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Longitudinal associations between e-cigarette use and onset of multiple modes of cannabis use among US adolescents

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Abstract

Objective—To examine the prospective associations between e-cigarette use and subsequent onset of various modes of cannabis use during a 12-month follow-up period among US adolescents.

Methods—Data were from the Wave 4 (2017, baseline) and Wave 4.5 (12-month follow-up) surveys of the Population Assessment of Tobacco and Health (PATH) Study, a nationally representative, longitudinal cohort study. Study population was cannabis-naïve US adolescents (12–16 years) at baseline who reported cannabis use status at follow-up (N=9,692). Outcomes were modality-specific past-12-month cannabis use (vaping, blunting, smoking with hookah) and any cannabis use (past-12-month and past-30-day) at follow-up. Multivariate logistic regressions were used to estimate the weighted association between baseline past-30-day e-cigarette use and each outcome.

Results—Baseline e-cigarette use were significantly associated with onset of cannabis vaping (aOR=4.00, 95% CI=2.25–7.10), blunting (aOR=5.30, 95% CI=2.82–9.94), any cannabis use (aOR=3.94, 95% CI=2.35–6.62), and past-30-day cannabis use (aOR=4.47, 95% CI=2.64–7.58) at follow-up. Non-Hispanic blacks were more likely to report past-12-month blunting (aOR=1.55, 95% CI=1.07–2.24) and smoking cannabis with hookah (aOR=3.13, 95% CI=1.14–8.63) compared with non-Hispanic whites. Other tobacco use, alcohol use, perceiving e-cigarette use as having little or some harm, older age, high severity of externalizing mental health problems, and

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living in states legalized adult recreational cannabis use were significantly associated with future onset of cannabis vaping, blunting, and any cannabis use.

Conclusions—The association of e-cigarette use with cannabis vaping was not stronger than its association with other modes of cannabis use. Future studies are needed to explain the mechanisms linking e-cigarettes and cannabis use.

Keywords

e-cigarette; cannabis; cannabis use modality; cannabis vaping; blunting; adolescents

1. Introduction

Cannabis is the most commonly used federally illicit psychoactive substance by US adolescents.¹ In 2020, 21.1% of 12th graders, 16.6% of 10th graders, and 6.5% of 8th graders reported using cannabis in the past 30 days, according to the Monitoring the Future (MTF) survey.¹ Cannabis experimentation and addiction are most likely to occur during adolescence.² Growing evidence indicates that adolescent cannabis use is associated with functional impairment and higher risks for executive functioning problems and psychosis.^{3,4} Adolescents who use cannabis heavily are more likely to show deficits in memory, sustained attention, and processing speed, leading to negative academic outcomes and risk behaviors extending into adulthood.^{3,5} Importantly, adolescence is a significant period of biological, cognitive, and psychosocial development, therefore, adolescents may be more vulnerable to the harmful effects of cannabis use.⁶

E-cigarettes has surpassed combustible cigarettes and become the most commonly used tobacco product among US adolescents since 2014,^{7,8} mostly due to its sleek design and aggressive marketing.^{9–12} In 2020, 19.6% of high school students and 4.7% of middle school students reported using e-cigarettes in the past 30 days.⁷ It is well-documented that e-cigarette use is significantly associated with combustible cigarette smoking initiation and use of other tobacco and nicotine products in the current literature.^{13–16} In addition, the modifiable design features of various e-cigarette products have raised public concerns that these devices may be used to vape other substances, such as cannabis.¹⁷ The 2016 Surgeon General Report, for example, documented the use of e-cigarettes for delivering cannabis products, such as liquid THC (tetrahydrocannabinol), hash oil, or wax.¹⁰ In 2019, the outbreak of e-cigarette, or vaping, product use-associated lung injury (EVALI) further highlighted the risks of using electronic nicotine delivery devices to vape cannabis products.¹⁸

A growing body of literature shows that e-cigarette use is significantly associated with subsequent initiation of cannabis use among US adolescents.^{19–21} Ksinan et al (2020) followed a large, diverse group of college students from freshman to senior year and found a consistent longitudinal association between e-cigarette use and cannabis use overall and among never cigarette smokers using cross-lagged models.²² However, previous studies focused primarily on overall, not modality-specific, cannabis use. With a more heterogeneous array of cannabis products available, cannabis can be used in a variety of modes, including but not limited to smoking, vaping, eating/drinking, or dabbing.²³ Previous

studies investigating the prospective association between e-cigarette use and overall cannabis use could not provide a full picture of how e-cigarette use might be associated with different modes of cannabis use. For example, given the modifiable design features of e-cigarettes and similarities of consumption methods of e-cigarette use and cannabis vaping, e-cigarette use might be more strongly associated with the onset of cannabis vaping than with the onset of blunting, a method to smoke cannabis by hollowing out part or all of a cigar/cigarillo to fill with cannabis, for adolescents who had never used cannabis products.

Although smoking (joints, blunts, bowls, etc.) is still the most common mode of cannabis consumption among US adolescents, current evidence suggests that its prevalence declined; and the prevalence of other non-combustible consumption modes, such as vaping and edible, increased in recent years.^{24,25} Given the change in cannabis consumption patterns and the rapidly evolving regulatory environment towards e-cigarettes and cannabis,^{1,26} it is important to examine the potentially differential relationships between e-cigarette use and various modes of cannabis use, particularly how e-cigarette use is associated with cannabis vaping compared with its association with other modes of cannabis use, which could in turn help better understand the mechanisms linking e-cigarettes and cannabis use, and the potential impact of the policies restricting youth access to e-cigarettes on future modality-specific cannabis use. Unfortunately, empirical evidence on the association between e-cigarette use and subsequent onset of different modes of cannabis use is scarce. One study using cross-sectional data from the 2018 National Youth Tobacco Survey (NYTS) found that current e-cigarette use and lifetime e-cigarette use were associated with higher likelihood of ever cannabis vaping.²⁷ However, the putative risk factors and outcomes in this study were measured simultaneously, which was not able to differentiate the temporality of e-cigarette use and cannabis use. In addition, it did not examine the relationship between e-cigarette use and other modes of cannabis use. A similar study followed a sample of college students (mostly young adults) in Hawaii and found that baseline cannabis-naïve participants who used e-cigarettes only or who were dual users of e-cigarettes and combustible cigarettes were both more likely to report cannabis vaping at 12-month follow-up compared with non-tobacco users.²⁸ Longitudinal research using nationally representative data to study the association between e-cigarette use and modality-specific cannabis use among US adolescents is nonexistent.

Our study aims to fill this critical knowledge gap by examining the prospective associations between baseline e-cigarette use and subsequent onsets of multiple modes of cannabis use during a 12-month follow-up period among baseline cannabis-naïve adolescents using the Population Assessment of Tobacco and Health (PATH) Study, an ongoing, large-scale, nationally representative cohort study of the US population. In addition to general cannabis use, the PATH Study also collected data on modality-specific cannabis use, which provided a unique opportunity to investigate this topic. We hypothesized that the association of e-cigarette use with future onset of cannabis vaping would be stronger than the association between e-cigarette use and other modes of cannabis use, after controlling for a wide range of individual- and state-level factors.

