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## Joint perceptions of the risk and availability of Cannabis in the United States, 2002-2018

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## ABSTRACT

**Background:** Prior work suggests that perceived risk and perceived availability of cannabis independently affect cannabis use. However, perceived risk likely modifies the effect of perceived availability, and vice versa. This study explored trends in joint perceived risk and availability of cannabis from 2002 to 2018 and the relationship between combined perceptions and cannabis use, frequent use, and cannabis use disorder (CUD).

**Methods:** National Surveys on Drug Use and Health data (n = 949,285, ages 12+) were used to create combined categories of perceived risk of weekly cannabis use and perceived cannabis availability. Descriptive analyses compared joint perceived risk/availability trends (pre/post-2015 due to survey redesign) overall and stratified by age, gender, past-year cannabis use, frequent use, and CUD. Regression analysis estimated associations between perceived risk/availability and cannabis outcomes.

**Results:** From 2002 to 2018, the prevalence of perceiving cannabis as low-risk doubled while perceiving cannabis as available remained unchanged. The proportion of individuals perceiving cannabis as Low-risk/Available increased by 86% from 2002 to 2014 (16.8%–31.2%) and 19% from 2015 to 2018 (30.1%–35.8%) while High-risk/Available and High-risk/Unavailable proportions declined. Differing patterns were observed by age and gender. Compared with individuals perceiving cannabis as High-risk/Unavailable, people in all other perception categories had greater risk of all cannabis outcomes. Results were consistent with additive interaction between perceived risk and availability in their effects on cannabis use.

**Conclusions:** Trends and associations with cannabis outcomes differ when considering perceived risk and availability independently versus jointly. Longitudinal studies and cannabis policy evaluations would advance understanding of links between cannabis perceptions and use.

### 1. Introduction

Previous work around cannabis use and perceptions supports the health behavior theory, which posits that individual health-related behaviors—including substance use—are influenced by both individual and contextual factors (Glanz et al., 2014; Janz and Becker, 2016; Rosenstock, 1974). Societal norms around the use and availability of legal and illegal substances are theorized to shape individual perceptions about the acceptability, availability, and risk of substances and these perceptions, in turn, influence individuals' substance use behavior (Glanz et al., 2014; Johnston, 2003; Keyes et al., 2011). From 2002 to 2014, the prevalence of past-year cannabis use in the United States (U.S.) increased from 10.4%–13.3% (Azofeifa et al., 2016; Compton et al., 2016). During this period, the prevalence of perceiving cannabis use as

high risk decreased, resulting in an inverse relationship between perceived great risk of cannabis and cannabis use (Azofeifa et al., 2016; Bachman et al., 1998; Carliner et al., 2017a; Compton et al., 2016; Hughes et al., 2013; Johnston, 2003; Keyes et al., 2016; Kilmer et al., 2007; Lipari et al., 2017; Okaneku et al., 2015; Pacek et al., 2015). These changes also coincided with expanding cannabis legalization (Klieger et al., 2017; ProCon.org, 2021). In light of substantial shifts in both cannabis policies and use over the past two decades, researchers have sought to understand how perceptions of cannabis and the relationship between cannabis perceptions and cannabis use outcomes may be evolving (Azofeifa et al., 2016; Gillespie et al., 2009; Martins et al., 2016).

Most studies of cannabis perceptions and use have focused on adolescents and young adults due to concerns about the potential impact of

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early initiation of cannabis and ensuing negative consequences for this age group. Evidence on recent shifts in adolescent and young adult perceptions of the harm and availability of cannabis is inconsistent. Among studies covering the period 1991 to 2014, some found an increasing prevalence of adolescents and young adults perceiving cannabis as low risk and as easily available (Brooks-Russell et al., 2019; Harpin et al., 2018; Sarvet et al., 2018b; Wen et al., 2019) while others documented increasing perceived harmfulness (Keyes et al., 2016; Wen et al., 2019) or no changes in perceived risk (Blevins et al., 2018) or perceived availability (Brooks-Russell et al., 2019; Wen et al., 2019). Concurrently, the prevalence of both past-month (Sarvet et al., 2018b) and past-year (Lipari, 2018) cannabis use decreased in this age group and most studies have not found evidence of increasing cannabis use among adolescents or young adults following the passage of medical or recreational cannabis laws (Blevins et al., 2018; Brooks-Russell et al., 2019; Cerdá et al., 2017; Harpin et al., 2018; Sarvet et al., 2018a). Although individual risk perceptions are associated with cannabis use among adolescents and young adults, the strength of this relationship appears to have decreased over time (Sarvet et al., 2018b). Based on these observations, some authors have questioned whether trends in perceptions remain a reliable indicator of future trends in cannabis use for adolescents and young adults (Sarvet et al., 2018b).

