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Short Communication

The association between cannabis vaping and other substance use

Ruoyan Sun [a,*], David Mendez [b], Kenneth E. Warner [b]

[a] Department of Health Policy and Organization, School of Public Health, University of Alabama at Birmingham, Birmingham, AL 35294, United States
[b] Department of Health Management and Policy, School of Public Health, University of Michigan, Ann Arbor, MI 48109, United States

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ABSTRACT

Introduction: The popularity of cannabis vaping has increased rapidly, especially among adolescents and young adults. We posit some possible explanations and, to evaluate them, examine whether cannabis vapers differ from non-vaping cannabis users in other substance use.

Methods: Using nationally representative data from the Population Assessment of Tobacco and Health (PATH) Study wave 5 (Dec. 2018-Nov. 2019), we assessed the association between cannabis vaping and other substance use. A total of 1,689 adolescents and 10,620 adults who reported cannabis use in the past 12 months were included in the study. We employed multivariable logistic regressions to assess the association between cannabis vaping and other substance use.

Results: Among past 12-month cannabis users, compared with those who do not vape cannabis, participants who vape cannabis had higher risks of using alcohol (adjusted relative risk [aRR] = 1.04, 95 % CI, 1.01–1.07), cigarettes (aRR = 1.09, 95 % CI, 1.02–1.15), cigars (aRR = 1.17, 95 % CI, 1.06–1.30), other tobacco products (aRR = 1.29, 95 % CI, 1.14–1.45), electronic nicotine products (aRR = 4.64, 95 % CI, 4.32–4.99), other illicit drugs (aRR = 1.53, 95 % CI, 1.29–1.80), and misuse of prescription drugs (aRR = 1.43, 95 % CI, 1.19–1.72). Compared to older cannabis vapers, younger cannabis vapers were at risk of using more other substances. Cannabis vaping was associated with all seven measures of substance use among young adults.

Conclusions: Compared to non-vaping cannabis users, cannabis vapers have higher likelihood of using other substances. Research is needed to understand why, as well as the implications of the association.

1. Introduction

The popularity of cannabis vaping has increased rapidly (Croker, Werts, Couch, & Chaffee, 2023; Knapp et al., 2019; Miech et al., 2021). While the prevalence of overall cannabis use did not change much, past 12-month cannabis vaping among adolescents nearly doubled from 2017 to 2020 (7.2 % to 13.2 %) (Lim et al., 2022). In 2022, 14.8 % of US twelfth-grade students reported past 30-day cannabis vaping (Johnston et al., 2023). Among adults, the proportion whose primary mode of consumption was vaping increased from 9.9 % in 2017 to 14.9 % in 2019 (Boakye et al., 2021). Still, smoking remains the dominant mode of cannabis use. Many cannabis users report multiple modes of use (Steigerwald et al., 2018; Stith et al., 2023).

Certainly, the novelty of vaping itself has contributed to the rapid increase in cannabis vaping. Vaping devices, which heat the desired substance to produce an aerosolized mixture of water vapor and active ingredients, have become popular for nicotine use in the past decade. These devices can also be used to consume cannabis through vaping cannabis concentrates, liquid, oil, or dried herbs (Chadi, Minato, & Stanwick, 2020). Individuals who have vaped nicotine may be more likely to vape cannabis due to their familiarity with vaping devices. Other features of vaping have also made it increasingly attractive to cannabis users. Cannabis users may perceive vaping as avoiding the toxins associated with combustion from cannabis smoking (Fischer et al., 2017). They may also have learned that vaping could produce greater pharmacodynamic effects, compared with equal doses of smoked cannabis (Spindle et al., 2018; Stuyt, 2018). Lastly, cannabis vaping is more convenient and discreet in public than smoking (Kenne, Fischbein, Tan, & Banks, 2017).