2. Materials and Methods

2.1 Data and study design

Data used in this study were from the Wave 4 and 4.5 surveys of the PATH Study youth cohort. Wave 4.5 is a 12-month follow-up of the Wave 4 Cohort and collected data only from youth. Wave 4 data were collected from December 2016 to January 2018, and Wave 4.5 data were collected from December 2017 to December 2018. Detailed sampling methods and study design are available elsewhere.²⁹

Adolescents who had never used cannabis at Wave 4 and reported cannabis using status at Wave 4.5 were included in this study. Among 14,798 adolescents who completed the Wave 4 interviews, 1,345 were excluded because they reported ever/current cannabis use or had no confirmative cannabis use status at Wave 4 or previous waves, 3,761 were excluded because they had no cannabis using status at Wave 4.5 (2,383 aged up to adults and was not interviewed at Wave 4.5 survey, 1,157 lost to follow-up, and 221 refused to report or did not know their cannabis using status), which led to a sample of 9,692 adolescents for data analysis. The proportion of observations with missing values were low (less than 2% for single-variable analysis, and about 5% for regression analysis). The PATH research team has imputed Wave 4 Cohort respondents' sex, race, and ethnicity to calculate sample weight.²⁹ Pairwise deletion was used to handle other missing values during data analysis to maximize all data available. This study was exempt from ethics review by the Georgia State University (GSU) Institutional Review Board (IRB).

2.2 Measures

The outcome of interest in this study was self-reported cannabis using status at 12-month follow-up survey. At Wave 4.5, adolescents were asked whether they had “ever used marijuana, marijuana concentrates, marijuana waxes, THC, or hash oil in an electronic product such as an e-cigarette, vape, mod, personal vaporizer, e-hookah, or hookah pen”, “ever smoked part or all of a traditional cigar, cigarillo, or filtered cigar with marijuana in it”, and “ever smoked marijuana in a hookah”. Since only baseline cannabis-naïve adolescents were included in this study, those who answered “Yes” were coded as past-12-month vaping, past-12-month blunting, and past-12-month smoking with hookah, respectively. Adolescents were also asked about “marijuana, hash, THC, grass, pot or weed” use in the past 12 months and past 30 days. Adolescents who reported any modality of past-12-month cannabis use or past-12-month general cannabis use at follow-up were coded as past-12-month any cannabis users. Adolescents who reported past-30-day blunting or past-30-day general cannabis use were coded as past-30-day any cannabis users.

The primary exposure of interest was current e-cigarette use at baseline, which was defined as past-30-day use of any electronic nicotine products at Wave 4. Baseline covariates included in this analysis were past-30-day use of other tobacco products (cigarette, cigar/cigarillo, pipe, hookah, smokeless tobacco, including snus and dissolvable products, bidi, and kretek), past-30-day alcohol use, past-30-day misuse of prescription drugs (Ritalin, Adderall, painkillers, sedatives, or tranquilizers), past-30-day use of other illicit drugs (cocaine or crack, stimulants like methamphetamine or speed, heroin, inhalants, solvents, or

hallucinogens), perception of harmfulness from e-cigarette use (no harm, little harm, some harm, and a lot of harm), age in years, biological sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or non-Hispanic other), parents' highest education (less than high school, high school graduate, some college or associate degree, and bachelor's degree or above), mental health conditions, and state-level adult recreational cannabis use legalization status.

Mental health conditions were measured as the severity of internalizing and externalizing mental health problems of adolescents, following an approach from previous studies.^{30–32} Specifically, the PATH study included a screening measure asking adolescents' symptoms pertinent to mental health conditions. There were four items for internalizing mental health conditions and seven items for externalizing mental health conditions. For each item, adolescents who had significant problems with it in the past 12 months were coded as 1 and others were coded as 0. Scores for internalizing and externalizing conditions are summed up separately and categorized to low (0–1), moderate (2–3), and high (4 and above) severity. Status of state-level recreational cannabis legalization at the survey year was compiled from the NIH Alcohol Policy Information System and was linked to the dataset using participants' state identifiers in the PATH Study Restricted Use Files.³³

2.3 Data analysis

All data management and analyses were conducted using Stata 16.1 (College Station, TX. StataCorp). The cross-sectional weights for Wave 4 cohort were applied to account for the complex sampling design and produce nationally representative estimates. Descriptive statistics for study sample were reported. The weighted prevalence of past-12-month cannabis vaping, blunting, smoking cannabis with hookah, any cannabis use, and past-30-day any cannabis use was estimated, for the entire sample and stratified by baseline exposure and covariates. Multivariate logistic regression models were used to estimate the association between each outcome and the exposure variable, controlling for individual-level characteristics and state-level cannabis legalization status listed above. All null hypothesis statistical tests were two-sided with significance level $\alpha=0.05$.

3. Results

Table 1 presented the descriptive statistics for baseline characteristics and cannabis use status at 12-month follow-up. Among adolescents who had never used cannabis at baseline, 1.2% were past-30-day e-cigarette users, 1.0% used other tobacco products in the past 30 days, 50.9% were boys, 53.2% were non-Hispanic whites, 13.0% were non-Hispanic blacks, and 23.4% were Hispanics. High severity of internalizing and externalizing mental health problems were reported by 20.1% and 29.4% of participants, respectively. More than one-fifth (20.1%) of adolescents lived in states with laws permitting recreational cannabis use for adults. At follow-up, 5.3% (95% CI: 4.8%–5.7%) reported past-12-month cannabis vaping, 3.2% (95% CI: 2.8%–3.6%) reported past-12-month blunting, 0.6% (95% CI: 0.4%–0.8%) reported past-12-month smoking cannabis with hookah, 8.2% (95% CI: 7.6%–8.8%) reported past-12-month any cannabis use, and 3.3% (95% CI: 3.0%–3.7%) reported past-30-day any cannabis use.

The weighted bivariate associations between baseline characteristics and cannabis using status at follow-up were presented in Table 2. All cannabis use outcomes at follow-up were more prevalent among adolescents who reported using e-cigarettes in the past 30 days at baseline versus those who did not report past-30-day e-cigarette use (cannabis vaping: 29.7% (95% CI: 21.7%–39.2%) vs. 4.9% (95% CI: 4.5%–5.4%); blunting: 26.3% (95% CI: 18.8%–35.6%) vs. 2.9% (95% CI: 2.5%–3.2%); smoking cannabis with hookah: 5.6% (95% CI: 2.4%–12.6%) vs. 0.5% (95% CI: 0.4%–0.7%); past-12-month any cannabis use: 43.2% (95% CI: 33.9%–53.1%) vs. 7.7% (95% CI: 7.1%–8.3%); and past-30-day any cannabis use: 28.8% (95% CI: 20.9%–38.4%) vs. 3.0% (95% CI: 2.6%–3.4%)) (see Supplemental Figure 1).

