Kreski Noah (Orcid ID: 0000-0003-3725-156X)
Cerdá Magdalena (Orcid ID: 0000-0001-8441-7046)
Hasin Deborah (Orcid ID: 0000-0002-6533-7021)
Martins Silvia (Orcid ID: 0000-0003-3059-9993)
Miech Richard (Orcid ID: 0000-0002-2812-1109)

Frequency of adolescent cannabis smoking and vaping in the US: trends, disparities, and concurrent substance use, 2017 to 2019

Katherine Keyes[1]
Noah Kreski[1]
Hadley Ankrum[1]
Magdalena Cerdá[2]
Qixuan Chen[3]
Deborah Hasin[1,4]
Silvia Martins[1]
Mark Olfson[1,4]
Richard Miech[5]

[1] Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, NY

[2] Department of Population Health, New York University School of Medicine, New York, NY, USA.

[3] Department of Biostatistics, Mailman School of Public Health, Columbia University, New York, NY, USA.

[4] Department of Psychiatry, New York State Psychiatric Institute, Vagelos College of Physicians and Surgeons, Columbia University Irving Medical Center, New York, NY, USA.

[5] Institute for Social Research, University of Michigan, 426 Thompson Street, Ann Arbor, MI 48104, United States

Corresponding author
Noah Kreski, MPH
Columbia University
Mailman School of Public Health
722 West 168th St., Room 733
New York, NY 10032
Phone: (203)-873-9660
Email: ntk2109@cumc.columbia.edu

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Abstract

Aim: To quantify the trends in frequent and occasional cannabis vaping, demographic differences, and concurrent nicotine and alcohol use.

Design: Observational study. Survey-weighted multinomial logistic regression models assessed trends and disparities in past 30-day cannabis use. Trends were assessed overall and by sex, race/ethnicity, parental education, and urbanicity. Multinomial logistic regression models also estimated associations of cannabis use (none, use without vaping, use with vaping) with past 2-week binge drinking and past 30-day nicotine/tobacco use.

Setting: USA, 2017-2019.

Participants: Participants in the national Monitoring the Future (N = 51,052) survey.

Measurements: Past 30-day frequent cannabis use (≥6 times/30 days) and past 30-day occasional use (1-5 times/30 days), with and without vaping.

Findings: Past 30-day frequent cannabis use with vaping increased (2.1% to 5.4%), while occasional use with vaping rose from 1.2 to 3.5% from 2017 to 2019. Past 30-day frequent (3.8 to 2.1%) and occasional (6.9 to 4.4%) cannabis use without vaping declined. Certain groups, such as Hispanic/Latino or lower socioeconomic status adolescents, experienced particularly notable increases in frequent cannabis use with vaping (e.g., prevalence among Hispanic/Latino adolescents in 2017: 2.2%, 2019: 6.7%). Adolescents who reported smoking and vaping nicotine, and 10+ occasions of binge drinking, were 42.3 (95% confidence interval [C.I.] 33.1-53.9) and 10.1 (95% C.I. 4.5-22.5) times more likely to report past 30-day cannabis use with vaping, respectively, compared with no use.

Discussion: Cannabis use without vaping appears to be declining among adolescents in the United States (US), while cannabis use with vaping is accelerating; frequent cannabis vaping is especially increasing, with consistent increases across almost all adolescent demographic groups. Cannabis use among US adolescents remains highly associated with other substance use.

Introduction

Cannabis use among US adolescents has not exhibited the recent declines seen in other forms of psychoactive substance use among this population.[1] Data from Monitoring the Future (MTF) indicate that past-year prevalence of any cannabis use has generally remained between 34 and 38% in 12th grade students from the late 1990s through 2020. While the prevalence of cannabis use among US adolescents remains lower than in other periods of recent US history (e.g., historic highs in prevalence were observed among adolescents in the late 1970s),[1] this persisting prevalence is concerning for several reasons. In 2020, prevalence of daily cannabis use was higher than any year since 1981.[1] Heavy levels of cannabis use are associated with adverse cognitive and social outcomes for youth, as well as long-term trajectories of drug use that may have adverse health and other consequences.[2,3] One concern in recent years is the increasingly widespread availability of cannabis products that can be consumed through vaporization.

Increasing use of vaporized cannabis devices among youth is particularly concerning given that high levels of tetrahydrocannabinol (THC) can be delivered through these devices,[4] which may lead to unpleasant and dangerous consequences for youth users with lower tolerance. In laboratory research, significantly higher doses

of blood THC and its metabolites have been detected following vaporization compared to smoking the same cannabis dose.[5] Given that it is easier for adolescents to conceal vaping than cannabis smoking, this mode of cannabis use may facilitate more frequent use. Acute health effects such as e-cigarette or vaping product use-associated lung injury in vaped cannabis products have been documented,[8] including among adolescents.[9,10] While vaping is understood to be an important health topic for adolescents, relatively little is known about time trends in vaping use (including trends in use frequency, emerging disparities, and co-occurring use of other substances, which are all critical for surveillance and public health programmatic efforts).

Data from MTF indicate that from 2017 to 2019, cannabis vaping prevalence increased across grades, with the largest burden among high school seniors for whom past-30-day prevalence almost tripled from 5% (2017) to 14% (2019).[11] The one-year increase in this grade from 2018 to 2019 (7.5% to 14%) is the second largest one-year increase in any type of substance use prevalence ever tracked by MTF.[11] Other national surveys have also reported increasingly high prevalence of cannabis vaping since approximately 2017,[12–14] with increases observed across demographic groups. Cannabis vaping is replacing more traditional forms of cannabis use such as smoking, with evidence that increases in vaping as compared with smoking are concentrated among non-Hispanic white and higher socioeconomic status (SES) adolescents,[15] the latter possibly reflecting the higher price point for vaping devices compared with other administration methods. Disparities in overall cannabis use (not disaggregated by vaping) by parental education are increasing, with youth in families with lower levels of educational attainment at increasingly higher risk,[16] suggesting a need for continued surveillance of potential emergent disparities as prevalence of use and modes of administration change.

Racial/ethnic disparities in cannabis vaping are to date largely unexamined. Considering cannabis use overall, there is evidence that racial/ethnic disparities are emerging; whereas historically racialized groups such as non-

Hispanic Black adolescents were less likely to use cannabis than non-Hispanic white youth throughout much of the 20th century, since approximately 2010, use is increasing among non-Hispanic Black youth, especially frequent use.[17] How these emergent disparities apply to trends in cannabis vaping, however, remains under-investigated, especially across levels of frequent versus infrequent cannabis vaping. Heavy and frequent use of cannabis is increasing among US adolescents,[16] and so understanding the prevalence and patterns of frequent cannabis vaping is important public health information for prevention.

Evaluating patterns of cannabis in conjunction with other products like alcohol and tobacco use provides an assessment of the extent to which these products are used in isolation or combination, which has implications of public health and prevention. Adolescent use of psychoactive products tends to correlate, and risks of substance use disorder and other harms increase with the number of substances used.[18] Available evidence indicates that young adults who use nicotine, especially through vaporizers, are more likely to subsequently use vaped cannabis,[19,20] which is indicative of common co-occurrence of substance use.[21–23] Examining these patterns across recent historical time remains relevant, though, given substantial increases in the proportion of adolescents who only vape (do not use substances in combustible forms),[24] and the rapid deceleration in the prevalence of alcohol, opioid and amphetamine, and other non-cannabis psychoactive substance use.[25] Further, cannabis is now the substance most likely to be first used among adolescents (historically, alcohol and tobacco were the first substances used), and links between cannabis and subsequent alcohol and tobacco use are becoming more tenuous.[26] Thus, it is possible that vaping is becoming less strongly correlated with other substance use. Intervening to reduce harm associated with substance use in adolescence is traditionally most effective when taking account of the patterns of co-occurrence of multiple substances, given the overlap in groups of adolescents

who use products such as tobacco and cannabis. However, if patterns of co-occurrence are shifting, then more targeted intervention may be warranted.

The present study contributes to three aspects of the literature on time trends in cannabis vaping. First, we examine trends from 2017 to 2019 in the prevalence and frequency of cannabis use that includes vaping as a mode of administration versus cannabis use without vaping. Second, we examine whether these trends exhibit differences by socio-demographic groups defined by sex, race/ethnicity, socio-economic status (using parental education as a proxy), and urbanicity. Third, we examine the concentration of risk by concurrent substance use among other commonly used psychoactive substances, including vaped and combustible nicotine as well as binge drinking.

Methods

Sample. MTF (years: 2017-2019; grades: 8, 10, 12; overall N restricted to pertinent subforms = 51,052) includes a nationally-representative annual survey of school-attending adolescents. Schools were chosen through a multi-stage random sampling design, and invited to participate for two years. Those that declined were replaced with schools with similar geographic location, urbanicity, and size. Study procedures and sampling frame and design are described elsewhere.[27] The analysis was restricted to students who received questions on cannabis vaping. In 2017-18, a randomly-selected 1/3 of students received these questions, and in 2019, a randomly-selected 2/3 of students received the questions.

Measures.