Evidence from the few available studies of the total and adult ( $\geq 18$  years) U.S. populations suggests differences in the relationship between cannabis perceptions and use both within and across age categories. Findings for adults are more consistent than those for younger ages, with increased cannabis use accompanied by decreases in the perceived risk of cannabis (Choi et al., 2018; Compton et al., 2016; Han et al., 2016) and by increases in perceived availability (Martins et al., 2016). Indeed, overall increases in the population prevalence of past-year cannabis use from 2002 to 2014 were driven by adults while decreasing or stable prevalence of cannabis use was observed for 12–17-year-olds (Mauro et al., 2018). Frequent cannabis use prevalence has increased for all ages 12–64 since 2007 while the prevalence of cannabis use disorder (CUD) has decreased, even among those using cannabis frequently, with the largest declines in CUD seen among adolescents (Compton et al., 2019; Mauro et al., 2018; Santaella-Tenorio et al., 2019). This disconnect may be due to changes in the characteristics of individuals using cannabis, which may be reflected in changing perceptions (Compton et al., 2016). Evidence also suggests that younger adults perceive fewer risks associated with cannabis use compared with older adults (Carliner et al., 2017a; Lipari et al., 2017; Okaneku et al., 2015), whereas older adolescents view cannabis as less harmful than younger adolescents (Keyes et al., 2011; Lipari et al., 2017; Schmidt et al., 2016; Wen et al., 2019). Additionally, across the age spectrum, males tend to perceive cannabis as lower risk compared with females and from 2002 to 2014, cannabis use increased more rapidly among males than females (Carliner et al., 2017a; Hellemans et al., 2019; Okaneku et al., 2015; Pacek et al., 2015).

While there is a broad literature documenting trends in perceived risk and availability and their respective relationships with cannabis use, all studies to date have explored perceived risk and perceived availability in isolation. However, it is likely that the effect of perceived availability on individual cannabis use is modified by perceived risk, and vice-versa. For example, among individuals who believe there are no risks associated with cannabis use, the propensity to use cannabis is likely higher for those who perceive cannabis as widely available compared with those who perceive it as difficult to obtain. As such, examining perceived risk and availability in conjunction may shed light on previous unexpected findings, such as the apparent decoupling of trends in cannabis-related perceptions and cannabis use among adolescents and young adults (Fleming et al., 2016; Sarvet et al., 2018b). Furthermore, health behavior theory predicts an interplay between changing social conditions and perceptions of the availability and risk of substances in influencing individual substance use decisions (Glanz et al., 2014; Janz and Becker, 2016; Johnston, 2003; Keyes et al., 2011; Rosenstock, 1974) and perceptions have been found to differ among

those who do and do not use cannabis (Pacek et al., 2015). As such, trends in joint perceptions of cannabis risk and availability may be evolving in response to changes in cannabis policies and as the overall prevalence of cannabis use continues to increase (Klieger et al., 2017; Lipari, 2018; Pacula et al., 2015; ProCon.org, 2021). Based on previous studies, the relationships between perceived risk/availability and cannabis use, frequent use, and CUD are also likely to differ by age and gender (Carliner et al., 2017b; Lipari et al., 2017; Martins et al., 2016; Mauro et al., 2018; Okaneku et al., 2015; Pacek et al., 2015).

In this study, we aimed to describe trends in combined categories of perceived risk and perceived availability from 2002 to 2018 for the overall U.S. community-based population ages 12 and older. We stratified associations by age, gender, past-year cannabis use, frequent use, and CUD and also explored relationships between joint cannabis perceptions and cannabis outcomes. We hypothesized that examining perceptions of risk and availability together would reveal different trends than are observed for each alone, potentially shedding light on previous unexpected findings. We further hypothesized that the combined effect of perceived risk and perceived availability on past-year cannabis use, frequent use, and CUD would differ from the effects of either one alone.

## 2. Methods

### 2.1. Data source and study population

Data were obtained from 2002 to 2018 National Survey on Drug Use and Health (NSDUH) public-use files. The NSDUH is conducted annually and is the primary source of information on substance use by the U.S. civilian, non-institutionalized population ages 12 years and older (Center for Behavioral Health Statistics and Quality, 2019). The NSDUH employs a multistage area probability sample design to produce state- and nationally-representative estimates. Participants were interviewed in person in their home in English or Spanish using a combination of questions asked and recorded directly by the interviewer and audio computer-assisted self-interviewing. Since 2002, respondents receive \$30 for participation. The average weighted interview response rate from 2002 to 2018 was 73% (range: 67%–79%) resulting in a combined sample size of 949,285 observations. Additional details of the NSDUH methodology have been published previously (Center for Behavioral Health Statistics and Quality, 2019).

### 2.2. Measures

#### 2.2.1. Joint perceived risk and perceived availability of cannabis use

To gauge perceived risk of regular cannabis use, all NSDUH participants were asked: “How much do people risk harming themselves physically and in other ways when they smoke cannabis once or twice a week?” Responses were dichotomized as “Low-risk” (“No risk” or “Slight risk”) and “High-risk” (“Moderate risk” or “Great risk”). Perceptions of cannabis availability were measured by the question: “How difficult or easy would it be for you to get some cannabis, if you wanted some?” Responses of “Fairly easy” and “Very easy” were coded as “Available” and “Probably impossible”, “Very difficult”, and “Fairly difficult” were coded as “Unavailable.” We combined the dichotomized risk and availability variables to create a single variable representing joint perceptions of cannabis risk and availability, which was categorized as: “High-risk/Available”, “High-risk/Unavailable”, “Low-risk/Available”, and “Low-risk/Unavailable.”

#### 2.2.2. Past-year cannabis use and frequent cannabis use

Participants affirming ever using cannabis were asked about frequency and recency of use. Using the NSDUH imputation-revised frequency of past-year use variable, those reporting using cannabis 1–365 days in the past year were coded as “Yes” for past-year use and those reporting never using cannabis or not using in the past year were coded as “No.” Following previous work, frequent cannabis use was defined as

using cannabis on  $\geq 300$  days in the past year (Mauro et al., 2018).