The adjusted associations between baseline e-cigarette use and each cannabis use outcome at follow-up were presented in Table 3. E-cigarette use at baseline were each significantly associated with subsequent onset of cannabis use except for smoking with hookah. Among cannabis-naïve adolescents at baseline, past-30-day e-cigarette users were more likely to report past-12-month cannabis vaping (aOR=4.00, 95% CI: 2.25–7.10), past-12-month blunting (aOR=5.30, 95% CI: 2.82–9.94), past-12-month any cannabis use (aOR=3.94, 95% CI: 2.35–6.62), and past-30-day any cannabis use (aOR=4.47, 95% CI: 2.64–7.58) at follow-up compared with adolescents who did not report past-30-day e-cigarette use at baseline. Adolescents who reported past-30-day other tobacco product use and past-30-day alcohol use at baseline were more likely to report past-12-month cannabis vaping, blunting, smoking cannabis with hookah, any cannabis use, and past-30-day cannabis use. Past-30-day other illicit drug use was also positively associated with past-12-month cannabis vaping, smoking with hookah, any cannabis use, and past-30-day cannabis use. Adolescents who perceived e-cigarette use as having “little harm” or “some harm” were more likely to report past-12-month cannabis vaping, blunting, any cannabis use, and past-30-day cannabis use compared with adolescents who perceived e-cigarette use as having “a lot of harm”.

Table 3 also presented the associations of other covariates with each cannabis use outcome. Generally, older adolescents were more likely to report past-12-month cannabis vaping, blunting, any cannabis use, and past-30-day cannabis use than adolescents who were 12 years old. Gradient increases with age were observed for 12–15-year-olds but not for 16-year-olds. Non-Hispanic blacks were more likely to report past-12-month blunting (aOR=1.55, 95% CI: 1.07–2.24) and smoking cannabis with hookah (aOR=3.13, 95% CI: 1.14–8.63) at follow-up compared with non-Hispanic whites. Adolescents with high severity of externalizing mental health problems were more likely to report past-12-month cannabis vaping (aOR=1.90, 95% CI: 1.44–2.51), blunting (aOR=2.35, 95% CI: 1.67–3.29), any cannabis use (aOR=2.10, 95% CI: 1.67–2.63), and past-30-day any cannabis use (aOR=2.14, 95% CI: 1.48–3.08) at follow-up compared with adolescents with low severity of externalizing mental health problems. Furthermore, adolescents living in states with laws permitting recreational cannabis use for adults at baseline were more likely to report past-12-month cannabis vaping (aOR=1.38, 95% CI: 1.16–1.64) blunting (aOR=1.30, 95% CI: 1.05–1.61), any cannabis use (aOR=1.21, 95% CI: 1.01–1.44), and past-30-day any cannabis use (aOR=1.42, 95% CI: 1.14–1.77) at follow-up compared with adolescents living in states without such laws.

4. Discussion

This study provided the first comprehensive examination of the associations between e-cigarette use and subsequent onsets of modality-specific cannabis use at 12-month follow-up using nationally representative data of US adolescents. The study findings have important policy implications, particularly in the context of youth vaping epidemic. Consistent with previous studies, e-cigarette use was found to be significantly associated with subsequent initiation of cannabis use among US adolescents in this study.^{19–21} However, contrary to our initial hypothesis, results from this study showed that the association between e-cigarette use and subsequent onset of cannabis vaping was not significantly stronger than the association between e-cigarette use and other modes of cannabis use, as indicated by the overlapping of confidence intervals.

There are several possible reasons why the result is inconsistent with our initial hypothesis. First, during the 12-month follow-up period, e-cigarette using adolescents may initiate cannabis vaping first, and then, within a short period of time, transition to other modes of cannabis use. Transition behaviors could be common particularly given the expanded legalization, increased availability of cannabis products, and increased social acceptability of cannabis use in recent years.^{34,35} If the transition occurred prior to the 12-month follow-up survey, this could lead to the comparable positive associations between baseline e-cigarette use and subsequent use of other modes of cannabis. Unfortunately, the PATH study did not include questions about the exact timing of initiation for each mode of cannabis use; therefore, we were not able to examine the sequence of initiation of different modes of cannabis use.

Second, it is possible that the association between e-cigarette use and cannabis use does not depend on consumption mode. E-cigarette use and cannabis use, regardless of modality of consumption, may share a common liability that elevates the risks of both,³⁶ i.e., it is possible that there are other latent characteristics of adolescents that may explain both e-cigarette and cannabis use, hence explaining the positive associations between e-cigarette use and all modes of cannabis use. Our results showed that among baseline cannabis-naïve adolescents, 5.3% (95% CI: 4.8%–5.7%) reported cannabis vaping at 12-month follow-up, which was higher than the proportion of blunting (3.2%, 95% CI: 2.8%–3.6%). However, these proportions were comparable among e-cigarette users (29.7%, 95% CI: 21.7%–39.2% for cannabis vaping vs. 26.3%, 95% CI: 18.8%–35.6% for blunting). However, in this study, we likely controlled for at least some, if not most, of the influence of these latent variables by including a wide variety of risk factors in our analysis, which included baseline use of other tobacco products, alcohol use, misuse of prescription drugs, and use of other illicit drugs.

Third, there might be other factors that were not controlled for in this study due to lack of data, such as the perception of harm based on cannabis use modality, and how it was correlated with the perception of harm for e-cigarette use. Existing literature showed that adolescents learned about risks of cigarette smoking from multiple sources, but received much less and often incorrect information on e-cigarette and cannabis use.³⁷ In addition, e-cigarette using adolescents were less likely to perceive cannabis use as risky.³⁸ If harm

perception of cannabis is a key factor in determining cannabis use, and if e-cigarette using adolescents did not perceive cannabis use as harmful regardless of modality of use, then they might have similar chance to initiate cannabis use regardless of the modes of use.

This study also revealed other important findings about other individual- and state-level factors associated with cannabis use. First, our study revealed different cannabis initiation patterns across racial/ethnic groups. Our results show that, *ceteris paribus*, non-Hispanic black cannabis-naïve adolescents were more likely to report past-12-month blunting or smoking cannabis with hookah at follow-up compared with non-Hispanic whites. Previous studies showed that compared with non-Hispanic white adolescents, non-Hispanic black adolescents were less likely to initiate cigarette smoking,^{31,39} but more likely to smoke cigars or use hookahs.³⁹ This may be partially attributable to the targeted marketing of tobacco industry.^{40,41} In addition, non-Hispanic black adolescents may be more likely to have lower perceived risks of using cigars/hookahs or have friends/peers who use cigars/hookahs compared with non-Hispanic white adolescents. Second, our study revealed that state-level recreational cannabis legalization was associated with increased odds of cannabis vaping, blunting, and any cannabis use. Current evidence on the effect of cannabis legalization on adolescent cannabis use is still inconclusive.^{34,42–46} Our study results suggest that adolescents living in states that legalized recreational cannabis use for adults were more likely to engage in cannabis vaping, blunting, and any cannabis use, than their counterparts living in states without such laws. Third, consistent with previous literature, we also found that other tobacco use, alcohol use, other illicit drug use, perceiving e-cigarette use as having little or some harm, older age, and high severity of externalizing mental health problems was associated with elevated odds of future cannabis use.^{47–54} Most factors were not significantly associated with smoking cannabis with hookah, which may be due to the small number of cannabis hookah users.