Cannabis use was assessed as: "On how many occasions (if any) have you used marijuana (grass, pot) or hashish (hash, hash oil) during the last 30 days?", with response options that ranged from zero to forty or more. This item was consistent across years. We divided overall cannabis use into occasional (1-5 occasions in past 30 days), and frequent (following our previous work,[16] at least weekly use, i.e., ≥6 occasions); we then additionally stratified by whether the adolescent reported any cannabis vaping. For 2017-2018, vaping was assessed as: "On how many occasions (if any) have you vaped marijuana during the last 30 days?". In 2019, the item was "On how many days (if any) have you vaped marijuana during the last 30 days?". Both items were dichotomized ("Any" vs. "None") and combined with the general use item as None, Use without vaping, Use with vaping. Sensitivity analyses used higher cutpoints between occasional and frequent overall cannabis use (1-9 vs. 10+ occasions, 1-19 vs. 20+ occasions, and 1-39 vs. 40+ occasions of overall cannabis use in the past 30 days, again subdivided based on whether there was any vaping). Binge drinking was assessed as follows: "Think back over the last two weeks. How many times have you had five or more drinks in a row? [Response options: None, Once, Twice, 3-5, 6-9, 10+]". Nicotine/tobacco items queried use in the last 30 days and yielded four groups: no nicotine/tobacco use, combustible cigarette use only, vaped nicotine use only, and both vaped and combustible nicotine/tobacco use.

Demographic items included: sex and race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic/Latino, non-Hispanic Asian/Pacific Islander, and Multiracial). Parental education included at least one parent with a college degree vs. none. Urbanicity was defined based on whether a respondent resided in a Metropolitan Statistical Area (MSA) as defined by census designation. The sample (N=51,052) included 48.6% male respondents and was diverse in race/ethnicity (Table 1); non-Hispanic white (49.3%). More of the sample had at

least one parent with a college degree (58.2%) and resided in an MSA (80.2%).

Statistical analysis. We mapped patterns of survey-weighted cannabis prevalence from 2017 to 2019. Survey weighting addressed selection probabilities, differing sample sizes by grade/school, and the over-representation of 2019 data. We stratified cannabis prevalence across sex, race/ethnicity, parental education and urbanicity, and tested for interaction between year (2017, 2018, and 2019) and each demographic variable on cannabis use using survey weighted multinomial logistic regression. Lastly, we used survey-weighted multinomial logistic regressions to test the associations between cannabis use and nicotine use and binge drinking in separate models. We ran models with and without adjusting for grade, sex, race/ethnicity, parental education, urbanicity, year, and the remaining substance use item not already included. These analyses were not pre-registered, and so the results should be considered exploratory. Missing data in study covariates ranged from 1.5% (nicotine use pattern) to 19.3% (parental education); covariate missingness was handled with multiple imputation by chained equations in Stata (k=5).

Results

Trends in the prevalence and frequency of cannabis use with and without vaping.

As cannabis use with vaping increased, cannabis use without vaping declined. By 2019, frequent cannabis use with vaping was more prevalent than occasional cannabis use with no vaping (5.4% vs 4.4%). Figure 1 describes trends in frequent and occasional cannabis use, with and without vaping. Increases in prevalence were observed for frequent (≥6 past 30-day instances) and occasional (1-5 instances) cannabis use that included any vaping, with the largest increases for frequent cannabis use including vaping, increasing from 2.1% in 2017 to 5.4% in 2019.

Frequent (3.8% in 2017 to 2.1% in 2019) and occasional (6.9% in 2017 to 4.4% in 2019) cannabis use without vaping declined from 2017 to 2019. Overall, the prevalence of any level of cannabis use increased from 13.9% in 2017 to 15.4% in 2019. Using a higher threshold for frequent use (10+, 20+, or 40+ past 30-day instances) yielded similar trends (Online Figures 1, 2, and 3); specifically, there were increases in cannabis use with vaping and decreases in cannabis use without vaping. However, it is worth noting that frequent cannabis use with vaping, and other cannabis use patterns, each impacted under 10% of adolescents in this sample.

Differences in trends by socio-demographic groups defined by sex, race/ethnicity, parental education, and urbanicity.

Figure 2 describes trends in frequency of cannabis vaping and other patterns of cannabis use by sex; the prevalence estimates underlying the figures can be found in Online Table 1. The largest increase observed across the study period among both male and female respondents was frequent cannabis use with vaping. Among male respondents, frequent cannabis use with vaping increased from 2.9% in 2017 to 6.2% in 2019 and among female respondents from 1.3% in 2017 to 4.7% in 2019. The absolute increase in frequent cannabis use with vaping was similar by sex, with an increase of 3.3 to 3.4 percentage points in both groups.

Online Figures 4-6 and Online Table 1 depict trends in frequency of cannabis vaping and other patterns of cannabis use by race/ethnicity, parental education, and urbanicity. Online Figure 4 demonstrates that the pattern of frequent cannabis use with vaping was the most prevalent for all racial/ethnic groups by 2019 except non-Hispanic Black adolescents, for whom occasional cannabis use with no vaping remained the most prevalent pattern for all years (e.g., prevalence of 5.2% in 2019). Results for trends by parental education indicate that

students without a parent with a college degree had higher prevalence of frequent use of cannabis with vaping (2019 prevalence: 6.8% vs. 4.5% among those with a parent with a college degree) and a sharper increase from 2017 to 2019 (Online Figure 5), but similar trends overall in cannabis use with and without vaping. Patterns across years were relatively similar between levels of urbanicity (Online Figure 6).

Association between cannabis use with and without vaping with concurrent nicotine and alcohol use.

Table 2 describes associations between levels of past 30-day nicotine use with or without vaping and concurrent past 30-day cannabis use, adjusted for binge-drinking, year, and demographic factors. Results indicate a consistent pattern between substances; students who only vaped nicotine (no combustible cigarette use) had nearly twenty-times higher odds of cannabis use with vaping than students who did not use nicotine (AOR = 19.76, 95% CI:17.29, 22.57), while the magnitude of association between nicotine vaping and cannabis use without vaping was lower (AOR = 4.16, 95% CI:3.63, 4.76). However, the link between nicotine use without vaping and cannabis use without vaping (AOR = 6.99, 95% CI: 5.42, 9.01) was similar to the link between nicotine use without vaping and cannabis use with vaping (AOR = 7.96, 95% CI: 5.75, 11.02). The strongest association was between smoking/vaping nicotine and cannabis use with vaping (AOR = 42.28, 95% CI:33.14, 53.93). Unadjusted associations can be found in Online Table 2, and follow similar patterns. Online Table 3 describes the associations between nicotine use and cannabis use, with latter category split into frequent (≥6 occasions) and occasional (1-5) overall use with or without vaping. All smoking/vaping nicotine categories were strongly associated with cannabis use with and without vaping (AORs = 3.76-54.94).

Table 3 describes associations between frequency of past-two-week binge drinking with past 30-day cannabis use

with and without vaping, adjusted for past 30-day nicotine/tobacco use, year, and demographic factors. Results indicate that different frequency levels of binge drinking were typically more strongly associated with cannabis use with vaping (AOR range = 4.48–10.09) than without vaping (AOR range = 3.89 – 6.23). The magnitude of these associations increased as the number of binge drinking occasions increased. Online Table 4 describes unadjusted associations, with similar findings, and Online Table 5 depicts these associations with cannabis use split into frequent (≥6 occasions) and occasional (1-5) use.

Online Tables 6 and 7 examined the links between cannabis use patterns and nicotine use and binge drinking patterns with a higher cutpoint between occasional (1-9 occasions/30 days) and frequent (10+ occasions/30 days) cannabis use. Online Tables 8 and 9 examined these links with an even higher cutpoint (1-19 vs. 20+ occasions/30 days), while online tables 10 and 11 used the highest possible available threshold (1-39 vs. 40+ occasions/30 days). Patterns were similar to other analyses with a lower cutpoint.

Discussion

The present study documents that cannabis vaping is increasing as the most popular method of cannabis delivery among adolescents in the US, and that frequent (≥6 times per month) use is increasing faster than occasional use. Using cannabis with vaping delivery systems is now more common than smoking alone in almost every demographic group across sex, race/ethnicity, urbanicity and parental education. The increases in frequent cannabis use with vaping among US adolescents were also observable across almost all demographic groups, and increased most among Hispanic/Latino adolescents and those of lower socio-economic status. Underscoring the importance of mode of administrations, cannabis vaping is very strongly associated with other

substance use; those who vape and smoke nicotine are more than 40 times more likely to also vape and smoke cannabis, and frequency of cannabis use with vaping increases in a monotonic fashion with increasing occasions of binge drinking. Given rising concerns about cannabis vaping in terms of safety, high THC delivery, and potential for transition to cannabis use disorder (especially at frequent levels of use), these results indicate an urgent need for public health intervention and increased regulation. Furthermore, given the strong associations of cannabis vaping with use of other substances, this study may portend increasing risk of injury and other adverse health consequences.