### 2.2.3. Cannabis use disorder (CUD)

NSDUH assessed past-year CUD using individual criteria following the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) for cannabis abuse and/or dependence (American Psychiatric Association, 1994). Consistent with recent work (Compton et al., 2019), we used DSM-IV cannabis abuse and dependence criteria to create a proxy of the updated DSM-5 CUD definition, which removed legal problems and added craving and withdrawal to the criteria (American Psychiatric Association, 2013; Hasin et al., 2013). The DSM-5 CUD proxy measure excluded craving and withdrawal symptoms which were not collected in the NSDUH (Compton et al., 2019). The mapping of NSDUH questions to DSM-5 criteria is provided in Table S1. Results were similar using both definitions; as such, only results using the DSM-5 proxy measure are presented.

### 2.2.4. Sociodemographic variables

Participant gender and age were included as sociodemographic variables. Interviewers recorded respondents' gender as either male or female and participants provided their date of birth and confirmed their age at interview. Age was categorized using a 5-level variable (12–17, 18–25, 26–34, 35–49, and 50+ years) provided in the public-use data. We used imputed age and gender variables provided by NSDUH that are corrected for missing and ambiguous responses (Center for Behavioral Health Statistics and Quality, 2019).

## 2.3. Statistical analysis

Descriptive analyses explored trends in perceived risk of cannabis, perceived availability of cannabis, and joint perceived risk/availability. Mean linear trends were assessed separately for 2002 to 2014 and 2015 to 2018. The Center for Behavioral Health Statistics and Quality determined that trends in perceived risk before and after 2015 were not comparable due to the 2015 NSDUH redesign. Starting in 2015, some questions were added, removed, or reworded; response choices were edited; and data collection procedures were changed (Center for Behavioral Health Statistics and Quality, 2016). Weighted annual proportions and accompanying 95% confidence intervals (CI) were calculated and analyzed both overall and stratified by age, gender, past-year cannabis use, frequent use, and CUD. Analyses accounted for the NSDUH complex survey design and incorporated analysis weights to account for sampling selection, adjust for nonresponse, and allow for post-stratification weighting to generalize to the U.S. non-institutionalized population. Mean trends over time were assessed using individual-level NSDUH data per National Center for Health Statistics guidelines (Ingram et al., 2018). A logistic regression model with continuous year as a predictor and a 5% alpha level were used to identify statistically significant linear trends.

Relative risk regression was used to estimate overall associations between perceived risk and availability of cannabis and past-year cannabis use, frequent cannabis use, and CUD. Models were constructed using a Poisson distribution, log link, and robust standard errors to generate coefficients interpretable as risk ratios (Naimi and Whitcomb, 2020; Zou, 2004); incorporated analysis weights; and applied standard error corrections to account for clustering resulting from the NSDUH complex survey design. For each cannabis use outcome, three models were executed with differing exposure variables: 1) perceived risk alone, 2) perceived availability alone, and 3) combined perceived risk/availability. All models were adjusted for age, gender, and continuous year as confounders associated with both perceptions and cannabis use outcomes (Azofeifa et al., 2016; Carliner et al., 2017a; Martins et al., 2016; Mauro et al., 2018; Pacek et al., 2015). Additive interaction was assessed using relative excess risk due to interaction (RERI), calculated using estimated relative risks (RR) as:  $RR(\text{Low-risk/Available}) - RR(\text{Low-risk/Unavailable}) - RR(\text{High-risk/Available}) + 1$  (Mathur and

VanderWeele, 2018; Rothman and Greenland, 1998; VanderWeele and Knol, 2014). RERI values greater than zero are indicative of additive interaction (Mathur and VanderWeele, 2018; Rothman and Greenland, 1998; VanderWeele and Knol, 2014). Standard errors for RERI were calculated using the delta method developed by Hosmer and Lemeshow (Assmann et al., 1996; Hosmer et al., 2008; Hosmer and Lemeshow, 1992).

All analyses were conducted using R software v4.0.0; the *survey* package was used to produce weighted estimates and calculate Horvitz-Thompson-type design-based standard errors accounting for clustering (Lumley, 2020, 2010; R Core Team, 2020).

This study was approved as exempt research by the Columbia University Institutional Review Board.