Our study has some limitations. First, variables included in this study, including tobacco, cannabis, and other illicit drug use status were self-reported, which may subject to recall bias and social desirability bias. Second, due to lack of data, we could not control for peer-/family-effect variables relating to cannabis use and individual's knowledge, attitude, and perception towards cannabis use, which are important factors that may influence adolescents' cannabis use. Third, the research design of this study does not permit causal inferences. However, this study did control for a wide range of potential confounders and established a temporal association between baseline e-cigarette use and subsequent cannabis use. Future studies, especially clinical studies and studies using qualitative data, are needed to better explain the mechanisms linking e-cigarette use and cannabis initiation. Fourth, the PATH study did not include questions on certain modes of cannabis consumption, such as eating, dabbing, etc.; therefore, we were not able to estimate the associations between e-cigarette use and these modes of cannabis use. In addition, as mentioned above, the PATH study did not specifically ask the timing of cannabis initiation and use frequency for each mode of cannabis use. Future studies are needed to explore the sequence of initiation for various modes of cannabis use and how different modes of cannabis use may interact with each other.

5. Conclusion

Baseline e-cigarette use was significantly associated with increased odds of onset of cannabis vaping, blunting, and any cannabis use at 12-month follow-up among baseline cannabis-naïve adolescents in the US. The magnitude of the association between e-cigarette use and cannabis vaping was not significantly stronger than the associations between e-cigarette use and other modes of cannabis use. Non-Hispanic blacks were more likely to report using cannabis by blunting and smoking with hookah than non-Hispanic whites. Use of other tobacco products and alcohol was associated with increased odds of cannabis use regardless of the modality. Perceiving e-cigarette use as having little or some harm, older age, high severity of externalizing mental health problems, and living in states legalized adult recreational cannabis use were significantly associated with future onset of cannabis vaping, blunting, and any cannabis use. Future studies are needed to better explain the mechanisms linking e-cigarette use and cannabis initiation, and examine how different modes of cannabis use may interact with each other.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME. Monitoring the Future national survey results on drug use 1975–2020: Overview, key findings on adolescent drug use. Institute for Social Research. 2021.
2. Degenhardt L, Stockings E, Patton G, Hall WD, Lynskey M. The increasing global health priority of substance use in young people. *The Lancet Psychiatry*. 2016;3(3):251–264. [PubMed: 26905480]
3. Wilson J, Freeman TP, Mackie CJ. Effects of increasing cannabis potency on adolescent health. *The Lancet Child & Adolescent Health*. 2019;3(2):121–128. [PubMed: 30573419]
4. Ammerman S, Ryan S, Adelman WP, Abuse CoS. The impact of marijuana policies on youth: clinical, research, and legal update. *Pediatrics*. 2015;135(3):e769–e785. [PubMed: 25624385]
5. Jacobus J, Bava S, Cohen-Zion M, Mahmood O, Tapert S. Functional consequences of marijuana use in adolescents. *Pharmacology Biochemistry and Behavior*. 2009;92(4):559–565.
6. Backes EP, Bonnie RJ. *The Promise of Adolescence: Realizing Opportunity for All Youth*. 2019.
7. Wang TW, Neff LJ, Park-Lee E, Ren C, Cullen KA, King BA. E-cigarette use among middle and high school students—United States, 2020. *Morbidity and Mortality Weekly Report*. 2020;69(37):1310. [PubMed: 32941408]
8. Cullen KA, Ambrose BK, Gentzke AS, Apelberg BJ, Jamal A, King BA. Notes from the field: use of electronic cigarettes and any tobacco product among middle and high school students—United States, 2011–2018. *Morbidity and Mortality Weekly Report*. 2018;67(45):1276. [PubMed: 30439875]
9. Huang J, Duan Z, Kwok J, et al. Vaping versus JUULing: how the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. *Tobacco control*. 2019;28(2):146–151. [PubMed: 29853561]

10. US Department of Health and Human Services. E-cigarette use among youth and young adults: a report of the Surgeon General. 2016.
11. Ali FRM, Marynak KL, Kim Y, et al. E-cigarette advertising expenditures in the USA, 2014–2018. *Tobacco Control*. 2020;29(e1):e124–e126. [PubMed: 32108086]
12. Duan Z, Wang Y, Emery SL, Chaloupka FJ, Kim Y, Huang J. Exposure to e-cigarette TV advertisements among US youth and adults, 2013–2019. *PloS one*. 2021;16(5):e0251203. [PubMed: 33961669]
13. Glasser A, Abudayyeh H, Cantrell J, Niaura R. Patterns of e-cigarette use among youth and young adults: review of the impact of e-cigarettes on cigarette smoking. *Nicotine and Tobacco Research*. 2019;21(10):1320–1330. [PubMed: 29788314]
14. Soneji S, Barrington-Trimis JL, Wills TA, et al. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. *JAMA pediatrics*. 2017;171(8):788–797. [PubMed: 28654986]
15. Wang Y, Duan Z, Emery SL, Kim Y, Chaloupka FJ, Huang J. The Association between E-Cigarette Price and TV Advertising and the Sales of Smokeless Tobacco Products in the USA. *International journal of environmental research and public health*. 2021;18(13):6795. [PubMed: 34202723]
16. Huang J, Wang Y, Duan Z, Kim Y, Emery SL, Chaloupka FJ. Do e-cigarette sales reduce the demand for nicotine replacement therapy (NRT) products in the US? Evidence from the retail sales data. *Preventive Medicine*. 2021;145:106376. [PubMed: 33346035]
17. Brown CJ, Cheng JM. Electronic cigarettes: product characterisation and design considerations. *Tobacco control*. 2014;23(suppl 2):ii4–ii10. [PubMed: 24732162]
18. Krishnasamy VP, Hallowell BD, Ko JY, et al. Update: characteristics of a nationwide outbreak of e-cigarette, or vaping, product use–associated lung injury—United States, August 2019–January 2020. *Morbidity and Mortality Weekly Report*. 2020;69(3):90. [PubMed: 31971931]
19. Park E, Livingston JA, Wang W, Kwon M, Eiden RD, Chang Y-P. Adolescent E-cigarette use trajectories and subsequent alcohol and marijuana use. *Addictive Behaviors*. 2020;103:106213. [PubMed: 31862618]
20. Evans-Polce RJ, Veliz PT, Boyd CJ, McCabe SE. E-Cigarette and Cigarette Use Among US Adolescents: Longitudinal Associations With Marijuana Use and Perceptions. *American Journal of Preventive Medicine*. 2020.
21. Chadi N, Schroeder R, Jensen JW, Levy S. Association between electronic cigarette use and marijuana use among adolescents and young adults: a systematic review and meta-analysis. *Jama Pediatrics*. 2019;173(10):e192574–e192574. [PubMed: 31403684]
22. Ksinan AJ, Spindle TR, Thomas NS, Eissenberg T, Dick DM, group SfSW. E-cigarette use is prospectively associated with initiation of cannabis among college students. *Addictive behaviors*. 2020;106:106312. [PubMed: 32120197]
23. Schauer GL, Njai R, Grant-Lenzy AM. Modes of marijuana use—smoking, vaping, eating, and dabbing: Results from the 2016 BRFSS in 12 States. *Drug and alcohol dependence*. 2020;209:107900. [PubMed: 32061947]
24. Patrick ME, Miech RA, Kloska DD, Wagner AC, Johnston LD. Trends in marijuana vaping and edible consumption From 2015 to 2018 among adolescents in the US. *JAMA pediatrics*. 2020;174(9):900–902. [PubMed: 32250422]
25. Tormohlen KN, Schneider KE, Johnson RM, Ma M, Levinson AH, Brooks-Russell A. Changes in prevalence of marijuana consumption modes among Colorado high school students from 2015 to 2017. *JAMA pediatrics*. 2019;173(10):988–989. [PubMed: 31381036]
26. King BA, Jones CM, Baldwin GT, Briss PA. The EVALI and youth vaping epidemics—implications for public health. *New England Journal of Medicine*. 2020;382(8):689–691.
27. Taleb ZB, Kalan ME, Bahelah R, Boateng GO, Rahman M, Alshbool FZ. Vaping while high: Factors associated with vaping marijuana among youth in the United States. *Drug and Alcohol Dependence*. 2020;217:108290. [PubMed: 32956975]
28. Pokhrel P, Fagan P, Kawamoto CT, Okamoto SK, Herzog TA. Predictors of marijuana vaping onset and escalation among young adults. *Drug and Alcohol Dependence*. 2020;216:108320. [PubMed: 33039921]