Cross-sectional studies of adolescents in the US and elsewhere have documented that cannabis vaping is highly prevalent among youth and associated with use of other vaped (and non-vaped) products.[12,28–30] Time series analyses of MTF and other national data sources have established that prevalence has been increasing since approximately 2015, when measures of vaping were first introduced into national surveys.[13,15] We add to that literature by showing that the increase in prevalence is not solely due to mere experimentation in use. Indeed, frequent cannabis use with vaping had the highest yearly increases from 2017 through 2019. Tobacco use and e-cigarettes, as well as binge drinking, are strongly linked to frequent cannabis use (both vaping and non-vaping), exhibiting a dose-response relationship with odds ratios that are in the 10-12 times higher range, suggesting a high risk for potential harms.

Increases in cannabis vaping are likely due to a combination of factors. Vaped delivery systems for products such as cannabis and nicotine are growing in number, and they provide an efficient delivery system that has minimal odor, thus making them more concealable by teens from parents and teachers.[31] The rise in adolescent nicotine vaping may serve as a new risk factor for subsequent cannabis vaping and other cannabis delivery, given the strong prospective association between nicotine use and subsequent cannabis use.[32] Overall, cannabis products

are generally more available to youth as more states allow legalized use for adults, although the impact of these laws on youth cannabis use remains inconsistent and generally null.[33–38] Indeed, adolescent cannabis vaping prevalence is higher in some states with legalized cannabis for adults.[39] Marketing efforts for a wide variety of cannabis products have proliferated in the legalized cannabis environment; these campaigns are viewed frequently by adolescents,[40,41] and likely influence their behavior.

Cannabis vaporizers are marketed on a wide variety of platforms including social media; on Instagram, cannabis vaporizers are followed by upwards of half a million people, and ads often feature young women and do not discuss age restrictions on use.[42] While states have regulations restricting the targeting of ads to youth,[43] enforcement is difficult. Adolescents who report engaging with cannabis promotions on social media are more likely to use cannabis,[45] and thus efforts to reduce exposure to marketing is critical to curbing high levels of adolescent use.

Trends by demographic subgroup also warrant attention. Generally, the groups with largest increases in frequent cannabis vaping are those at higher risk for cannabis use overall, including those with less educated parents. However, across racial/ethnic groups, adolescents are increasing frequent cannabis use, with Non-Hispanic Black adolescents exhibiting lower levels of frequent cannabis vaping than other racial/ethnic groups. Previous studies have documented that non-Hispanic Black adolescents have a higher prevalence of blunt smoking than other racial/ethnic groups, which may include high THC content.[46] Historically, non-Hispanic white adolescents had higher prevalence of cannabis use than racially minoritized groups,[47–49] yet the gap by race/ethnicity has been closing for more than a decade.[50] Overall, efforts to provide inclusive and broadly-based drug use education and prevention need to include health information on vaped product use. Further, given that racially minoritized students are more likely to face repercussions for drug use (from the criminal legal system

[51,52] and schools[53,54]), these efforts should focus on equity and access to prevention and treatment services, such as early school-based education efforts.[55]

The results of this and other studies underscore the need to reduce cannabis use, including vaped cannabis, in adolescents. Intervention development has been limited, and existing programs focus mainly on vaped nicotine.[56–60] Interventions for adolescents who engage in heavy cannabis use involve evidence-based, clinician-administered motivational interviewing or cognitive behavioral therapy.[62,63] Barriers to treatment include cost, availability, and the failure to recognize a need for treatment.[64,65] More broadly, a focus on policies that deter cannabis use among adolescents should be a priority as legalization efforts continue. These policies should be crafted to reduce an emphasis on criminalization in preference for public health promotion given the history of unequal application of punitive consequences of drug use for racialized minorities in the US.

Limitations of the study should be noted. The questionnaire did not query students about the THC or cannabidiol content of cannabis products used, thus the potency and chemical composition of the cannabis used is not known. However, evidence indicates that THC concentrations of cannabis products sold nationally are increasing,[66] and that the concentration of THC in vaped cannabis concentrates is available in particularly strong formulations,[67] thus it is likely that adolescents are increasingly exposed to higher THC levels than in the past. We also do not have information on the quantity of cannabis used, only the frequency, and the questionnaire did not ask separate questions for vaping of cannabis oils versus other vaped cannabis products, so we have limited information on total exposure. Binge drinking was assessed as 5+ drinks for all students, rather than 4+ for female students, which may undercount binge drinking among female students. Vaping items had slightly different wording across time, which may impact measurement, though these items have been dichotomized into Any vs. None to minimize any potential measurement discrepancies, and sensitivity analyses suggest robust findings

across operationalizations that employ this division. MTF sampling frame includes only school-attending adolescents, among whom cannabis use may differ from those who do not attend school. Thus, prevalence estimates and associations should be generalized only to school-attending students. Lastly, data are cross sectional, and so we cannot make causal attributions to the associations between past 30-day nicotine use or binge drinking and cannabis use.

In summary, an increasing national trend of frequent cannabis use with vaping among adolescents may signal future increases in harms associated with cannabis. These risks arise from the greater efficiency of vaping as a THC delivery device, high association of its use with other products that are known to be harmful to health, and observations that heavy and prolonged periods of cannabis use increase the risk of cannabis use disorder[68] as well as other adverse health outcomes.[69] As cannabis legalization continues across US states, and as products, delivery systems, potency and marketing proliferate within a for-profit industry, increased attention to youth trends, including investment in sustained and evidence-based prevention and intervention, is increasingly necessary.

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Table 1. Demographic Characteristics and Outcome Distribution, 2017-2019, n=51,052

Variable	Weighted/Imputed %
Sample Size (N=51,052)	100.0
Cannabis Use in Past 30 Days	
None	85.6
Use without vaping	8.7
Use with vaping	5.7
Sex	
Male	48.6
Female	51.4
Race/Ethnicity	
Non-Hispanic white	49.3
Non-Hispanic Black	11.8
Hispanic or Latino	27.8
Multiracial	5.5
Non-Hispanic Asian or Pacific Islander	5.6
Parental Education	
At least one college graduate	58.2
No college graduate parent	41.8
Urbanicity	
MSA residence	80.2
non-MSA residence	19.8
Grade	
8	35.2
10	35.9
12	28.9
Nicotine Use in Past 30 Days	
None	85.8
Smoke only	1.8
Vape only	10.1
Smoke and vape	2.3
Binge Drinking in the past 2 weeks	
None	91.3
Once	4.3
Twice	2.4

Three to Five	1.5
Six to Nine	0.3
Ten+	0.3

Figure 1. Trends in smoked and vaped cannabis use among US adolescents, 2017-2019, by frequency of use (1-5 past 30-day instances [Occasional] vs 6+ [Frequent])