## 3. Results

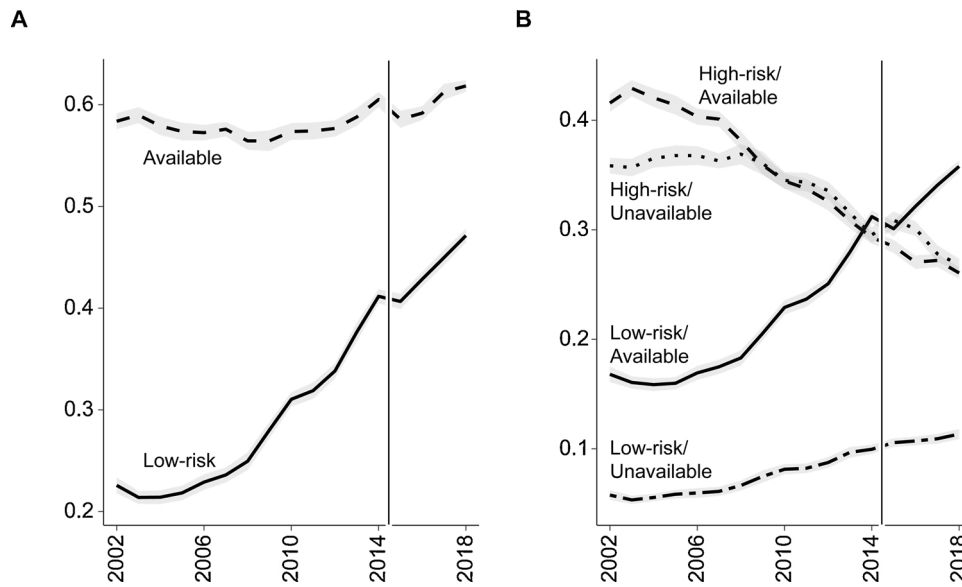
### 3.1. Trends in perceived risk and perceived availability of cannabis

From 2002 to 2014, the prevalence of perceiving cannabis use as low risk nearly doubled, from 22.6%–41.2% (Fig. 1A). From 2015 to 2018, the prevalence grew by 16%, from 40.7%–47.1%. The proportion of the population perceiving cannabis as available increased marginally over this period. Combining perceptions of cannabis risk and availability revealed a more nuanced pattern (Fig. 1B). In 2002, most of the population perceived cannabis as High-risk/Available (41.6%) or High-risk/Unavailable (35.8%), while only 16.8% perceived cannabis as Low-risk/Available. From 2002 to 2014, the prevalence of perceiving cannabis as Low-risk/Available increased by 86% (16.8%–31.2%) and by 19% from 2015 to 2018 (30.1%–35.8%). By 2018, a larger proportion of the population perceived cannabis as Low-risk/Available (35.8%) than High-risk/Available (26.1%) and High-risk/Unavailable (26.8%). From 2002 to 2014, the prevalence declined more for the High-Risk/Available category (-29.5%) than the High-Risk/Unavailable category (-17.6%). The reverse was observed from 2015 to 2018 (*High-risk/Available*: -8.5%, *High-risk/Unavailable*: -13.1%). The Low-risk/Unavailable category remained the least endorsed, though its prevalence increased over time (2002 to 2014: 5.8%–10.0%, 2015 to 2018: 10.6%–11.3%).

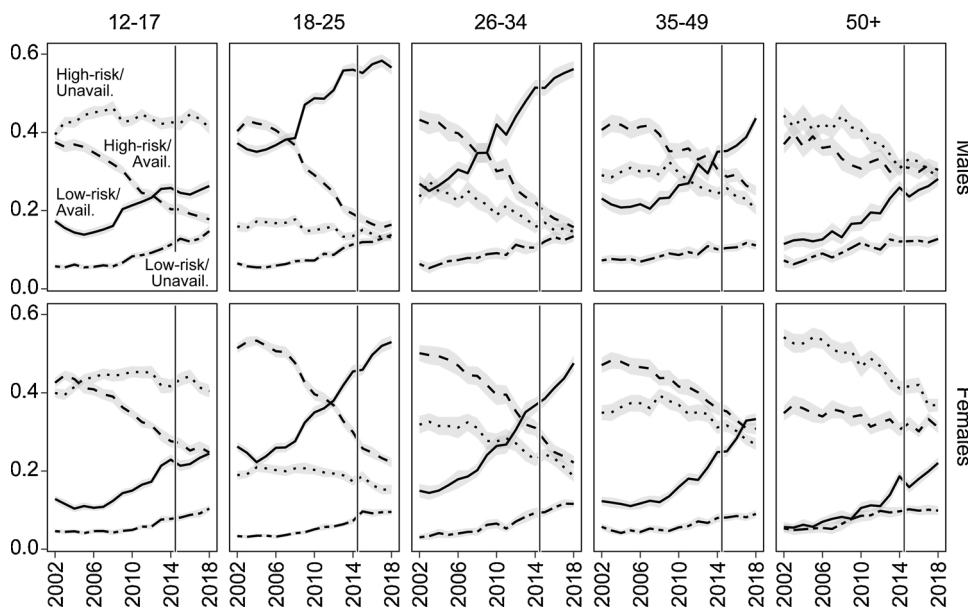
### 3.2. Trends in perceived risk/availability by age and gender

Within age groups, trends in perceptions were similar for females and males (Fig. 2). Increasing trends in perceiving cannabis as Low-risk/Available and decreasing trends of High-risk/Available perceptions were observed across all age groups and by gender. However, among ages 12–17, the proportion of individuals endorsing each perception category was very similar for both males and females, while the prevalence of perception categories varied by gender for all other age groups. For ages 18+, perceiving cannabis as Low-risk/Available was more common among males than females whereas a larger proportion of females than males perceived cannabis as High-risk/Unavailable in every year.