29. United States Department of Health Human Services. National Institutes of Health. National Institute on Drug Abuse, United States Department of Health Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. 2020. doi:10.3886/ICPSR36231.v25.
30. Conway KP, Green VR, Kasza KA, et al. Co-occurrence of tobacco product use, substance use, and mental health problems among youth: Findings from wave 1 (2013–2014) of the population assessment of tobacco and health (PATH) study. *Addictive behaviors*. 2018;76:208–217. [PubMed: 28846942]
31. Duan Z, Wang Y, Huang J. Sex difference in the association between electronic cigarette use and subsequent cigarette smoking among US adolescents: findings from the PATH study waves 1–4. *International journal of environmental research and public health*. 2021;18(4):1695. [PubMed: 33578770]
32. Duan Z, Wang Y, Spears CA, et al. Role of Mental Health in the Association Between E-Cigarettes and Cannabis Use. *American journal of preventive medicine*. 2021.
33. Alcohol Policy Information System. Recreational Use of Cannabis: Volume 1. <https://alcoholpolicy.niaaa.nih.gov/cannabis-policy-topics/recreational-use-of-cannabis-volume-1/104>. Accessed May 25, 2021.
34. Brooks-Russell A, Ma M, Levinson AH, et al. Adolescent marijuana use, marijuana-related perceptions, and use of other substances before and after initiation of retail marijuana sales in Colorado (2013–2015). *Prevention science*. 2019;20(2):185–193. [PubMed: 30043198]
35. Hall W, Lynskey M. Assessing the public health impacts of legalizing recreational cannabis use: the US experience. *World Psychiatry*. 2020;19(2):179–186. [PubMed: 32394566]
36. Chan GC, Stjepanovi D, Lim C, et al. Gateway or common liability? A systematic review and meta-analysis of studies of adolescent e-cigarette use and future smoking initiation. *Addiction*. 2021;116(4):743–756. [PubMed: 32888234]
37. Roditis ML, Halpern-Felsher B. Adolescents' perceptions of risks and benefits of conventional cigarettes, e-cigarettes, and marijuana: a qualitative analysis. *Journal of Adolescent Health*. 2015;57(2):179–185.
38. Evans-Polce RJ, Veliz PT, Boyd CJ, McCabe SE. E-cigarette and cigarette use among US adolescents: Longitudinal associations with marijuana use and perceptions. *American journal of preventive medicine*. 2020;58(6):854–857. [PubMed: 32201183]
39. Gentzke AS, Wang TW, Jamal A, et al. Tobacco Product Use Among Middle and High School Students—United States, 2020. *Morbidity and Mortality Weekly Report*. 2020;69(50):1881. [PubMed: 33332300]
40. Cantrell J, Kreslake JM, Ganz O, et al. Marketing little cigars and cigarillos: advertising, price, and associations with neighborhood demographics. *American journal of public health*. 2013;103(10):1902–1909. [PubMed: 23948008]
41. Ribisl KM, D'Angelo H, Feld AL, et al. Disparities in tobacco marketing and product availability at the point of sale: results of a national study. *Preventive medicine*. 2017;105:381–388. [PubMed: 28392252]
42. Cerdá M, Mauro C, Hamilton A, et al. Association between recreational marijuana legalization in the United States and changes in marijuana use and cannabis use disorder from 2008 to 2016. *JAMA psychiatry*. 2020;77(2):165–171. [PubMed: 31722000]
43. Cerdá M, Wall M, Feng T, et al. Association of state recreational marijuana laws with adolescent marijuana use. *JAMA pediatrics*. 2017;171(2):142–149. [PubMed: 28027345]
44. Wang GS, Davies SD, Halmo LS, Sass A, Mistry RD. Impact of marijuana legalization in Colorado on adolescent emergency and urgent care visits. *Journal of Adolescent Health*. 2018;63(2):239–241.
45. Duan Z, Wang Y, Weaver SR, et al. Effect modification of legalizing recreational cannabis use on the association between e-cigarette use and future cannabis use among US adolescents. *Drug and Alcohol Dependence*. 2021:109260. [PubMed: 35152099]
46. Stone AL. Adolescent Cannabis Use and Perceived Social Norm Trends Pre-and Post-Implementation of Washington State's Liberalized Recreational Cannabis Policy: Healthy Youth Survey, 2008–2018. *Prevention Science*. 2020;21:772–783. [PubMed: 32507995]