Our study examines the first three possible explanations by evaluating the associations between cannabis vaping and other substance use. Specifically, the association between cannabis vaping and nicotine vaping addresses the familiarity with vaping devices. The explanation that cannabis vapers may perceive lower health risks with vaping

* Corresponding author at: University of Alabama at Birmingham, Health Policy and Organization, 310C Ryals Public Health Building, 1665 University Boulevard, Birmingham, AL 35294, United States.
E-mail address: rysun@uab.edu (R. Sun).

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suggests that they should be less likely to report high-risk behaviors such as other substance use. In contrast, if cannabis vapers seek the greater pharmacodynamic effects associated with vaping, this may indicate greater need from substance use and hence higher likelihood of using other substances.

Most US national surveys fail to differentiate cannabis consumption modes. One exception is the Population Assessment of Tobacco and Health (PATH) Study, which has added a question on cannabis vaping since wave 4 (December 2016-January 2018). We used PATH wave 5 data (December 2018-November 2019) to examine whether cannabis vapers, compared with non-vaping cannabis users, are more likely to use other substances. This permits us to address the aforementioned possible explanations. We considered seven outcome measures to assess substance use: alcohol, cigarettes, cigars, other tobacco products (pipe, hookah, snus, smokeless tobacco, bidi, kretek, and dissolvable tobacco), electronic nicotine products (e-cigarettes), other illicit drug use (cocaine or crack, stimulants or other illicit drugs), and misuse of prescription drugs (Ritalin or Adderall, or painkillers, sedatives, or tranquilizers). We also explored potential differences in the association between cannabis vaping and other substance use across age groups.

2. Methods

2.1. Data

We utilized wave 5 data from PATH, a nationally representative survey of tobacco use and health among adults (ages ≥18) and youth (ages 12–17). The survey adopted a four-stage stratified area probability sample design to select participants. Weighted response rates were 88.0 % for adults and 83.5 % for youth (US Department of Health and Human Services, 2022). Our sample included 1,689 adolescents and 10,620 adults who reported cannabis use in the past 12 months.

2.2. Measures

Our independent variable of interest is self-reported past 12-month cannabis vaping, constructed through two questions: 1) whether the respondent used an electronic nicotine product in the past 12 months; and 2) how often the respondent used marijuana, marijuana concentrates, marijuana waxes, THC, or hash oils in an electronic product (with no 12-month time limit mentioned). Participants who reported past 12-month electronic nicotine product use and answered every time, most of the time, sometimes, or rarely to the second question were categorized as cannabis vapers. Others were identified as non-vaping cannabis users. (Cannabis vapers may have consumed cannabis via other modes, such as smoking and eating, in addition to vaping. See Appendix Table 1 for details on variable construction.)

We identified the seven substance categories mentioned above. E-cigarette use was defined as past 12-month use of an electronic nicotine product and not using it every time for cannabis.

Socio-demographic variables included age (12–17, 18–24, 25–34, 35–44, 45–54, 55–64,≥65), sex (male vs female), race/ethnicity (Hispanic, non-Hispanic black, non-Hispanic white, and non-Hispanic other), highest education (≤high school/GED, some college, ≥college (highest parental education for adolescents)), and household income (<$50,000, $50,000-$100,000, >$100,000). Psychosocial variables included self-perception of mental health (excellent/very good/good vs fair/poor) and internalizing problems and externalizing problems, coded into a 3-level severity measure based on the Global Appraisal of Individual Needs-Short Screener (Dennis, Feeney, Laverne, Stevens, & Bedoya, 2008). See Appendix Table 2 for details.

2.3. Analysis

We used Stata version 17 to conduct our analysis (Stata Corp, 2021). Variance was estimated using Fay's method of balanced repeated replication following PATH's user guide (Judkins, 1990; US Department of Health and Human Services, 2021). Survey weights were incorporated via Stata's "svy" command. Due to the minimal impact of missing data (<5%), we adopted complete case analysis.