In the youngest (12–17) and oldest (50+) age groups, the High-risk/Unavailable category was the most prevalent in every year. For 12–17-year-olds, the prevalence of perceiving cannabis as High-risk/Unavailable was unchanged over the study period, with approximately 40% of males and females endorsing this category each year. A decreasing trend in the prevalence of the High-risk/Unavailable category was observed for those 50+, with larger declines for males than females. While the prevalence of both the High-risk/Available and High-risk/Unavailable categories declined for those 35–49, a majority continued to endorse these categories over time. In contrast, by 2018, the Low-risk/Available category was the most prevalent for both males and females aged 18–25 (*Males*: 56.9%, *Females*: 53.0%) and 26–34 (*Males*: 56.2%, *Females*: 47.6%).



**Fig. 1.** Weighted prevalence of perceived risk and perceived availability of cannabis individually (A) and in combination (B), among the United States population 12 years of age and older, 2002 to 2018. Vertical bars separate trends before and after the 2015 redesign of the National Surveys on Drug Use and Health as these trends are not considered comparable. All trends were statistically significant ( $p < 0.05$ ). Shading represents 95% confidence intervals.



**Fig. 2.** Weighted prevalence of perceived risk and perceived availability of cannabis by age group and gender, 2002 to 2018. Vertical bars separate trends before and after the 2015 redesign of the National Surveys on Drug Use and Health as these trends are not considered comparable. All trends were significant ( $p < 0.05$ ) with the exception of High-risk/Unavailable among males 12-17. Shading represents 95% confidence intervals.

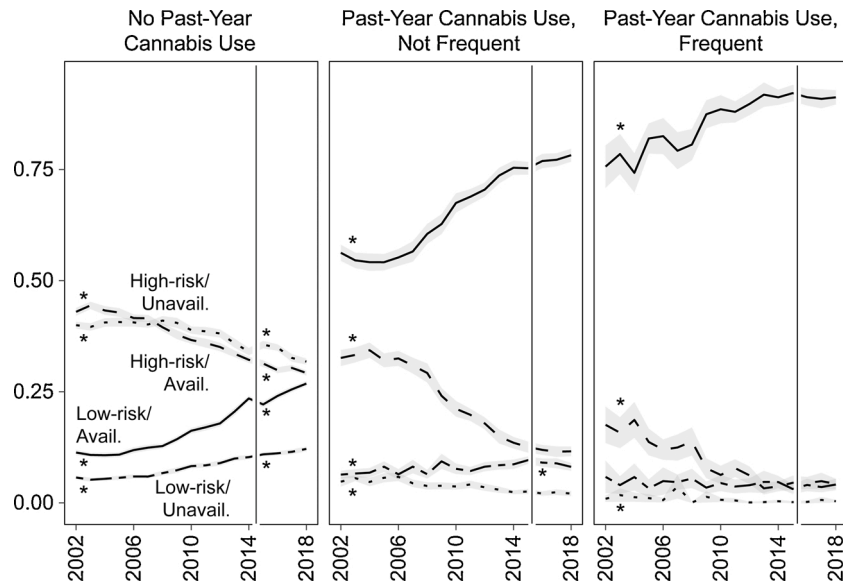
3.3. Trends in cannabis perceptions by cannabis outcomes

In 2018, most individuals who reported no past-year cannabis use perceived cannabis as High-risk/Unavailable (31.8%) or High-risk/Available (29.2%); however, the prevalence of these categories declined over time while the proportion perceiving cannabis as Low-risk/Available and Low-risk/Unavailable increased (Fig. 3). In contrast, the majority of individuals who used cannabis in the past year perceived cannabis as Low-risk/Available and the absolute prevalence of this perception was higher among those reporting frequent use. The prevalence of perceiving cannabis as Low-risk/Available increased for individuals with both non-frequent (2002 to 2014: 56.3%–75.4%, 2015 to 2018: 75.3%–78.2%) and frequent past-year cannabis use (2002 to 2014: 75.7%–91.3%, 2015 to 2018: 92.2%–91.2%). Simultaneously, the

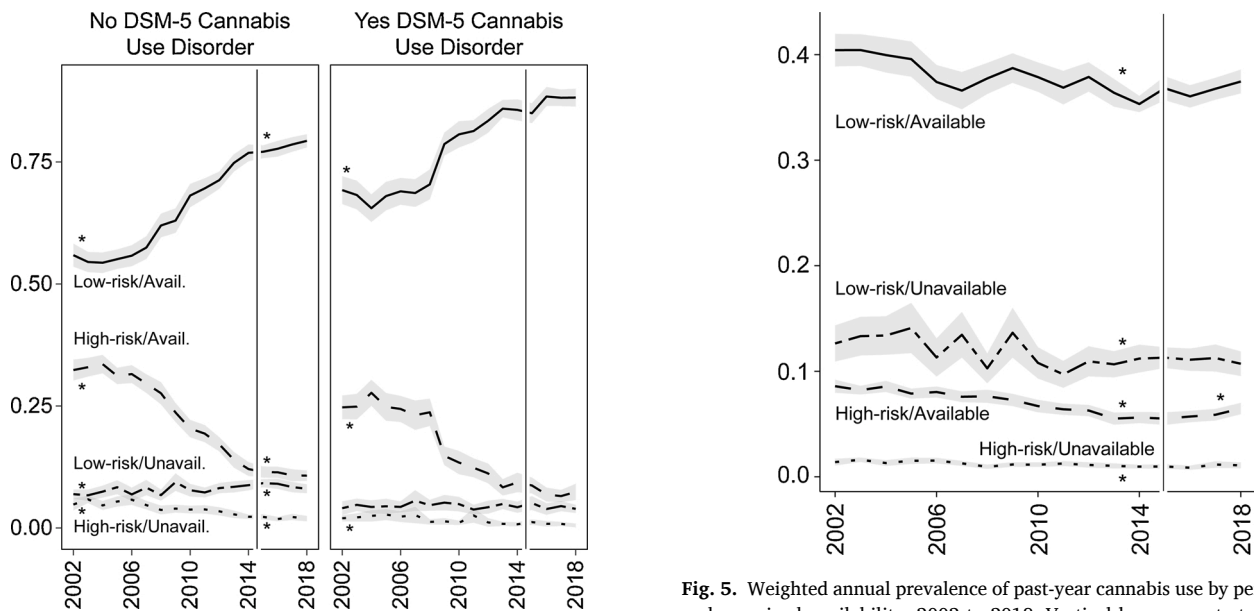
prevalence of perceiving cannabis as High-risk/Available declined for all those reporting past-year cannabis use. Similar patterns were observed by gender and age (available upon request).