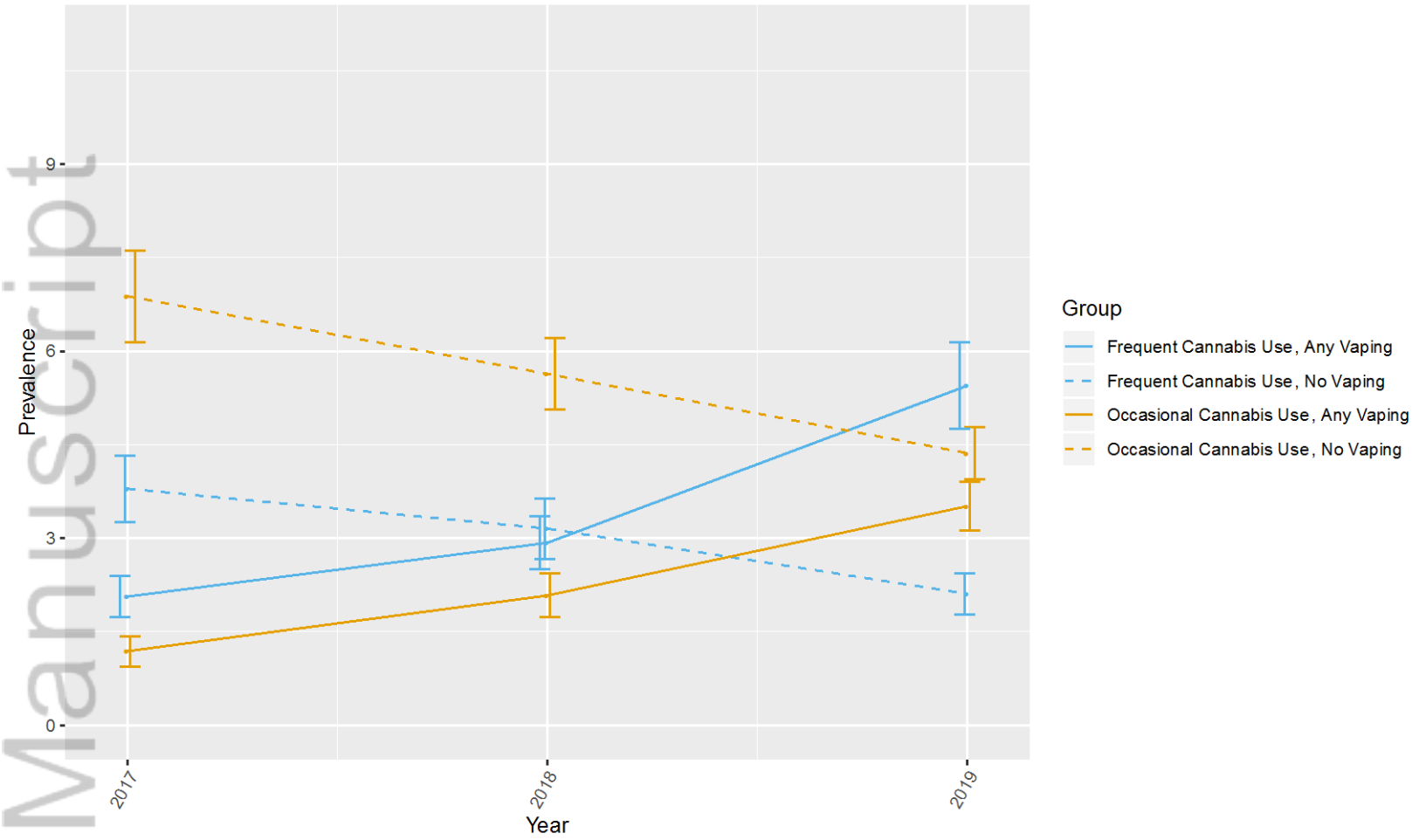
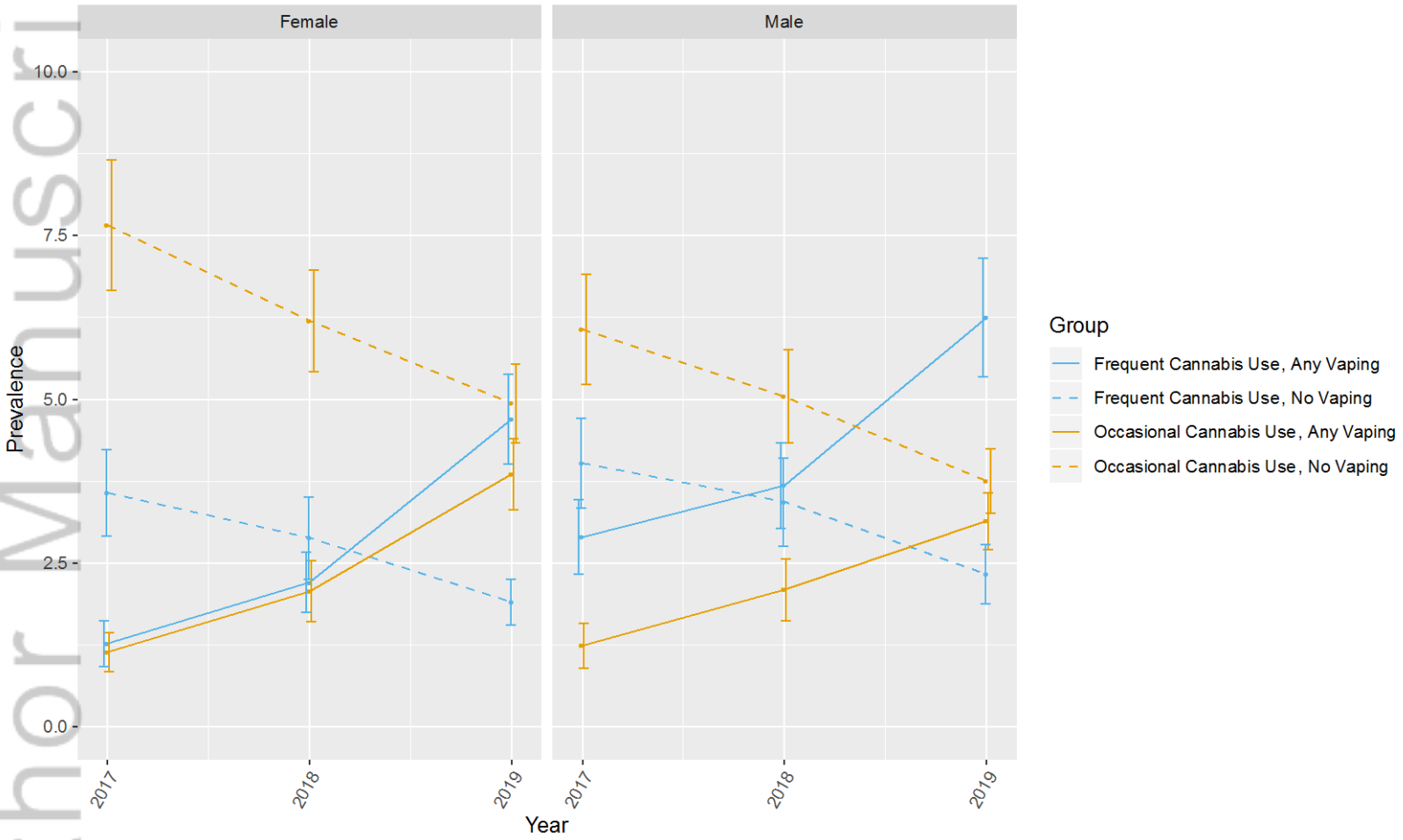


Figure 2. Trends in Cannabis Use, 2017-2019, by Sex



* Test for interaction between year and sex in predicting cannabis use frequency with and without vaping: F=1.61, df=(8, 677.2), p=0.1170.

Table 2. Adjusted * association between past 30-day nicotine use (combustible and vaping) with past 30-day cannabis use (combustible and vaping), 2017-2019

Past 30-day Nicotine Use Predictor	Past 30-day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only (vs No Use)	Without Vaping (vs No Use)	6.99	5.42	9.01
Smoking Only (vs No Use)	With Vaping (vs No Use)	7.96	5.75	11.02
Vaping Only (vs No Use)	Without Vaping (vs No Use)	4.16	3.63	4.76
Vaping Only (vs No Use)	With Vaping (vs No Use)	19.76	17.29	22.57
Smoking and Vaping (vs No Use)	Without Vaping (vs No Use)	8.96	7.04	11.40
Smoking and Vaping (vs No Use)	With Vaping (vs No Use)	42.28	33.14	53.93

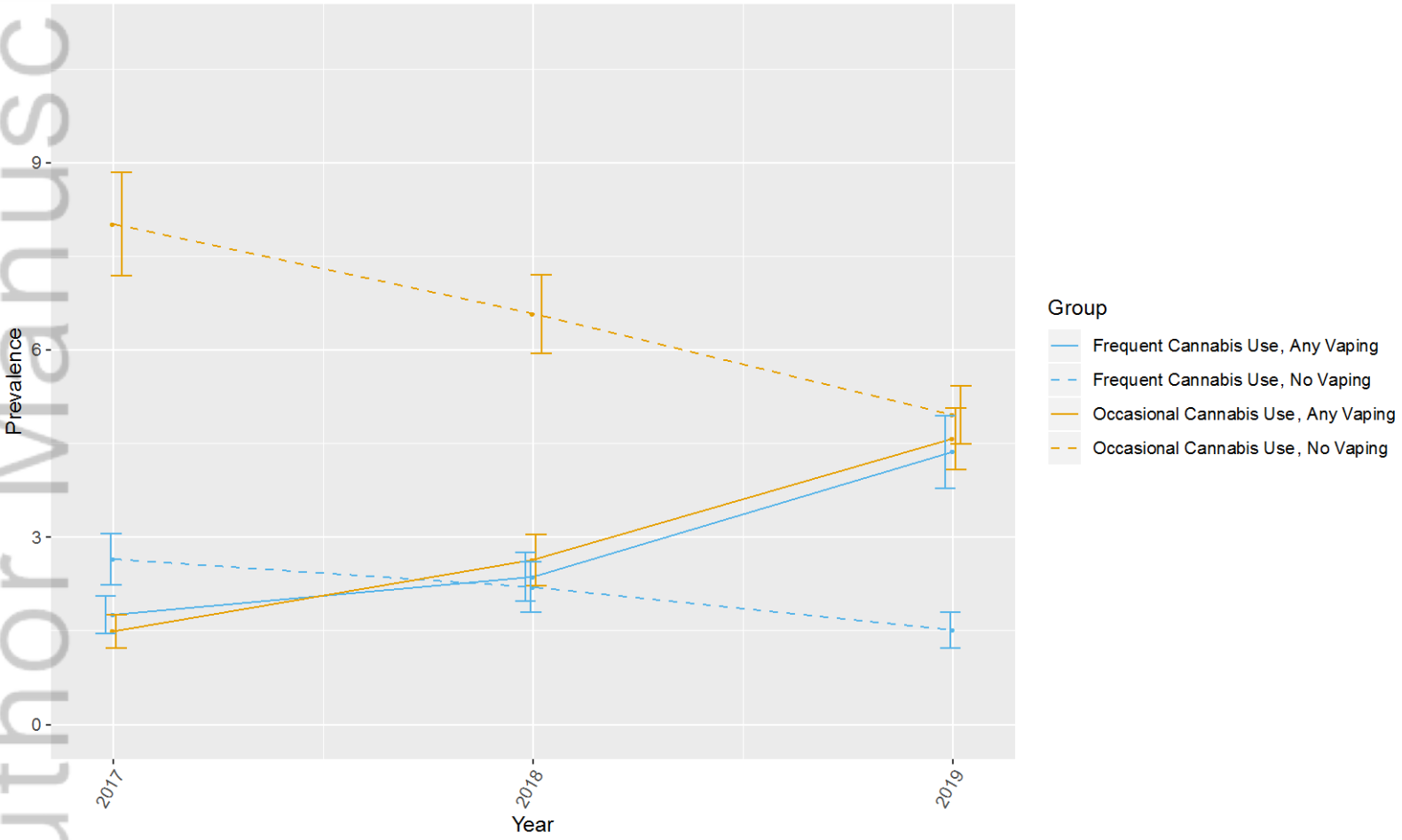
* Adjusted for grade, sex, race, parental education, urbanicity, binge drinking, and year