We performed multivariable logistic regressions to examine the association between cannabis vaping and other substance use, controlling for sociodemographic variables and psychosocial measures. Because of large differences in cannabis vaping prevalence across age groups, the regressions also included an interaction term between age group and cannabis vaping, accounting for potential differences in the association across age groups. We ran a total of seven regressions, with use of each substance as the outcome, controlling for cannabis vaping and various covariates mentioned above, along with the other six substance use measures. We reported the main results as adjusted relative risks (aRRs) using Stata's "margins" command given the high prevalence of substance use, which renders odds ratios poor substitutes for relative risks (Norton, Dowd, & Maciejewski, 2018). All P values were from 2-sided tests, and results were deemed statistically significant at $P < .05$.

We conducted two sensitivity analyses: 1) excluding interaction terms between cannabis vaping and age groups (Appendix Table 3), and 2) including past 30-day cannabis use as the only available frequency measure from PATH to alleviate omitted variable bias, since frequent cannabis users may be more likely to use other substances (Appendix Table 4).

3. Results

Around a third (32.2 %, 95 % CI, 31.2 %–33.3 %) of past 12-month cannabis users reported cannabis vaping. Table 1 shows the characteristics of past 12-month cannabis users. Compared with non-vaping cannabis users, cannabis vapers were younger, less likely to be non-Hispanic black, and more educated. A higher proportion of cannabis vapers reported high internalizing problems (34.2 % vs 24.6 %) and externalizing problems (31.8 % vs 20.1 %), along with lower likelihood of good self-perceived mental health (70.0 % vs 76.8 %). Cannabis vapers had higher prevalence of all substance use: 82.1 % vs 79.9 % for alcohol, 64.1 % vs 43.5 % for cigarettes, 40.1 % vs 23.8 % for cigars, 32.9 % vs 14.3 % for other tobacco products, 81.1 % vs 13.6 % for e-cigarettes, 18.7 % vs 8.2 % for other illicit drug use, and 18.4 % vs 10.6 % for misuse of prescription drugs.

The proportion of cannabis users who have vaped in the past 12 months varied significantly by age. Among adolescents (12–17 years) and young adults (18–24 years), half of cannabis users reported cannabis vaping, at 52.0 % and 48.2 % respectively. The proportion of vapers among cannabis users steadily decreased with older age. The proportion was 35.7 % for cannabis users ages 25–34, 25.3 % for 35–44, 21.1 % for 45–54, 13.2 % for 55–64 and 8.5 % for ≥ 65.

Table 2 shows the association between cannabis vaping and other substance use, controlling for all covariates, use of other substances and the interaction between age group and cannabis vaping. In general, cannabis vaping is positively associated with all substance use outcomes. The aRRs were 1.04 (95 % CI, 1.01–1.07) for the use of alcohol, 1.09 (95 % CI, 1.02–1.15) for cigarettes, 1.17 (95 % CI, 1.06–1.30) for cigars, 1.29 (95 % CI, 1.14–1.45) for other tobacco products, 4.64 (95 % CI, 4.32–4.99) for e-cigarettes, 1.53 (95 % CI, 1.29–1.80) for other illicit drugs, and 1.43 (95 % CI, 1.19–1.72) for prescription drug misuse. Cannabis vaping is more strongly associated with various substance use among younger respondents. For adolescents, cannabis vaping is significantly associated with past 12-month use of alcohol, cigarettes, cigars, other tobacco products, and e-cigarettes. Cannabis vaping is associated with all seven outcomes for young adults and four outcomes (cigars, e-cigarettes, other illicit drugs and misuse of prescription drugs) for adults 25–34. However, cannabis vaping is only significantly associated with e-cigarette use for 35–44 year-olds and those ≥65, with e-cigarette use and misuse of prescription drugs for 45–54 year-olds and e-cigarette use and other tobacco product use for 55–64 year-olds. The

Table 1
Sample characteristics of past 12-month non-vaping cannabis users and past 12-month cannabis vapers, Population Assessment of Tobacco and Health Study (2018–2019).