47. Mayet A, Legleye S, Chau N, Falissard B. Transitions between tobacco and cannabis use among adolescents: a multi-state modeling of progression from onset to daily use. *Addictive behaviors*. 2011;36(11):1101–1105. [PubMed: 21794987]
48. von Sydow K, Lieb R, Pfister H, Höfler M, Wittchen H-U. What predicts incident use of cannabis and progression to abuse and dependence?: A 4-year prospective examination of risk factors in a community sample of adolescents and young adults. *Drug and alcohol dependence*. 2002;68(1):49–64. [PubMed: 12167552]
49. Scalco MD, Colder CR, Hawk LW Jr, Read JP, Wieczorek WF, Lengua LJ. Internalizing and externalizing problem behavior and early adolescent substance use: A test of a latent variable interaction and conditional indirect effects. *Psychology of Addictive Behaviors*. 2014;28(3):828. [PubMed: 25134030]
50. Colder CR, Frndak S, Lengua LJ, Read JP, Hawk LW, Wieczorek WF. Internalizing and externalizing problem behavior: A test of a latent variable interaction predicting a two-part growth model of adolescent substance use. *Journal of Abnormal Child Psychology*. 2018;46(2):319–330. [PubMed: 28229368]
51. Miettunen J, Murray G, Jones P, et al. Longitudinal associations between childhood and adulthood externalizing and internalizing psychopathology and adolescent substance use. *Psychological medicine*. 2014;44(8):1727–1738. [PubMed: 24028974]
52. Pedersen MU, Thomsen KR, Heradstveit O, Skogen JC, Hesse M, Jones S. Externalizing behavior problems are related to substance use in adolescents across six samples from Nordic countries. *European child & adolescent psychiatry*. 2018;27(12):1551–1561. [PubMed: 29619558]
53. Audrain-McGovern J, Rodriguez D, Testa S, Alexander E, Pianin S. Adolescent E-Cigarette Onset and Escalation: Associations With Internalizing and Externalizing Symptoms. *Journal of Adolescent Health*. 2020.
54. Dai H, Catley D, Richter KP, Goggin K, Ellerbeck EF. Electronic cigarettes and future marijuana use: a longitudinal study. *Pediatrics*. 2018;141(5).

Highlights

- Youth e-cigarette use was associated with onset of multiple modes of cannabis use.
- Association between e-cigarette and cannabis vaping was not stronger than others.
- Non-Hispanic black youth were more likely to blunt or smoke cannabis with hookah.
- Adult recreational cannabis legalization was associated with youth cannabis use.

Table 1.

Descriptive statistics for study variables among baseline never cannabis users.

	Weighted %	95% CI	Unweighted n
Wave 4.5 outcome variables			
Past-12-month cannabis vaping			
Yes	5.3	4.8 – 5.7	523
No	94.7	94.3 – 95.2	9,153
Past-12-month blunting			
Yes	3.2	2.8 – 3.6	320
No	96.8	96.4 – 97.2	9,355
Past-12-month smoking cannabis with Hookah			
Yes	0.6	0.4 – 0.8	57
No	99.4	99.2 – 99.6	9,626
Past-12-month any cannabis use			
Yes	8.2	7.6 – 8.8	810
No	91.8	91.2 – 92.4	8,859
Past-30-day any cannabis use			
Yes	3.3	3.0 – 3.7	328
No	96.7	96.3 – 97.0	9,363
Wave 4 baseline variables			
Past-30-day e-cigarette use			
Yes	1.2	1.0 – 1.4	110
No	98.8	98.6 – 99.0	9,551
Past-30-day use of other tobacco *			
Yes	1.0	0.8 – 1.2	91
No	99.0	98.8 – 99.2	9,495
Past-30-day alcohol use			
Yes	4.7	4.2 – 5.2	440
No	95.3	94.8 – 95.8	9,245
Past-30-day misuse of prescription drugs			
Yes	2.8	2.5 – 3.1	284
No	97.2	96.9 – 97.5	9,408
Past-30-day use of other illicit drugs			
Yes	0.1	0.0 – 0.2	7
No	99.9	99.8 – 100.0	9,684
Perception of harmfulness of e-cigarette			
No harm	1.6	1.3 – 1.9	151
Little harm	9.2	8.6 – 9.9	886
Some harm	29.9	29.0 – 30.9	2,874
A lot of harm	59.3	58.2 – 60.3	5,709
Age in years			

	Weighted %	95% CI	Unweighted n
12	22.8	21.9 – 23.7	2,019
13	22.0	21.1 – 22.9	2,191
14	20.8	19.9 – 21.6	2,109
15	18.3	17.5 – 19.1	1,799
16	16.2	15.4 – 17.0	1,574
Sex			
Male	50.9	49.9 – 52.0	5,030
Female	49.1	48.0 – 50.1	4,662
Race/ethnicity			
Non-Hispanic White	53.2	52.2 – 54.3	4,571
Non-Hispanic Black	13.0	12.3 – 13.7	1,277
Hispanic	23.4	22.6 – 24.2	2,896
Non-Hispanic Other	10.4	9.7 – 11.1	948
Parental education			
Less than high school	15.1	14.4 – 15.8	1,732
High school graduate	16.7	16.0 – 17.6	1,710
Some college or associate degree	30.5	29.5 – 31.4	2,979
Bachelor's degree or above	37.7	36.7 – 38.8	3,193
Severity of internalizing mental health problems			
Low	51.4	50.3 – 52.5	4,975
Moderate	28.6	27.6 – 29.5	2,676
High	20.1	19.2 – 20.9	1,943
Severity of externalizing mental health problems			
Low	40.9	39.8 – 42.0	3,998
Moderate	29.7	28.7 – 30.7	2,749
High	29.4	28.4 – 30.4	2,786
State-level recreational cannabis legalization			
Yes	20.1	19.2 – 20.9	2,038
No	79.9	79.1 – 80.8	7,654

* Other tobacco included cigarette, cigar/cigarillo, pipe, hookah, smokeless tobacco (including snus and dissolvable products), bidi, and kretek.

Table 2.

Weighted prevalence of past-12-month cannabis vaping, past-12-month blunting, past-12-month smoking cannabis with hookah, past-12-month any cannabis use, and past-30-day any cannabis use at Wave 4.5 by baseline characteristics.