Table 3. Adjusted * association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), 2017-2019

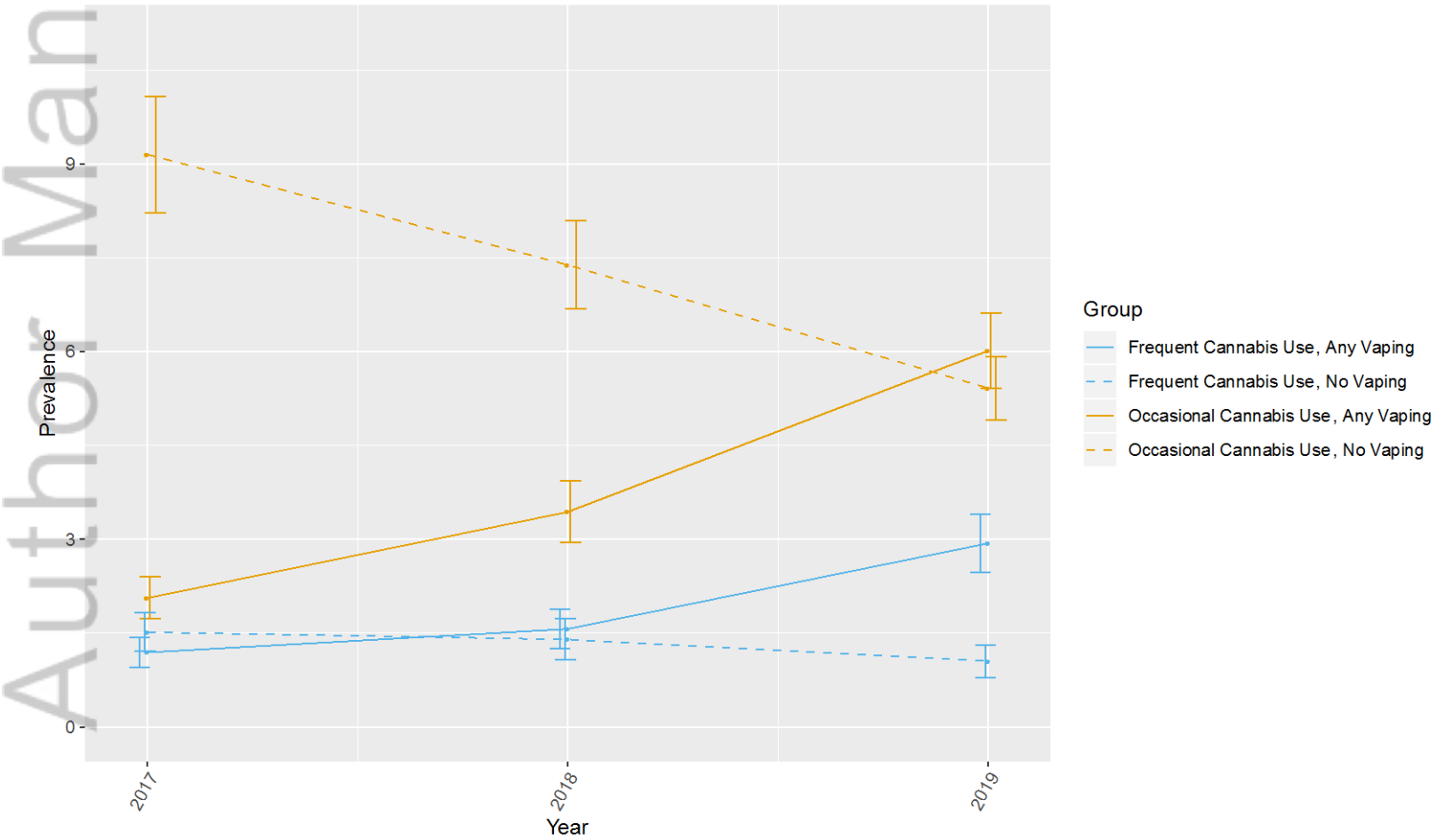
Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once vs None	Without Vaping (vs No Use)	3.89	3.23	4.70
Once vs None	With Vaping (vs No Use)	4.48	3.66	5.48
Twice vs None	Without Vaping (vs No Use)	4.12	3.26	5.20
Twice vs None	With Vaping (vs No Use)	5.73	4.49	7.32
Three to Five vs None	Without Vaping (vs No Use)	4.26	3.18	5.72
Three to Five vs None	With Vaping (vs No Use)	7.96	5.70	11.12
Six to Nine vs None	Without Vaping (vs No Use)	6.23	3.55	10.95
Six to Nine vs None	With Vaping (vs No Use)	6.21	3.33	11.57
Ten+ vs None	Without Vaping (vs No Use)	5.96	2.82	12.60
Ten+ vs None	With Vaping (vs No Use)	10.09	4.51	22.53

*Adjusted for grade, sex, race, parental education, urbanicity, nicotine/tobacco use, and year

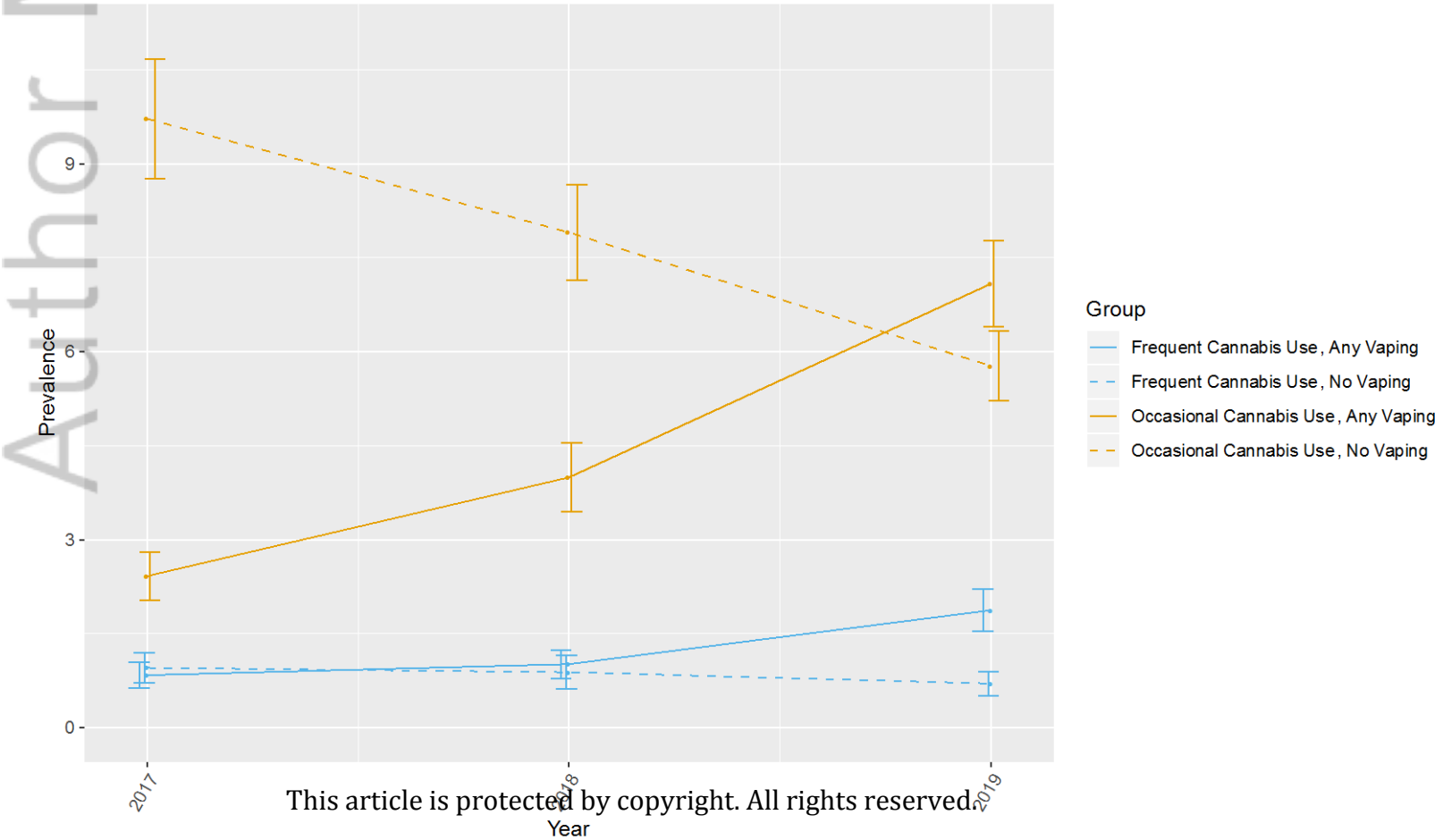
Online Figure 1. Trends in smoked and vaped cannabis use among US adolescents, 2017-2019, by frequency of use (1-9 past 30-day instances [Occasional] vs 10+ [Frequent])