Trends in risk/availability perceptions were similar when stratifying individuals reporting past-year cannabis use by the DSM-5 CUD proxy measure (Fig. 4). While a larger proportion of individuals meeting proxy DSM-5 CUD criteria perceived cannabis as Low-risk/Available than those not meeting CUD criteria in every year, this perception category was endorsed by the majority of individuals in both categories. By 2018, 88.2% of individuals meeting CUD proxy criteria and 79.3% of those not meeting criteria perceived cannabis as Low-risk/Available. Comparable findings were observed when using the DSM-IV CUD definition (available upon request.)





**Fig. 3.** Weighted prevalence of perceived risk and perceived availability of cannabis by past-year cannabis use and frequency of cannabis use, 2002 to 2018. Frequent use was defined as use on 300 days or more in the past year. Vertical bars separate trends before and after the 2015 redesign of the National Surveys on Drug Use and Health as these trends are not considered comparable. Asterisks indicate significant trends ( $p < 0.05$ ). Shading represents 95% confidence intervals.



**Fig. 4.** Weighted prevalence of perceived risk and perceived availability of cannabis among individuals who used cannabis in the past-year by DSM-5 cannabis use disorder, 2002 to 2018. Cannabis use disorder was measured using a proxy definition of DSM-5 criteria. Vertical bars separate trends before and after the 2015 redesign of the National Surveys on Drug Use and Health as these trends are not considered comparable. Asterisks indicate significant trends ( $p < 0.05$ ). Shading represents 95% confidence intervals.

**Fig. 5.** Weighted annual prevalence of past-year cannabis use by perceived risk and perceived availability, 2002 to 2018. Vertical bars separate trends before and after the 2015 redesign of the National Surveys on Drug Use and Health as these trends are not considered comparable. Asterisks indicate significant trends ( $p < 0.05$ ). Shading represents 95% confidence intervals.

3.4. Trends in cannabis use by cannabis perceptions

While perceptions of cannabis risk/availability differed by various cannabis use outcomes and changed over time, patterns of past-year cannabis use by perception category remained stable (Fig. 5). The prevalence of cannabis use decreased slightly (<1-3 percentage points)

for all perception categories from 2002 to 2014 and no significant changes were observed from 2015 to 2018, with the exception of a small increase (<1 percentage point) in cannabis use among the High-risk/Available category. As a result, the highest prevalence of cannabis use was consistently observed among those perceiving cannabis as Low-risk/Available (2002 to 2014: 40.4%-35.3%, 2015 to 2018: 36.8%-37.5%) while the lowest prevalence was observed for the High-risk/Unavailable category (2002 to 2014: 1.4%-1.0%, 2015 to 2018: 1.0%-1.2%).

**Table 1**

Relative risk regression models of the association between perceived risk and perceived availability of cannabis use and past-year cannabis use, frequent use, and cannabis use disorder.

	Past-year Cannabis Use		Past-year Frequent Cannabis Use		Past-Year Cannabis Use Disorder	
	RR	95% CI	RR	95% CI	RR	95% CI
<i>2002–2014</i>						
Low-risk	5.90	5.77, 6.04	2.80	2.58, 3.04	1.47	1.42, 1.53
Available	4.71	4.55, 4.86	2.14	1.89, 2.42	1.58	1.47, 1.69
High-risk/Unavailable	1.00	–	1.00	–	1.00	–
High-risk/Available	5.13	4.81, 5.47	1.87	1.41, 2.47	1.45	1.25, 1.68
Low-risk/Unavailable	8.72	8.05, 9.44	2.54	1.84, 3.51	1.36	1.16, 1.59
Low-risk/Available	22.40	21.01, 23.89	5.12	3.85, 6.81	2.12	1.83, 2.45
RERI	9.56	8.86, 10.25	1.71	1.26, 2.16	0.31	0.16, 0.46
<i>2015–2018</i>						
Low-risk	7.61	7.30, 7.93	2.55	2.21, 2.95	1.48	1.32, 1.61
Available	5.20	4.94, 5.47	2.48	2.12, 2.91	1.81	1.61, 2.02
High-risk/Unavailable	1.00	–	1.00	–	1.00	–
High-risk/Available	5.68	4.81, 6.70	2.25	1.23, 4.13	1.44	1.07, 1.93
Low-risk/Unavailable	9.86	8.48, 11.48	2.33	1.24, 4.37	1.14	0.86, 1.53
Low-risk/Available	29.62	25.70, 34.13	5.55	3.13, 9.84	2.08	1.58, 2.74
RERI	15.08	13.13, 17.02	1.97	1.22, 2.72	0.50	0.26, 0.75