Baseline characteristics	Past-12-month cannabis vaping			Past-12-month blunting			Past-12-month use with hookah			Past-12-month any cannabis use			Past-30-day any cannabis use		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	
Past-30-day e-cigarette use															
Yes	29.7	21.7 – 39.2	26.3	18.8 – 35.6	5.6	2.4 – 12.6	43.2	33.9 – 53.1	28.8	20.9 – 38.4					
No	4.9	4.5 – 5.4	2.9	2.5 – 3.2	0.5	0.4 – 0.7	7.7	7.1 – 8.3	3.0	2.6 – 3.4					
Past-30-day use of other tobacco*															
Yes	25.4	17.2 – 35.9	21.0	13.4 – 31.5	6.4	2.7 – 14.7	40.4	30.1 – 51.7	26.3	17.9 – 36.8					
No	5.1	4.6 – 5.5	3.0	2.6 – 3.4	0.5	0.4 – 0.7	7.9	7.3 – 8.5	3.1	2.7 – 3.5					
Past-30-day alcohol use															
Yes	15.9	12.4 – 20.1	10.3	7.5 – 14.1	3.0	1.4 – 6.5	27.4	23.1 – 32.3	13.3	10.0 – 17.3					
No	4.7	4.3 – 5.2	2.8	2.5 – 3.2	0.4	0.3 – 0.6	7.2	6.7 – 7.8	2.8	2.5 – 3.2					
Past-30-day misuse of prescription drugs															
Yes	9.3	6.4 – 13.5	6.7	4.1 – 10.7	0.9	0.3 – 2.7	13.2	9.5 – 17.9	3.6	1.9 – 6.5					
No	5.1	4.7 – 5.6	3.1	2.7 – 3.5	0.6	0.4 – 0.8	8.0	7.5 – 8.7	3.3	2.9 – 3.7					
Past-30-day use other illicit drugs															
Yes	33.2	7.7 – 74.8	11.5	1.5 – 53.1	11.5	1.5 – 53.1	33.2	7.7 – 74.8	33.2	7.7 – 74.8					
No	5.2	4.8 – 5.7	3.2	2.8 – 3.6	0.6	0.4 – 0.8	8.2	7.6 – 8.8	3.3	2.9 – 3.7					
Perception of harmfulness of e-cigarette															
No harm	6.2	3.1 – 12.3	6.9	3.5 – 13.3	1.8	0.5 – 6.9	11.0	6.6 – 17.6	4.5	2.1 – 9.2					
Little harm	12.5	10.4 – 14.9	8.0	6.3 – 10.0	1.3	0.7 – 2.4	18.5	16.0 – 21.4	8.7	7.0 – 10.9					
Some harm	6.1	5.3 – 7.1	4.1	3.3 – 4.9	0.6	0.3 – 1.1	9.9	8.8 – 11.1	4.0	3.3 – 4.9					
A lot of harm	3.7	3.2 – 4.2	1.9	1.6 – 2.3	0.4	0.3 – 0.7	5.7	5.1 – 6.4	2.1	1.7 – 2.5					
Age in years															
12	2.1	1.6 – 2.9	1.3	0.9 – 2.0	0.2	0.1 – 0.7	3.7	2.9 – 4.7	0.7	0.4 – 1.1					
13	4.3	3.5 – 5.3	2.2	1.6 – 2.9	0.5	0.3 – 0.9	6.2	5.2 – 7.5	2.6	1.9 – 3.5					
14	6.0	5.0 – 7.2	3.6	2.8 – 4.5	0.5	0.3 – 0.9	9.0	7.8 – 10.5	3.8	2.9 – 4.8					

Baseline characteristics	Past-12-month cannabis vaping			Past-12-month blunting			Past-12-month use with hookah			Past-12-month any cannabis use			Past-30-day any cannabis use		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	
15	7.6	6.4–9.1	4.9	3.9–6.2	1.2	0.7–2.1	11.5	10.0–13.2	5.1	4.1–6.4	5.1	4.1–6.4	5.1	4.1–6.4	
16	7.3	6.0–8.8	4.7	3.7–5.9	0.5	0.3–1.1	12.4	10.7–14.2	5.5	4.4–6.8	5.5	4.4–6.8	5.5	4.4–6.8	
Sex															
Male	5.1	4.5–5.8	3.2	2.7–3.7	0.6	0.4–0.9	8.1	7.3–9.0	3.4	2.9–4.0	3.4	2.9–4.0	3.4	2.9–4.0	
Female	5.4	4.7–6.1	3.2	2.7–3.8	0.5	0.3–0.9	8.2	7.4–9.1	3.2	2.7–3.8	3.2	2.7–3.8	3.2	2.7–3.8	
Race/ethnicity															
Non-Hispanic White	5.0	4.4–5.7	3.0	2.5–3.6	0.4	0.2–0.8	7.9	7.1–8.8	3.4	2.9–4.1	3.4	2.9–4.1	3.4	2.9–4.1	
Non-Hispanic Black	5.3	4.1–6.7	3.9	2.9–5.2	1.0	0.5–1.8	8.8	7.3–10.6	3.5	2.6–4.7	3.5	2.6–4.7	3.5	2.6–4.7	
Hispanic	5.5	4.7–6.5	3.1	2.5–3.8	0.7	0.4–1.1	8.3	7.3–9.4	3.0	2.4–3.7	3.0	2.4–3.7	3.0	2.4–3.7	
Non-Hispanic Other	6.0	4.6–7.8	3.3	2.3–4.6	0.4	0.2–1.0	8.6	6.9–10.6	3.4	2.3–4.8	3.4	2.3–4.8	3.4	2.3–4.8	
Parental education															
Less than high school	6.1	4.9–7.4	3.5	2.7–4.6	0.8	0.5–1.5	8.6	7.2–10.2	3.1	2.3–4.1	3.1	2.3–4.1	3.1	2.3–4.1	
High school graduate	4.6	3.6–5.8	3.5	2.7–4.6	0.6	0.3–1.2	8.2	6.8–9.8	3.8	2.9–5.0	3.8	2.9–5.0	3.8	2.9–5.0	
Some college or associate degree	5.5	4.7–6.5	3.6	3.0–4.4	0.5	0.3–0.9	8.7	7.7–9.8	3.1	2.6–3.9	3.1	2.6–3.9	3.1	2.6–3.9	
Bachelor's degree or above	4.8	4.1–5.7	2.5	2.0–3.1	0.4	0.2–0.8	7.5	6.5–8.5	3.3	2.6–4.0	3.3	2.6–4.0	3.3	2.6–4.0	
Severity of internalizing mental health problems															
Low	3.8	3.3–4.4	2.3	1.9–2.7	0.3	0.2–0.6	6.2	5.5–7.0	2.6	2.1–3.1	2.6	2.1–3.1	2.6	2.1–3.1	
Moderate	4.8	4.0–5.7	3.1	2.4–3.8	0.4	0.2–0.8	7.9	6.8–9.0	3.3	2.7–4.1	3.3	2.7–4.1	3.3	2.7–4.1	
High	9.6	8.2–11.1	5.6	4.5–6.8	1.4	0.9–2.2	13.6	12.0–15.3	5.3	4.3–6.6	5.3	4.3–6.6	5.3	4.3–6.6	
Severity of externalizing mental health problems															
Low	3.4	2.8–4.0	1.9	1.5–2.4	0.3	0.2–0.6	5.3	4.6–6.1	2.1	1.6–2.6	2.1	1.6–2.6	2.1	1.6–2.6	
Moderate	4.6	3.9–5.5	2.5	2.0–3.2	0.4	0.2–0.7	7.3	6.3–8.4	3.0	2.4–3.7	3.0	2.4–3.7	3.0	2.4–3.7	
High	8.6	7.5–9.8	5.6	4.7–6.6	1.1	0.7–1.7	13.2	11.8–14.6	5.5	4.6–6.6	5.5	4.6–6.6	5.5	4.6–6.6	
State-level recreational cannabis legalization															
Yes	6.4	5.3–7.6	3.5	2.8–4.5	0.7	0.4–1.1	8.9	7.6–10.3	3.9	3.1–4.8	3.9	3.1–4.8	3.9	3.1–4.8	
No	5.0	4.5–5.5	3.1	2.7–3.5	0.5	0.4–0.8	8.0	7.4–8.7	3.2	2.8–3.7	3.2	2.8–3.7	3.2	2.8–3.7	

* Other tobacco included cigarette, cigar/cigarillo, pipe, hookah, smokeless tobacco (including snus and dissolvable products), bidi, and kretek.