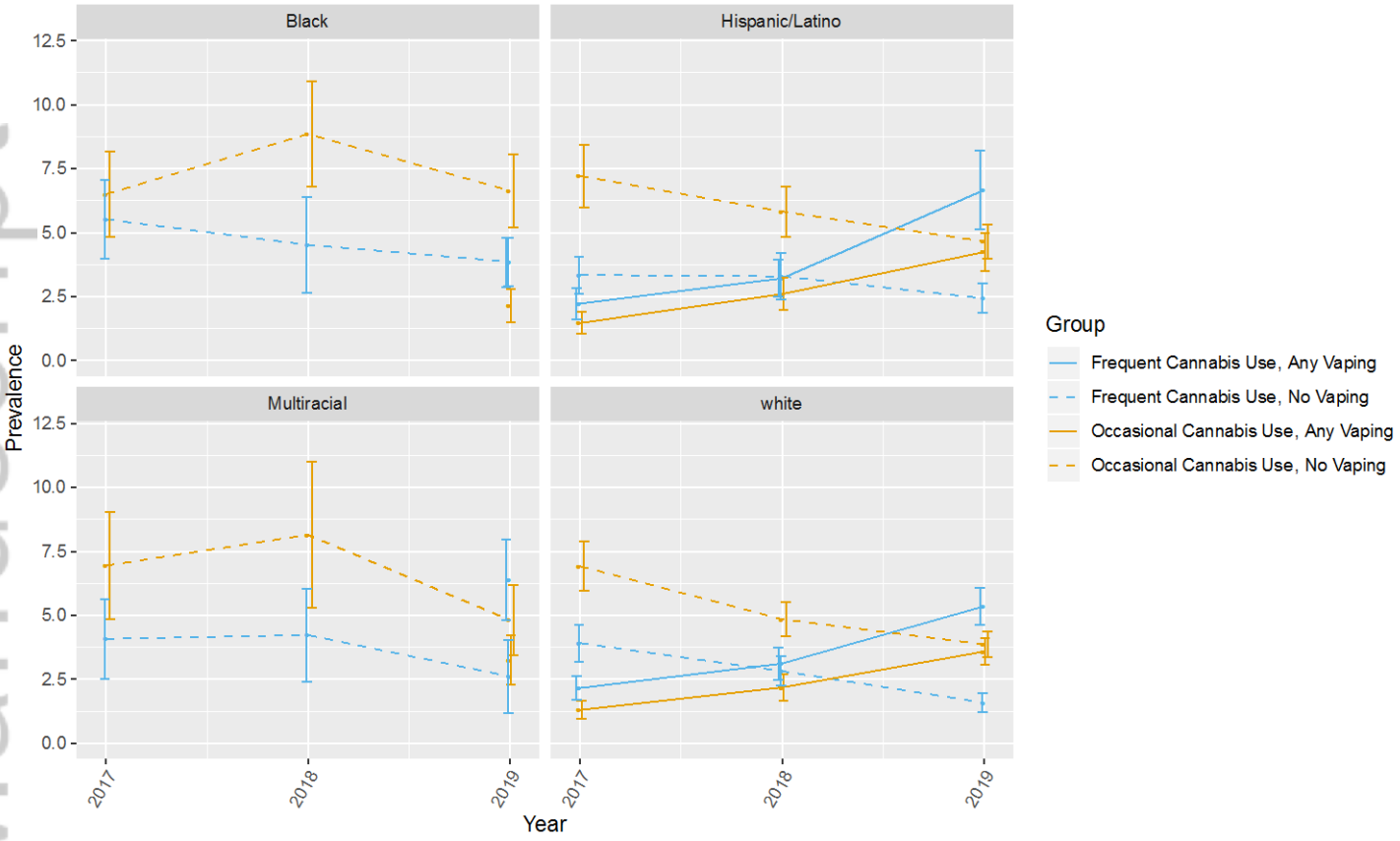
Online Figure 2. Trends in smoked and vaped cannabis use among US adolescents, 2017-2019, by frequency of use (1-19 past 30-day instances [Occasional] vs 20+ [Frequent])



Online Figure 3. Trends in smoked and vaped cannabis use among US adolescents, 2017-2019, by frequency of use (1-39 past 30-day instances [Occasional] vs 40+ [Frequent])



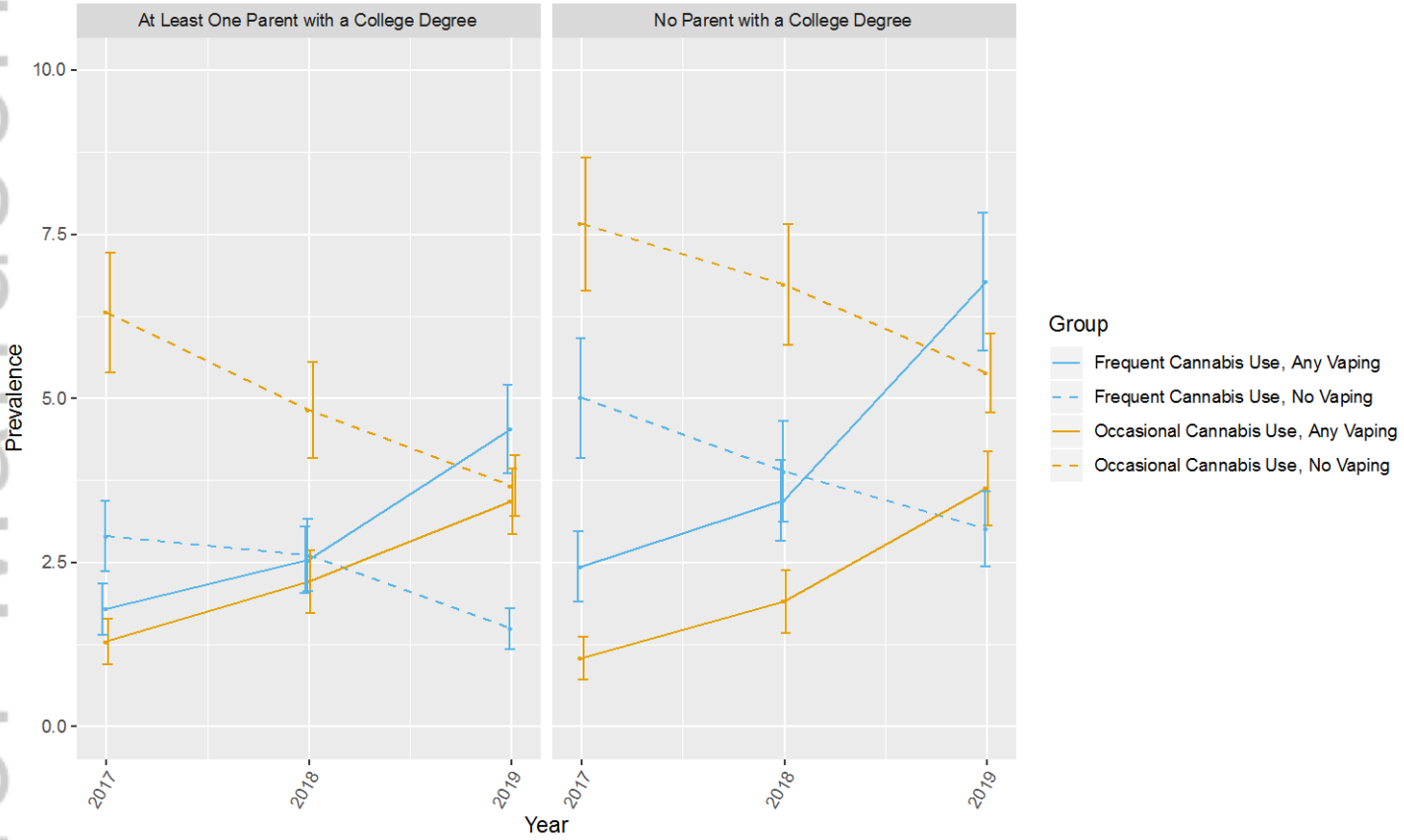
Online Figure 4. Trends in Frequency of Vaped and non-Vaped Cannabis Use, 2017-2019, by Race/Ethnicity*



*Limited sample sizes prevented displaying results for non-Hispanic Asian/Pacific Islander adolescents. Additional censoring occurred for several estimates among Black and Multiracial adolescents.