All models were adjusted for age, gender, and continuous year; account for the complex survey design of the National Survey on Drug Use and Health; and incorporate sampling weights to adjust for nonresponse and to reweight the sample to represent the total United States non-institutionalized population 12 years of age and older. Separate relative risk models were constructed for perceived risk alone, perceived availability alone, and using the four-level combined variable of perceived risk and perceived availability. Frequent cannabis use was defined as using cannabis on  $\geq 300$  days in the past year. Cannabis use disorder was measured using a proxy definition of DSM-5 criteria. The Relative Excess Risk due to Interaction (RERI) is a measure of additive interaction calculated using estimated risk ratios as:  $RR(\text{Low-risk/Available}) - RR(\text{Low-risk/Unavailable}) - RR(\text{High-risk/Available}) + 1$ . Standard errors for the RERI measure were estimated using the delta method.

RR = risk ratio; 95% CI = 95% confidence interval; RERI = Relative Excess Risk due to Interaction.

### 3.5. Associations between cannabis perceptions and past-year cannabis use, frequent use, and CUD

In adjusted regression models, cannabis perceptions were associated with past-year cannabis use, frequent cannabis use, and proxy DSM-5 CUD for both 2002 to 2014 and 2015 to 2018 (Table 1). Perceiving cannabis as low- vs. high-risk and available vs. unavailable was associated with an increased risk of past-year cannabis use, frequent use, and CUD. Compared with individuals perceiving cannabis as High-risk/Unavailable, those in all other joint perception categories had greater estimated risk of all cannabis outcomes. The strongest associations were observed between joint perceptions and any past-year cannabis use. RERI measures for all outcomes were larger than zero, consistent with the presence of positive additive interaction between perceived risk and perceived availability for all cannabis outcomes. For example, from 2015 to 2018, the estimated risk of past-year cannabis use for those perceiving cannabis as Low-risk/Available (29.62) was greater than the sum of the individual risks associated with perceiving cannabis as Low-risk (9.86) and perceiving cannabis as Available (5.68;  $9.86 + 5.68 = 15.54$ ;  $RERI = 29.62 - 9.86 - 5.68 + 1 = 15.08$ ).

## 4. Discussion

This study described the evolution of joint perceptions of cannabis risk/availability from 2002 to 2018 and estimated the relationship between combined perceptions and past-year cannabis use, frequent use, and CUD. Studying perceived risk and availability in conjunction revealed more nuanced patterns than considering each perception in isolation. We found that the proportion of individuals perceiving cannabis as Low-risk/Available increased substantially from 2002 to 2018 (2002 to 2014: +86%, 2015 to 2018: +19%), whereas the proportions perceiving cannabis as High-risk/Available and High-risk/Unavailable decreased and the prevalence of perceiving cannabis as Low-risk/Unavailable remained low. We also found evidence consistent with additive interaction between perceived risk and availability in their effects on past-year cannabis use, frequent use, and CUD, suggesting that the combined effects of perceived risk and availability on cannabis use outcomes may be greater than the sum of the effects of risk and

availability alone.

The prevalence of joint cannabis perceptions and trends differed by age. Among people 12–17 and 50+ years old, the High-risk/Unavailable perception category remained the most prevalent from 2002 to 2018. Among individuals 18–34, there were large increases in the prevalence of perceiving cannabis as Low-risk/Available and the majority of individuals in this age range held that perception by 2018. Our findings are consistent with other studies of perceptions that used NSDUH data and included all age groups (Okane et al., 2015; Pacek et al., 2015). However, most studies have focused exclusively on adolescents and young adults and produced inconsistent results. For example, Salas-Wright et al. found declines in perceiving cannabis as very easy to obtain for U.S. youth 12–17 years old (Salas-Wright et al., 2017). While we also observed declines in perceived availability in this age group, this only occurred among 12–17-year-olds who also perceived cannabis as high risk. Sarvet et al. described a “divergence” of perceived cannabis risk and use in adolescents, finding that the prevalence of cannabis use remained stable from 2002 to 2014 while an increasing proportion of adolescents reported that cannabis use carries no risks (Sarvet et al., 2018b). One potential explanation for these observed trends may be that although adolescents increasingly perceived cannabis as low risk, the High-risk/Unavailable category consistently remained the most commonly endorsed in the 12–17 age group, with the prevalence remaining around 40% from 2002 to 2018. This suggests that cannabis risk perceptions and use likely remain closely linked among adolescents. Our findings indicate that considering perceived risk absent perceived availability may provide an incomplete and possibly misleading picture. Indeed, discrepant results across studies of adolescents and young adults may be in part attributable to the observed interaction between perceived risk and availability.