Characteristics	Past 12-month cannabis users Weighted % (95 % CI) Overall	Non-vaping cannabis users	Cannabis vapers[a]	P[b]
Age (years)				<0.001
12–17	6.4 (6.0–6.7)	4.5 (4.1–4.9)	10.3 (9.6–11.1)	
18–24	23.2 (22.3–24.2)	17.8 (16.8–18.8)	34.7 (33.2–36.2)	
25–34	25.9 (24.9–26.9)	24.6 (23.3–25.9)	28.6 (27.1–30.2)	
35–44	16.3 (15.3–17.3)	18.0 (16.7–19.3)	12.8 (11.6–14.1)	
45–54	11.3 (10.2–12.4)	13.1 (11.7–14.6)	7.4 (6.1–8.9)	
55–64	11.8 (10.6–13.2)	15.2 (13.5–17.0)	4.9 (3.9–6.1)	
≥65	5.2 (4.3–6.1)	7.0 (5.8–8.3)	1.4 (0.9–2.2)	
Sex				0.85
Male	55.2 (53.9–56.5)	55.1 (53.4–56.8)	55.4 (53.6–57.2)	
Female	44.8 (43.5–46.1)	44.9 (43.2–46.6)	44.6 (42.8–46.5)	
Race/Ethnicity				<0.001
Hispanic	16.3 (15.3–17.5)	14.8 (13.6–16.2)	19.6 (17.8–21.4)	
Non-Hispanic black	14.4 (13.6–15.2)	16.3 (15.3–17.4)	10.2 (9.1–11.5)	
Non-Hispanic white	61.3 (59.9–62.6)	60.9 (59.2–62.6)	62.0 (60.0–64.0)	
Non-Hispanic other[c]	8.0 (7.1–9.1)	7.9 (6.8–9.3)	8.3 (7.3–9.4)	
Education[d]				0.01
≤ High school/ GED	35.0 (33.5–36.6)	36.2 (34.3–38.0)	32.7 (30.7–34.6)	
Some college	32.0 (30.7–33.3)	31.4 (29.8–33.0)	33.3 (31.6–35.0)	
≥ College	33.0 (31.6–34.4)	32.5 (30.8–34.2)	34.0 (32.2–35.9)	
Household income				0.51
< 50 k	55.5 (53.7–57.3)	55.2 (53.1–57.3)	56.3 (54.0–58.6)	
50 k to 100 k	24.3 (23.1–25.6)	24.3 (22.8–25.9)	24.3 (22.7–25.9)	
> 100 k	20.2 (18.6–21.8)	20.5 (18.7–22.5)	19.4 (17.7–21.2)	
Internalizing problems[e]				<0.001
Low	46.0 (44.6–47.4)	50.0 (48.1–51.9)	37.7 (35.8–39.5)	
Medium	26.3 (25.2–27.5)	25.5 (24.0–26.9)	28.1 (26.4–30.0)	
High	27.7 (26.6–28.8)	24.6 (23.1–26.1)	34.2 (32.7–35.8)	
Externalizing problems[e]				<0.001
Low	50.6 (49.2–51.9)	55.5 (53.7–57.3)	40.2 (38.3–42.2)	
Medium	25.6 (24.4–26.8)	24.4 (22.9–26.0)	28.0 (26.3–29.8)	
High	23.8 (22.8–24.9)	20.1 (18.8–21.5)	31.8 (30.0–33.5)	
Mental health[f]				<0.001
Good	74.6 (73.5–75.7)	76.8 (75.3–78.1)	70.0 (68.3–71.7)	
Not good	25.4 (24.3–26.5)	23.2 (21.9–24.7)	30.0 (28.3–31.7)	
Past 12-month substance use				
Alcohol	80.6 (79.3–81.8)	79.9 (78.4–81.2)	82.1 (80.5–83.5)	0.01
Cigarette	50.2 (48.8–51.6)	43.5 (41.7–45.4)	64.1 (62.3–65.8)	<0.001
Cigar	28.7 (27.6–29.9)	23.8 (22.4–25.3)	39.1 (37.2–41.0)	<0.001
Other tobacco[g]	20.3 (19.3–21.4)	14.3 (13.3–15.4)	32.9 (31.1–34.8)	<0.001
Electronic cigarette[h]	35.3 (34.2–36.5)	13.6 (12.6–14.6)	81.1 (79.7–82.5)	<0.001
Other illicit drug[i]	11.6 (10.8–12.4)	8.2 (7.4–9.1)	18.7 (17.0–20.5)	<0.001
Misuse of prescription drugs[j]	13.1 (12.3–14.0)	10.6 (9.6–11.7)	18.4 (16.8–20.1)	<0.001
Prevalence by age groups				<0.001
12–17		48.0 (45.4–50.6)	52.0 (49.4–54.6)	
18–24		51.8 (50.3–53.4)	48.2 (46.6–49.7)	
25–34		64.3 (62.1–66.5)	35.7 (33.5–37.9)	
35–44		74.7 (72.1–77.0)	25.3 (23.0–27.9)	
45–54		78.9 (74.7–82.5)	21.1 (17.5–25.3)	
55–64		86.8 (83.8–89.3)	13.2 (10.7–16.2)	
≥65		91.5 (86.6–94.7)	8.5 (5.3–13.4)	