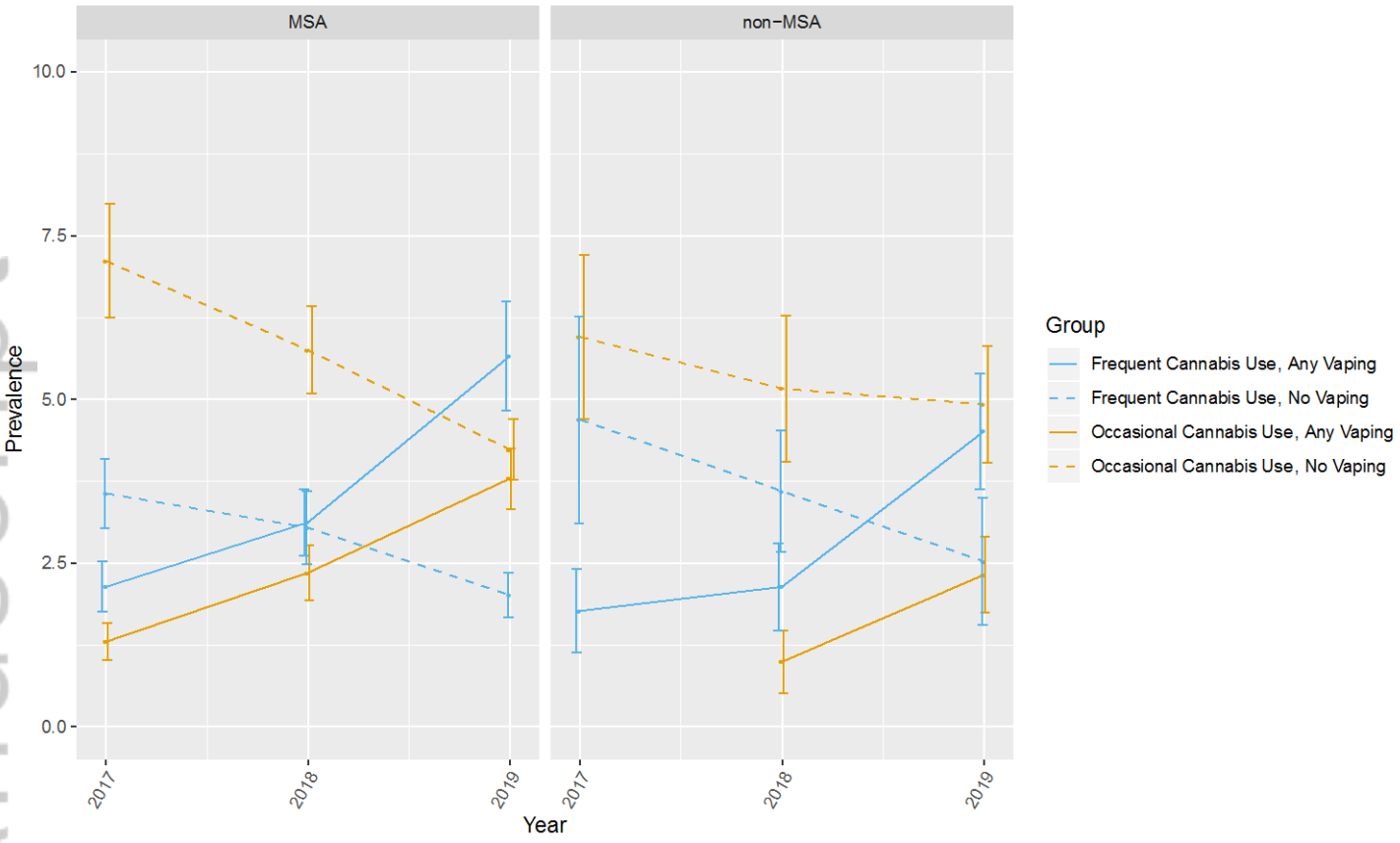
** Test for interaction between year and race/ethnicity in predicting cannabis use frequency with and without vaping: F=1.59, df=(32, 764.4), p=0.0206.

Online Figure 5. Trends in Cannabis Use, 2017-2019, by Parental Education



* Test for interaction between year and parental education in predicting cannabis use frequency with and without vaping: F=0.82, df=(8, 473.2), p=0.5883.

Online Figure 6. Trends in Cannabis Use, 2017-2019, by Urbanicity



*Limited sample size prevented displaying results for certain estimates among non-MSA adolescents in 2017.

** Test for interaction between year and urbanicity in predicting cannabis use frequency with and without vaping: F=0.92, df=(8, 777.0), p=0.4949.

Online Table 1. 2017 to 2019 Shifts in Cannabis Use Pattern Prevalence by Demographics

	No cannabis use		Difference in percent	Occasional Cannabis Use, No Vaping		Difference in percent	Frequent Cannabis Use, No Vaping		Difference in percent	Occasional Cannabis Use, Any Vaping		Difference in percent	Frequent Cannabis Use, Any Vaping		Difference in percent
	2017	2019		2017	2019		2017	2019		2017	2019		2017	2019	
	% (N)	% (N)		% (N)	% (N)		% (N)	% (N)		% (N)	% (N)		% (N)	% (N)	
Overall	86.1 (11071)	84.6 (21316)	-1.5	6.9 (934)	4.4 (1068)	-2.5	3.8 (501)	2.1 (456)	-1.7	1.2 (172)	3.5 (1010)	2.3	2.1 (304)	5.4 (1390)	3.3
Male	85.8 (5721)	84.5 (10178)	-1.3	6.1 (388)	3.8 (465)	-2.3	4.0 (244)	2.3 (245)	-1.7	1.2 (86)	3.1 (449)	1.9	2.9 (198)	6.2 (768)	3.3
Female	86.4 (5446)	84.6 (10671)	-1.8	7.7 (515)	4.9 (579)	-2.8	3.6 (229)	1.9 (197)	-1.7	1.1 (82)	3.9 (539)	2.8	1.3 (93)	4.7 (566)	3.4
Non-Hispanic white	85.7 (5185)	85.6 (10975)	-0.1	6.9 (474)	3.9 (478)	-3.0	3.9 (257)	1.6 (162)	-2.3	1.3 (93)	3.6 (534)	2.3	2.2 (160)	5.4 (702)	3.2
Hispanic/Latino	85.7 (2989)	82.0 (5128)	-3.7	7.2 (246)	4.7 (289)	-2.5	3.3 (108)	2.4 (130)	-0.9	**	**	**	2.2 (83)	6.7 (382)	4.5
Other *	87.2 (2562)	85.3 (4475)	-1.9	6.4 (191)	5.1 (270)	-1.3	4.1 (118)	2.9 (138)	-1.2	**	**	**	1.7 (47)	4.2 (231)	2.5
At least one parent graduated college	87.7 (5474)	86.9 (11177)	-0.8	6.3 (450)	3.7 (483)	-2.6	2.9 (220)	1.5 (152)	-1.4	1.3 (102)	3.4 (546)	2.1	1.8 (145)	4.5 (604)	2.7
None	83.9 (3490)	81.2 (6361)	-2.7	7.7 (341)	5.4 (412)	-2.3	5.0 (206)	3.0 (193)	-2.0	1.0 (46)	3.6 (334)	2.6	2.4 (117)	6.8 (563)	4.4
MSA residence	85.9 (8860)	84.3 (16798)	-1.6	7.1 (776)	4.2 (803)	-2.9	3.6 (391)	2.0 (351)	-1.6	**	**	**	2.1 (256)	5.7 (1147)	3.6
Non-MSA residence	86.8 (2211)	85.7 (4518)	-1.1	6.0 (158)	4.9 (265)	-1.1	4.7 (110)	2.5 (105)	-2.2	**	**	**	1.8 (48)	4.5 (243)	2.7
*(non-Hispanic Black, non-Hispanic Asian / Pacific Islander, Multiracial); ** Censored															

Online Table 2. Unadjusted association between nicotine use (combustible and vaping) with cannabis use (combustible and vaping), 2017-2019

Past 30-Day Nicotine Use Predictor	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only (vs No Use)	Without Vaping (vs No Use)	11.06	8.85	13.80
Smoking Only (vs No Use)	With Vaping (vs No Use)	10.52	7.75	14.27
Vaping Only (vs No Use)	Without Vaping (vs No Use)	4.99	4.39	5.66
Vaping Only (vs No Use)	With Vaping (vs No Use)	29.29	25.77	33.30
Smoking and Vaping (vs No Use)	Without Vaping (vs No Use)	15.07	12.22	18.60
Smoking and Vaping (vs No Use)	With Vaping (vs No Use)	74.06	60.34	90.90

Online Table 3. Adjusted* association between nicotine use (combustible and vaping) with cannabis use (combustible and vaping), None vs Occasional (1-5 Instances) vs Frequent (6+ Instances), 2017-2019

Past 30-Day Nicotine Predictor	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only (vs None)	Occasional Cannabis Use, No Vaping	5.21	3.85	7.04
Smoking Only (vs None)	Frequent Cannabis Use, No Vaping	10.52	7.71	14.34
Smoking Only (vs None)	Occasional Cannabis Use, Any Vaping	3.83	2.15	6.82
Smoking Only (vs None)	Frequent Cannabis Use, Any Vaping	11.41	7.84	16.61
Vaping Only (vs None)	Occasional Cannabis Use, No Vaping	4.38	3.76	5.10
Vaping Only (vs None)	Frequent Cannabis Use, No Vaping	3.76	3.00	4.70
Vaping Only (vs None)	Occasional Cannabis Use, Any Vaping	17.78	14.48	21.84
Vaping Only (vs None)	Frequent Cannabis Use, Any Vaping	21.60	18.12	25.76
Both (vs None)	Occasional Cannabis Use, No Vaping	7.67	5.73	10.26
Both (vs None)	Frequent Cannabis Use, No Vaping	11.50	8.34	15.87
Both (vs None)	Occasional Cannabis Use, Any Vaping	27.44	19.52	38.55
Both (vs None)	Frequent Cannabis Use, Any Vaping	54.94	41.55	72.64