Cannabis perceptions also differed by gender. Overall, a larger proportion of males viewed cannabis as lower risk and more available compared with females, but patterns differed by age. We found minimal differences in perceptions by gender in the 12–17-year age group while among all those 18+, the prevalence of perceiving cannabis as Low-risk/Available was higher for males than females and perceiving cannabis as High-risk/Unavailable was more common among females. Previous studies have similarly observed lower perceived risk of cannabis among

males than females (Fleary et al., 2010; Hellemans et al., 2019; Okaneku et al., 2015; Pacek et al., 2015; Terry-McElrath et al., 2017). Fleary et al. further observed that peer norms explained adolescent males' risk perceptions whereas parental norms were more important for females (Fleary et al., 2010). This suggests the importance not only of evaluating cannabis perceptions by gender, but further interrogating differences in how perceptions are formed.

The findings of this study are consistent with the hypothesis that perceptions of cannabis risk and availability together influence cannabis use and that their trends and associations with cannabis use when considered jointly differ from those observed for each alone. Our results provide a more complete picture of the evolution of cannabis perceptions and their potential relationship with use. For example, the proportion of the population perceiving cannabis as available was largely unchanged at around 60% from 2002 to 2018, despite the fact that half of all U.S. states legalized medical cannabis use and 11 passed recreational cannabis laws during this time period. Considering perceived risk and availability jointly, however, revealed that this overall stable prevalence resulted from a declining prevalence of perceiving cannabis as High-risk/Available (2002: 41.6%, 2018: 26.1%) while the prevalence of perceiving cannabis as Low-risk/Available more than doubled, from 16.8% in 2002 to 35.8% in 2018, consistent with an overall increase in the prevalence of cannabis use. Decreasing or stable prevalence of past-year cannabis use was observed among 12–17 and 35–49-year-olds (Figure S1)—among whom a majority perceived cannabis as High-risk/Available or High-risk/Unavailable—while cannabis use increased in those 18–34, concurrent with an increasing proportion perceiving cannabis as Low-risk/Available.

Our results indicated a strong association between perceived risk/availability and past-year cannabis use, and were consistent with synergistic effects of perceived risk and availability on use. While we also observed associations between perceived risk/availability and both frequent use and CUD, the magnitude of these associations was smaller than those observed for any past-year cannabis use. Kilmer et al. similarly found that perceived risk was associated with cannabis use among college students, but did not observe any associations between perceived risk and frequency of use nor experiencing negative cannabis-related consequences (Kilmer et al., 2007). Together, this may suggest that while perceptions appear to influence global decisions around whether or not an individual uses cannabis, they may play less of a role in affecting patterns or frequency of cannabis use.

In this study, we estimated the effects of perceived risk/availability on cannabis outcomes. However, previous work indicates that cannabis use is also associated with perceptions (Grevenstein et al., 2015; Parker and Anthony, 2018; Salloum et al., 2018). Individuals who use cannabis are likely to perceive cannabis as lower risk and more available than those who do not. We observed that most individuals who used cannabis in the past year perceived cannabis as Low-risk/Available and the prevalence of this perception category was higher among those reporting frequent use than those without frequent use in every year. Since we used cross-sectional survey data, we were unable to directly explore the temporal relationship between cannabis perceptions and outcomes. We did, however, observe that the prevalence of cannabis use within perceived risk/availability categories was stable over time while the prevalence of perceptions by cannabis use changed. This may suggest that the effect of perceptions on use has remained consistent over time and that perceptions may have a greater influence on use than use has on perceptions. Future work should directly explore the direction and strength of these relationships.

Our study is also limited by the NSDUH exclusion of people who did not speak English or Spanish and institutionalized populations and the use of binary gender, restricting the generalizability of results to the entire U.S. population. Additionally, the NSDUH perceived risk of cannabis question combines a number of different potential risks (“physical” and “in other ways”) that cannot be disaggregated. While respondents selecting the same risk level may be doing so for different

reasons, it was not possible to interrogate how perceptions of different risks (e.g. legal vs. physical) may be changing over time or how different risks influence cannabis use. Finally, cannabis legislation changed substantially over the study period, with 26 states passing medical cannabis laws and 11 legalizing recreational cannabis use; however, we were unable to assess the effects of cannabis legislation on perceptions in this analysis, as state of residence is not available in the public-use NSDUH data.

In conclusion, this study advances our understanding of how cannabis perceptions have evolved in the U.S. overall and by age and gender and is the first to consider the joint effects of perceived risk and perceived availability. Our results provide a starting point for future research exploring specific hypotheses regarding the effects of perceptions on individual cannabis outcomes and highlight the importance of exploring perceived risk and availability together. For example, our findings suggest that prevention efforts that focus only on the risks of cannabis use may be less effective among individuals who perceive cannabis as easily available. Trends in perceptions may also identify priority groups for intervention, for example males and 18–34-year-olds. Perceptions among younger age groups should be monitored as a potential indicator of changes in cannabis use. Further understanding of these relationships is particularly important in light of rapidly changing cannabis policies, a contextual factor that may influence perceptions of both risk and availability of cannabis and subsequent use. Future work should consider the interplay between cannabis legalization, changes in cannabis supply, and perceived risk/availability of cannabis across a broad range of ages and by gender.

## Contributors

All authors participated in the development of this manuscript. PM and SM developed the original research question. NL conducted the literature review, performed all analyses, and led writing of the article. LS performed data cleaning and assisted with analyses. CM assisted with the analytical strategy. All authors reviewed all manuscript drafts and provided feedback. The final article was approved by all authors.

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Nothing declared.

## Declaration of Competing Interest

The authors report no declarations of interest.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.drugalcdep.2021.108873>.

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