSDUH Series H-51; 2016 Available at: http://store.samhsa.gov/data (accessed 31 January 2018).

[2] Asbridge M, Hayden JA, Cartwright JL. Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. BMJ 2012;344:e536.

[3] National Academies of Sciences, Engineering, and Medicine. The health effects of cannabis and cannabinoids: the current state of evidence and recommendations for research. Washington: The National Academies Press, 2017. https://doi.org/10.17226/24625.

[4] Stiby AI, Hickman M, Munafò MR, Heron J, Yip VL, Macleod J. Adolescent cannabis and tobacco use and educational outcomes at age 16: birth cohort study. Addiction 2015;110:658–68.

[5] Whitehill JM, Rivara FP, Moreno MA. Marijuana-using drivers, alcohol-using drivers, and their passengers. JAMA Pediatr 2014, 2014;168:618.

[6] Galston WA, Dionne E. The new politics of marijuana legalisation: why opinion is changing. The Brookings institution; 2012 Available at: https://www.brookings.edu/research/the-new-politics-of-marijuana-legalisation-why-opinion-is-changing/ (accessed 31 January 2018).

[7] Hall W, Weier M. Assessing the public health impacts of legalizing recreational cannabis use in the USA. Clin Pharmacol Ther 2015;97:607–15.

[8] Hall W, Lynskey M. Evaluating the public health impacts of legalizing recreational cannabis use in the United States. Addiction 2016;111:1764–73.

[9] Pacula RL, Sevigny EL. Marijuana liberalization policies: why we can't learn much from policy still in motion. J Policy Anal Manage 2014;33:212–21.

[10] Colorado Department of Public Health & Environment. Monitoring health concerns related to marijuana in Colorado: 2016. Changes in marijuana use patterns, systematic literature review, and possible marijuana-related health effects. Colorado: Colorado Department of Public Health & Environment, 2016 Available at: https://drive.google.com/file/d/0B0tmPQ67k3NVQlFnY3VzZGVmdFk/view (accessed 31 January 2018).

[11] Forecasting and Research Division. Monitoring impacts of recreational marijuana legalisation 2016 update report monitoring impacts of recreational marijuana legalisation. Washington; 2017 Available at: https://www.ofm.wa.gov/sites/default/files/public/legacy/reports/marijuana_impacts_update_2016.pdf (accessed 31 January 2018).

[12] Rocky Mountain High Intensity Drug Trafficking Area. The legalisation of marijuana in colorado: the impact. Rocky Mountain HIDTA; 2017. Available at: http://www.rmhidta.org/html/FINAL 2017 Legalisation of Marijuana in Colorado The Impact.pdf (accessed 31 January 2018).

[13] Smart Approaches to Marijuana. Lessons learned after 4 years of marijuana legalisation. Smart Approaches to Marijuana; 2016 Available at: https://learnaboutsam.org/wp-content/uploads/2016/11/SAM-report-on-CO-and-WA-issued-31-Oct-2016.pdf (accessed 31 January 2018).

[14] Keyes KM, Wall M, Cerdá M et al. How does state marijuana policy affect US youth? Medical marijuana laws, marijuana use and perceived harmfulness: 1991-2014. Addiction 2016;111:2187–95.

[15] Johnston LD, O'Malley PM, Miech RA, Bachman JG, Schulenberg JE. Monitoring the future national survey results on drug use, 1975–2016: overview, key findings on adolescent drug use. Ann Arbor: Institute for Social Research, The University of Michigan, 2017 Available at: http://www.monitoringthefuture.org/pubs/monographs/mtf-overview2016.pdf (accessed 31 January 2018).

[16] Salloum NC, Krauss MJ, Agrawal A, Bierut LJ, Grucza RA. A reciprocal effects analysis of cannabis use and perceptions of risk. Addiction 2018;113:1077–85.

[17] Government of Canada. Canadian student tobacco, alcohol and drugs survey. Ottawa: Health Canada, 2016 Available at: https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey.html (accessed 1 February 2018).

[18] Hartley JEK, Levin K, Currie C. A new version of the HBSC family affluence scale -FAS III: Scottish qualitative findings from the international FAS development study. Child Ind Res 2016;9:233–45.