Table 3. Adjusted odds ratios (aORs) of multiple modes of cannabis use among baseline never cannabis users.

Baseline characteristics	Past-12-month cannabis vaping		Past-12-month blunting		Past-12-month use with hookah		Past-12-month any cannabis use		Past-30-day any cannabis use	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Past-30-day e-cigarette use										
Yes	4.00	2.25 – 7.10	5.30	2.82 – 9.94	3.08	0.97 – 9.78	3.94	2.35 – 6.62	4.47	2.64 – 7.58
No	Ref.		Ref.		Ref.		Ref.		Ref.	
Past-30-day use of other tobacco										
Yes	2.93	1.61 – 5.34	2.73	1.19 – 6.26	3.63	1.33 – 9.87	3.41	1.88 – 6.16	3.80	2.09 – 6.93
No	Ref.		Ref.		Ref.		Ref.		Ref.	
Past-30-day alcohol use										
Yes	2.15	1.42 – 3.24	2.20	1.27 – 3.80	4.87	1.84 – 12.85	2.98	2.19 – 4.03	2.79	1.92 – 4.04
No	Ref.		Ref.		Ref.		Ref.		Ref.	
Past-30-day misuse of prescription drugs										
Yes	1.21	0.79 – 1.84	1.53	0.94 – 2.48	0.79	0.26 – 2.44	1.10	0.75 – 1.63	0.72	0.41 – 1.27
No	Ref.		Ref.		Ref.		Ref.		Ref.	
Past-30-day use other illicit drugs										
Yes	10.21	2.25 – 46.27	3.70	0.43 – 31.11	18.25	2.02 – 164.63	6.06	1.47 – 25.09	18.53	4.14 – 82.95
No	Ref.		Ref.		Ref.		Ref.		Ref.	
Perception of harmfulness of e-cigarette										
No harm	0.73	0.37 – 1.42	1.63	0.75 – 3.55	1.01	0.22 – 4.58	1.07	0.65 – 1.79	1.18	0.58 – 2.37
Little harm	2.52	1.75 – 3.61	2.72	2.03 – 3.63	1.39	0.65 – 2.97	2.59	1.96 – 3.42	2.67	1.88 – 3.79
Some harm	1.42	1.13 – 1.80	1.76	1.32 – 2.35	1.10	0.49 – 2.48	1.51	1.24 – 1.83	1.58	1.14 – 2.18
A lot of harm	Ref.		Ref.		Ref.		Ref.		Ref.	
Age in years	Ref.		Ref.		Ref.		Ref.		Ref.	
12	1.70	1.25 – 2.32	1.38	0.88 – 2.16	1.84	0.46 – 7.31	1.63	1.18 – 2.26	3.33	1.68 – 6.60
13	2.29	1.69 – 3.12	2.03	1.27 – 3.24	1.76	0.50 – 6.19	2.26	1.65 – 3.10	4.37	2.42 – 7.87
14	2.77	2.02 – 3.80	2.56	1.56 – 4.18	3.52	0.88 – 14.14	2.70	1.97 – 3.71	5.77	3.36 – 9.93
15	2.44	1.64 – 3.62	2.39	1.41 – 4.06	1.44	0.38 – 5.37	2.85	1.93 – 4.22	5.85	3.52 – 9.73

Baseline characteristics	Past-12-month cannabis vaping		Past-12-month blunting		Past-12-month use with hookah		Past-12-month any cannabis use		Past-30-day any cannabis use	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Sex										
Male	0.98	0.80 – 1.21	0.95	0.72 – 1.27	1.27	0.68 – 2.38	0.97	0.83 – 1.14	0.99	0.76 – 1.30
Female	Ref.		Ref.		Ref.		Ref.		Ref.	
Race/ethnicity										
Non-Hispanic White	Ref.		Ref.		Ref.		Ref.		Ref.	
Non-Hispanic Black	1.27	0.97 – 1.66	1.55	1.07 – 2.24	3.13	1.14 – 8.63	1.36	1.05 – 1.77	1.39	0.85 – 2.29
Hispanic	1.13	0.84 – 1.52	1.05	0.83 – 1.33	1.61	0.63 – 4.13	1.13	0.91 – 1.41	0.98	0.68 – 1.42
Non-Hispanic Other	1.38	1.08 – 1.77	1.37	0.94 – 2.00	1.34	0.49 – 3.69	1.29	1.04 – 1.60	1.19	0.78 – 1.82
Parental education										
Less than high school	Ref.		Ref.		Ref.		Ref.		Ref.	
High school graduate	0.73	0.50 – 1.08	1.00	0.55 – 1.82	0.65	0.27 – 1.54	0.89	0.66 – 1.21	1.18	0.72 – 1.95
Some college or associate degree	0.89	0.65 – 1.21	1.04	0.67 – 1.63	0.61	0.25 – 1.46	0.99	0.76 – 1.28	1.04	0.70 – 1.53
Bachelor's degree or above	0.73	0.53 – 1.02	0.65	0.41 – 1.02	0.52	0.15 – 1.78	0.80	0.61 – 1.06	0.98	0.64 – 1.51
Severity of internalizing mental health problems										
Low	Ref.		Ref.		Ref.		Ref.		Ref.	
Moderate	1.01	0.76 – 1.35	0.98	0.69 – 1.40	1.09	0.50 – 2.37	0.98	0.76 – 1.25	1.00	0.74 – 1.34
High	1.52	1.20 – 1.92	1.16	0.77 – 1.75	2.33	0.84 – 6.49	1.25	0.95 – 1.65	1.12	0.76 – 1.68
Severity of externalizing mental health problems										
Low	Ref.		Ref.		Ref.		Ref.		Ref.	
Moderate	1.24	0.94 – 1.63	1.24	0.87 – 1.77	0.82	0.24 – 2.83	1.25	0.99 – 1.58	1.29	0.92 – 1.81
High	1.90	1.44 – 2.51	2.35	1.67 – 3.29	1.73	0.59 – 5.08	2.10	1.67 – 2.63	2.14	1.48 – 3.08
State-level recreational cannabis legalization										
Yes	1.38	1.16 – 1.64	1.30	1.05 – 1.61	1.36	0.80 – 2.33	1.21	1.01 – 1.44	1.42	1.14 – 1.77
No	Ref.		Ref.		Ref.		Ref.		Ref.	

* Other tobacco included cigarette, cigar/cigarillo, pipe, hookah, smokeless tobacco (including snus and dissolvable products), bidi, and kretek.