Notes
[a] Cannabis vapers may have consumed cannabis through other modes in addition to vaping, such as smoking and eating.
[b] Pearson's chi-squared test was performed to compare the distribution of sample characteristics between past 12-month non-vaping cannabis users and cannabis vapers at Wave 5.
[c] Non-Hispanic other includes American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander.
[d] Highest parental education was used for participants between 12 and 24, participants' own education was used for those older than 24.
[e] Assessed by the Global Appraisal of Individual Needs-Short Screener (GAIN-SS). Participants classified as low (0–1 symptom), moderate (2–3 symptoms), or high (≥4 symptoms). See Appendix Table 2 for details.
[f] Good mental health statuses include excellent, very good, or good. Not good mental health statuses include poor or fair.
[g] Other tobacco products include pipe, hookah, snus, smokeless tobacco, bidi (12–17 only), kretek (12–17 only), and dissolvable tobacco.
[h] Nicotine vaping.
[i] Other illicit drugs include cocaine or crack, stimulants like methamphetamine or speed, heroin, inhalants, solvents, or hallucinogens.
[j] Prescription drugs include Ritalin, Adderall, painkillers, sedatives, or tranquilizers.

association between cannabis vaping and e-cigarette use grows consistently and substantially with increasing age.

Findings from the sensitivity analyses are similar. Regressions excluding age-and-vaping interaction terms produced almost identical results on the association between cannabis vaping and the seven outcome measures (Appendix Table 3). Appendix Table 4 shows regression results with the addition of past 30-day cannabis vaping as a covariate.

4. Discussion

Among cannabis users, those who vape cannabis had higher risks of using all the substances we considered. Younger cannabis vapers, especially adolescents and young adults, were most at risk. The results are consistent with a prior study of high school students in Connecticut (Morean et al., 2021). Our study included three new contributions: 1)

Table 2
Association between cannabis vaping and other substance use among past 12-month cannabis users, Population Assessment of Tobacco and Health Study (2018–2019).