[19] Torsheim T, Cavallo F, Levin KA et al. Psychometric validation of the revised family affluence scale: a latent variable approach. Child Indic Res 2016;9:771–84.

[20] Hughes A, Lipari R, Williams M. State estimates of adolescent marijuana use and perceptions of risk of harm from marijuana use: 2013 and 2014. The Substance Abuse and Mental Health Services Administration (SAMHSA); 2015 Available at: https://www.samhsa.gov/data/sites/default/files/report_2121/ShortReport-2121.html (accessed 28 January 2018).

[21] Cerdá M, Wall M, Feng T et al. Association of state recreational marijuana laws with adolescent marijuana use. JAMA Pediatr 2017;171:142–9.

[22] Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? Replication study and extension. Ann Epidemiol 2012;22:207–12.

[23] Hasin DS, Wall M, Keyes KM et al. Medical marijuana laws and adolescent marijuana use in the USA from 1991 to 2014: results from annual, repeated cross-sectional surveys. Lancet Psychiatry 2015;2:601–8.

[24] Wall MM, Poh E, Cerdá M, Keyes KM, Galea S, Hasin DS. Adolescent marijuana use from 2002 to 2008: higher in states with medical marijuana laws, cause still unclear. Ann Epidemiol 2011;21:714–6.

[25] Coombes R. Cannabis regulation: high time for change? BMJ 2014;348: g3382.

[26] Hopfer C. Implications of marijuana legalisation for adolescent substance use. Subst Abus 2014;35:331–5.

[27] Hindocha C, Freeman TP, Ferris JA, Lynskey MT, Winstock AR. No smoke without tobacco: a global overview of cannabis and tobacco routes of administration and their association with intention to quit. Front Psych 2016;7:104.

[28] Lynne-Landsman SD, Livingston MD, Wagenaar AC. Effects of state medical marijuana laws on adolescent marijuana use. Am J Public Health 2013;103:1500–6.

[29] Schuermeyer J, Salomonsen-Sautel S, Price RK et al. Temporal trends in marijuana attitudes, availability and use in Colorado compared to non-medical marijuana states: 2003–11. Drug Alcohol Depend 2014; 140:145–55.

[30] Harpin SB, Brooks-Russell A, Ma M, James KA, Levinson AH. Adolescent marijuana use and perceived ease of access before and after recreational marijuana implementation in Colorado. Subst Use Misuse 2018;53:451–6.

[31] Pardo B. Cannabis policy reforms in the Americas: a comparative analysis of Colorado, Washington, and Uruguay. Int J Drug Policy 2014;25:727–35.

[32] Washington State Department of Health. You Can. Washington State Department of Health; 2018 Available at: https://www.youcanwa.org/ (accessed 3 May 2018)

[33] Colorado Department of Public Health & Environment. Protect What's Next Retail Marijuana Education Program; 2017 Available at: http://protectwhatsnext.com/ (accessed 3 May 2018)

[34] Compton R. Marijuana-impaired driving: a report to congress. Washington: National Highway Traffic Safety Administration, 2017 Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812440-marijuana-impaired-driving-report-to-congress.pdf (accessed 1 February 2018).

[35] Colorado Department of Transportation. Drugged driving: campaign materials. Colorado Department of Transportation; 2017 Available at: https://www.codot.gov/safety/alcohol-and-impaired-driving/druggeddriving/safety/alcohol-and-impaired-driving/druggeddriving/campaign-materials.html (accessed 31 January 2018).

[36] Hall W. How should we respond to cannabis-impaired driving? Drug Alcohol Rev 2018;37:3–5.

[37] University of Michigan. Monitoring the future: a continuing study of American youth. University of Michigan; 2018 Available at: http://www.monitoringthefuture.org/ (accessed 3 May 2018)

[38] Substance Abuse and Mental Health Services Administration. National Survey on Drug Use and Health (NSDUH). Substance Abuse and Mental Health Services Administration; 2018 Available at: https://nsduhweb.rti.org/respweb/homepage.cfm (accessed 3 May 2018)