	Past 12-month other substance use aRR[a] (95 % CI)						
	Alcohol N = 9,379	Cigarettes N = 6,344	Cigars N = 3,948	Other tobacco products N = 2,938	Electronic Cigarettes[b] N = 5,431	Other illicit drugs N = 1,442	Misuse of prescription drugs N = 1,638
Cannabis vaping[c] (Ref: non-vaping cannabis use)							
	1.04*	1.09**	1.17**	1.29***	4.64***	1.53***	1.43***
	(1.01–1.07)	(1.02–1.15)	(1.06–1.30)	(1.14–1.45)	(4.32–4.99)	(1.29–1.80)	(1.19–1.72)
Cannabis vaping by age group (Ref: non-vaping cannabis use)							
12–17	1.20***	1.57***	1.49**	1.36*	2.04***	1.27	1.21
	(1.09–1.33)	(1.31–1.88)	(1.14–1.96)	(1.02–1.83)	(1.85–2.26)	(0.80–2.02)	(0.92–1.57)
18–24	1.11***	1.14*	1.22***	1.32***	2.57***	1.43***	1.61***
	(1.07–1.14)	(1.02–1.26)	(1.10–1.35)	(1.15–1.50)	(2.37–2.79)	(1.18–1.74)	(1.29–2.01)
25–34	1.03	1.08	1.20*	1.14	5.64***	1.73***	1.53**
	(0.99–1.07)	(0.99–1.19)	(1.03–1.40)	(0.96–1.34)	(4.92–6.47)	(1.39–2.16)	(1.14–2.04)
35–44	1.05	1.08	1.19	1.36	8.13***	1.44	1.30
	(0.98–1.11)	(0.97–1.19)	(0.95–1.50)	(0.96–1.92)	(6.16–10.72)	(0.97–2.13)	(0.89–1.92)
45–54	0.96	1.09	1.01	1.22	8.71***	1.30	1.90*
	(0.89–1.05)	(0.94–1.28)	(0.73–1.41)	(0.81–1.85)	(6.26–12.12)	(0.72–2.33)	(1.11–3.25)
55–64	0.99	1.00	1.19	2.06**	11.55***	1.65	1.23
	(0.90–1.10)	(0.77–1.31)	(0.80–1.78)	(1.21–3.52)	(8.57–15.57)	(0.88–3.10)	(0.72–2.10)
≥ 65	1.00	0.84	0.58	1.37	11.15***	NA[d]	0.60
	(0.70–1.43)	(0.46–1.52)	(0.17–2.03)	(0.25–7.50)	(5.10–24.38)		(0.12–3.01)

Notes
*p <.050; **p <.010; ***p <.001.
[a] Adjusted relative risk.
[b] Nicotine vaping.
[c] Adjusted for all study covariates: age, sex, race/ethnicity, education, household income, internalizing problems, externalizing problems, mental health status, past 12-month use of other substances excluding the dependent/outcome variable. Other substances include alcohol, cigarette, electronic cigarette, other tobacco products, other illicit drugs and misuse of prescription drugs. We also controlled for the interaction between age groups and cannabis vaping (age x cannabis vaping).
[d] Due to the limited number of participants reporting other illicit drug use in this age group.

examining the use of substances (other illicit drugs and prescription drug misuse) in addition to alcohol, tobacco, and e-cigarette; 2) expanding the study population to include adults; and 3) exploring differential effects by age groups.

Our findings support two of our initial explanations while challenging one. The strong association between cannabis vaping and nicotine vaping, especially in older ages, suggests that cannabis vapers are familiar with vaping through their use of nicotine e-cigarettes. Cannabis vapers' higher likelihood of using other substances, indicative of drug seeking behavior, is consistent with the explanation that they seek greater pharmacodynamic effects. In contrast, the strong association with other substance use implies that, as a group, cannabis vapers may not choose vaping because they perceive it entails lower health risks. All this said, our findings cannot fully confirm or reject these explanations.

There are two other possible explanations for the association between cannabis vaping and other substance use. Studies have found that adolescent cannabis vapers use more modes of consuming cannabis than do non-vaping cannabis users (Knapp et al., 2019; Morean et al., 2021). The number of cannabis consumption modes could indicate the respondent's extent of interest in drug use, reflected in other substance use. PATH does not assess the number of modes. Another plausible explanation is that adolescent cannabis vapers are more frequent cannabis users (Palamar, 2021), indicating greater need from substance use and hence may be more likely to use other substances. We included past 30-day cannabis use in our sensitivity analysis as the only available, if imperfect, control for frequency of cannabis use.

Cannabis consumption modes may affect the onset, intensity and duration of drug effects, and possibly health outcomes (Vandrey et al., 2017). Since cannabis vaping is still an emerging behavior, more studies are needed to understand its long-term health risks. There are challenges, however. First, vaping devices have evolved rapidly in the last decade (Ozga, Felicione, Douglas, Childers, & Blank, 2022). Their design could affect delivery of chemicals such as THC. Cannabis vapers could also vape other psychoactive substances simultaneously, making it harder to assess the health risks. Lastly, existing nationally representative surveys on cannabis use lack important details on product characteristics relevant to public health (Stith et al., 2023).

This study has some limitations. First, PATH offers limited information on cannabis use modes and product characteristics. We could not identify exclusive cannabis vapers. Second, PATH does not ask about frequency or intensity of cannabis use, beyond any past 30-day use. Frequency or intensity might be associated with other substance use and reduce the relationships we found between cannabis vaping and other substance use. Third, PATH survey questions did not clearly permit distinguishing cannabis vaping from nicotine vaping. Some participants may have vaped nicotine and cannabis simultaneously. Fourth, due to the survey questions used to construct our measure of cannabis vaping (past 12-month e-cigarette use + frequency of using cannabis in an electronic product), the association reported between cannabis vaping and e-cigarette use is likely inflated. Fifth, since PATH wave 5 was administered before the COVID pandemic, cannabis use trends post-COVID could be different. Lastly, we did not adjust for state cannabis legalization due to a lack of geographic information in the dataset.

5. Conclusions

Adolescent cannabis use may negatively impact brain development and result in adverse health outcomes (National Academies of Science Engineering and Medicine, 2017), but the relationship between adverse health outcomes and cannabis consumption modes remains unclear. Furthermore, besides modes of consumption, both the frequency of using cannabis and product characteristics may have varying effects on health (Stith et al., 2023). Our study did not examine explanatory mechanisms for these associations.

We have just scratched the surface of the distinction between vaping

cannabis and using cannabis by other modes. More research is needed to understand what underlies the phenomenon we have described, and what implications it may have for health and well-being.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used in this study is publicly available and can be accessed at https://www.icpsr.umich.edu/web/NAHDAP/studies/36498.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.abrep.2023.100519.

References

Boakye, E., Obisesan, O. H., Uddin, S. I., El-Shahawy, O., Dzaye, O., Osei, A. D., … Blaha, M. J. (2021). Cannabis vaping among adults in the United States: Prevalence, trends, and association with high-risk behaviors and adverse respiratory conditions. *Preventive Medicine, 153*, Article 106800.

Chadi, N., Minato, C., & Stanwick, R. (2020). Cannabis vaping: Understanding the health risks of a rapidly emerging trend. *Paediatrics & Child Health, 25*(Supplement_1), S16–S20.

Croker, J. A., Werts, M., Couch, E. T., & Chaffee, B. W. (2023). Cannabis use among adolescents and emerging adults who use e-cigarettes: Findings from an online, national US Sample. *Addictive Behaviors, 140*, Article 107620.

Dennis, M. L. T., Feeney, M. A., Laverne, H., Stevens, L. & Bedoya, B. A. (2008). GAIN-SS Global Appraisal of Individual Needs-Short Screener (GAIN-SS): Administration and Scoring Manual, (309).

Fischer, B., Russell, C., Sabioni, P., Van Den Brink, W., Le Foll, B., Hall, W., … Room, R. (2017). Lower-risk cannabis use guidelines: A comprehensive update of evidence and recommendations. *American Journal of Public Health, 107*(8), e1–e12.

Johnston, L. D., Miech, R. A., Patrick, M. E., O'Malley, P. M., Schulenberg, J. E., & Bachman, J. G. (2023). *Monitoring the Future National Survey Results on Drug Use, 1975–2022: Overview*. Key Findings on Adolescent Drug Use: Institute for Social Research.

Judkins, D. R. (1990). Fay's method for variance estimation. *Journal of Official Statistics, 6*(3), 223–239.

Kenne, D. R., Fischbein, R. L., Tan, A. S., & Banks, M. (2017). The use of substances other than nicotine in electronic cigarettes among college students. *Substance Abuse: Research and Treatment, 11*, 1178221817733736.

Knapp, A. A., Lee, D. C., Borodovsky, J. T., Auty, S. G., Gabrielli, J., & Budney, A. J. (2019). Emerging trends in cannabis administration among adolescent cannabis users. *Journal of Adolescent Health., 64*(4), 487–493.

Lim, C. C., Sun, T., Leung, J., Chung, J. Y., Gartner, C., Connor, J., … Chan, G. C. (2022). Prevalence of adolescent cannabis vaping: A systematic review and meta-analysis of US and Canadian studies. *JAMA Pediatrics, 176*(1), 42–51.

Miech, R., Leventhal, A., Johnston, L., O'Malley, P. M., Patrick, M. E., & Barrington-Trimis, J. (2021). Trends in use and perceptions of nicotine vaping among US youth from 2017 to 2020. *JAMA Pediatrics, 175*(2), 185–190.

Morean, M. E., Davis, D. R., Kong, G., Bold, K. W., Camenga, D. R., Suttiratana, S., Lee, J., Rajeshkumar, L. & Krishnan-Sarin, S. (2021). Demographic and substance use-related differences among high school adolescents who vape cannabis versus use other cannabis modalities. *Drug and Alcohol Dependence*, 228, 109104.

National Academies of Sciences Engineering and Medicine (2017). The health effects of cannabis and cannabinoids: Current state of evidence and recommendations for research.

Norton, E. C., Dowd, B. E., & Maciejewski, M. L. (2018). Odds ratios—current best practice and use. *JAMA, 320*(1), 84–85.

Ozga, J. E., Felicione, N. J., Douglas, A., Childers, M., & Blank, M. D. (2022). Electronic cigarette terminology: Where does one generation end and the next begin? *Nicotine and Tobacco Research, 24*(3), 421–424.

Palamar, J. J. (2021). Increases in frequent vaping of cannabis among high school seniors in the United States, 2018–2019. *Journal of Adolescent Health., 69*(1), 153–156.

Spindle, T. R., Cone, E. J., Schlienz, N. J., Mitchell, J. M., Bigelow, G. E., Flegel, R., Hayes, E. & Vandrey, R. (2018). Acute effects of smoked and vaporized cannabis in healthy adults who infrequently use cannabis: a crossover trial. *JAMA Network Open*, 1(7), e184841.

Stata Corp (2021). Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC.

Steigerwald, S., Wong, P. O., Cohen, B. E., Ishida, J. H., Vali, M., Madden, E., & Keyhani, S. (2018). Smoking, vaping, and use of edibles and other forms of marijuana among US adults. *Annals of Internal Medicine, 169*(12), 890–892.

Stith, S., Pearson, J., Brockelman, F., Keeling, K., Hall, B., & Friedman, A. S. (2023). Nationally representative surveys on cannabis use lack product details relevant to public health. *Drug and Alcohol Dependence Reports, 6*, Article 100134.

Stuyt, E. (2018). The problem with the current high potency THC marijuana from the perspective of an addiction psychiatrist. *Missouri Medicine, 115*(6), 482.

United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products (2021). ICPSR Public-Use Files User Guide. Inter-university Consortium for Political and Social Research [distributor].

United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products (2022). Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files. Inter-university Consortium for Political and Social Research [distributor].

Vandrey, R., Herrmann, E. S., Mitchell, J. M., Bigelow, G. E., Flegel, R., LoDico, C., & Cone, E. J. (2017). Pharmacokinetic profile of oral cannabis in humans: Blood and oral fluid disposition and relation to pharmacodynamic outcomes. *Journal of Analytical Toxicology, 41*(2), 83–89.