* Adjusted for grade, sex, race, parental education, urbanicity, binge drinking, and year

Online Table 4. Unadjusted association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), 2017-2019

Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once vs None	Without Vaping (vs No Use)	6.57	5.60	7.71
Once vs None	With Vaping (vs No Use)	11.80	10.24	13.60
Twice vs None	Without Vaping (vs No Use)	8.39	6.87	10.24
Twice vs None	With Vaping (vs No Use)	18.17	14.95	22.08
Three to Five vs None	Without Vaping (vs No Use)	10.56	8.24	13.53
Three to Five vs None	With Vaping (vs No Use)	28.82	22.21	37.38
Six to Nine vs None	Without Vaping (vs No Use)	13.03	7.66	22.15

Six to Nine vs None	With Vaping (vs No Use)	22.03	13.23	36.69
Ten+ vs None	Without Vaping (vs No Use)	15.75	8.59	28.90
Ten+ vs None	With Vaping (vs No Use)	47.64	29.51	76.90

Online Table 5. Adjusted* association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), None vs Occasional (1-5 Instances) vs Frequent (6+ Instances), 2017-2019

Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once (vs None)	Occasional Cannabis Use, No Vaping	3.78	3.07	4.64
Once (vs None)	Frequent Cannabis Use, No Vaping	4.15	3.18	5.42
Once (vs None)	Occasional Cannabis Use, Any Vaping	4.54	3.49	5.91
Once (vs None)	Frequent Cannabis Use, Any Vaping	4.46	3.53	5.63
Twice (vs None)	Occasional Cannabis Use, No Vaping	3.81	2.96	4.90
Twice (vs None)	Frequent Cannabis Use, No Vaping	4.80	3.50	6.60
Twice (vs None)	Occasional Cannabis Use, Any Vaping	4.79	3.52	6.52
Twice (vs None)	Frequent Cannabis Use, Any Vaping	6.47	4.92	8.50
3-5 times (vs None)	Occasional Cannabis Use, No Vaping	3.48	2.50	4.84
3-5 times (vs None)	Frequent Cannabis Use, No Vaping	5.84	3.97	8.62
3-5 times (vs None)	Occasional Cannabis Use, Any Vaping	5.80	3.70	9.08
3-5 times (vs None)	Frequent Cannabis Use, Any Vaping	9.49	6.66	13.51
6-9 times (vs None)	Occasional Cannabis Use, No Vaping	3.16	1.56	6.41
6-9 times (vs None)	Frequent Cannabis Use, No Vaping	12.30	6.24	24.25
6-9 times (vs None)	Occasional Cannabis Use, Any Vaping	3.57	1.54	8.25
6-9 times (vs None)	Frequent Cannabis Use, Any Vaping	7.97	4.00	15.87
10+ (vs None)	Occasional Cannabis Use, No Vaping	3.85	1.43	10.37
10+ (vs None)	Frequent Cannabis Use, No Vaping	10.25	4.40	23.88
10+ (vs None)	Occasional Cannabis Use, Any Vaping	3.57	1.22	10.39

10+ (vs None)	Frequent Cannabis Use, Any Vaping	14.23	5.96	33.97

* Adjusted for grade, sex, race, parental education, urbanicity, nicotine use, and year

Online Table 6. Adjusted* association between nicotine use (combustible and vaping) with cannabis use (combustible and vaping), None vs Occasional (1-9 Instances) vs Frequent (10+ Instances), 2017-2019

Past 30-Day Nicotine Predictor	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only	Occasional Use, No Vaping	5.68	4.30	7.49
Smoking Only	Frequent Use, No Vaping	11.48	8.19	16.09
Smoking Only	Occasional Use, Any Vaping	3.92	2.36	6.50
Smoking Only	Frequent Use, Any Vaping	13.33	8.98	19.78
Vaping Only	Occasional Use, No Vaping	4.26	3.69	4.93
Vaping Only	Frequent Use, No Vaping	3.82	2.90	5.02
Vaping Only	Occasional Use, Any Vaping	18.15	15.19	21.69
Vaping Only	Frequent Use, Any Vaping	22.29	18.18	27.33
Both	Occasional Use, No Vaping	7.81	5.96	10.23
Both	Frequent Use, No Vaping	13.16	9.08	19.07
Both	Occasional Use, Any Vaping	27.66	20.32	37.64
Both	Frequent Use, Any Vaping	62.24	45.71	84.75

* Adjusted for grade, sex, race, parental education, urbanicity, binge drinking, and year

Online Table 7. Adjusted* association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), None vs Occasional (1-9 Instances) vs Frequent (10+ Instances), 2017-2019

Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once	Occasional Use, No Vaping	4.00	3.29	4.85
Once	Frequent Use, No Vaping	3.54	2.52	4.97
Once	Occasional Use, Any Vaping	4.58	3.60	5.83
Once	Frequent Use, Any Vaping	4.40	3.40	5.69
Twice	Occasional Use, No Vaping	3.86	3.01	4.95
Twice	Frequent Use, No Vaping	5.04	3.53	7.18
Twice	Occasional Use, Any Vaping	5.05	3.79	6.73
Twice	Frequent Use, Any Vaping	6.59	4.96	8.75
Three to Five	Occasional Use, No Vaping	3.90	2.84	5.36
Three to Five	Frequent Use, No Vaping	5.52	3.58	8.50
Three to Five	Occasional Use, Any Vaping	6.34	4.22	9.52
Three to Five	Frequent Use, Any Vaping	9.75	6.77	14.02

Six to Nine	Occasional Use, No Vaping	5.49	3.02	10.00
Six to Nine	Frequent Use, No Vaping	8.78	3.64	21.17
Six to Nine	Occasional Use, Any Vaping	3.58	1.71	7.51
Six to Nine	Frequent Use, Any Vaping	8.69	4.23	17.87
Ten+	Occasional Use, No Vaping	4.14	1.69	10.14
Ten+	Frequent Use, No Vaping	11.73	4.63	29.70
Ten+	Occasional Use, Any Vaping	4.94	1.96	12.45
Ten+	Frequent Use, Any Vaping	15.36	6.32	37.33

* Adjusted for grade, sex, race, parental education, urbanicity, nicotine use, and year

Online Table 8. Adjusted* association between nicotine use (combustible and vaping) with cannabis use (combustible and vaping), None vs Occasional (1-19 Instances) vs Frequent (20+ Instances), 2017-2019

Past 30-Day Nicotine Predictor	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only	Occasional Use, No Vaping	6.24	4.68	8.33
Smoking Only	Frequent Use, No Vaping	11.08	7.43	16.53
Smoking Only	Occasional Use, Any Vaping	5.41	3.51	8.33
Smoking Only	Frequent Use, Any Vaping	15.43	9.90	24.04
Vaping Only	Occasional Use, No Vaping	4.33	3.78	4.97
Vaping Only	Frequent Use, No Vaping	3.30	2.33	4.68
Vaping Only	Occasional Use, Any Vaping	18.50	15.78	21.68
Vaping Only	Frequent Use, Any Vaping	24.08	19.19	30.23
Both	Occasional Use, No Vaping	8.51	6.57	11.02
Both	Frequent Use, No Vaping	11.89	7.37	19.17
Both	Occasional Use, Any Vaping	29.78	22.41	39.58
Both	Frequent Use, Any Vaping	77.37	54.65	109.54

* Adjusted for grade, sex, race, parental education, urbanicity, binge drinking, and year

Online Table 9. Adjusted* association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), None vs Occasional (1-19 Instances) vs Frequent (20+ Instances), 2017-2019

Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once	Occasional Use, No Vaping	3.84	3.17	4.65
Once	Frequent Use, No Vaping	3.97	2.81	5.62
Once	Occasional Use, Any Vaping	4.49	3.50	5.77
Once	Frequent Use, Any Vaping	4.34	3.25	5.78
Twice	Occasional Use, No Vaping	3.95	3.14	4.98
Twice	Frequent Use, No Vaping	5.47	3.41	8.76
Twice	Occasional Use, Any Vaping	6.01	4.58	7.88
Twice	Frequent Use, Any Vaping	5.29	3.92	7.14
Three to Five	Occasional Use, No Vaping	4.07	2.98	5.56
Three to Five	Frequent Use, No Vaping	6.15	3.62	10.42
Three to Five	Occasional Use, Any Vaping	7.58	5.18	11.09
Three to Five	Frequent Use, Any Vaping	9.53	6.61	13.74
Six to Nine	Occasional Use, No Vaping	6.32	3.58	11.18
Six to Nine	Frequent Use, No Vaping	4.02	1.50	10.78
Six to Nine	Occasional Use, Any Vaping	5.86	2.95	11.66
Six to Nine	Frequent Use, Any Vaping	6.79	3.23	14.24
Ten+	Occasional Use, No Vaping	4.95	2.16	11.33
Ten+	Frequent Use, No Vaping	14.12	4.96	40.19

Ten+	Occasional Use, Any Vaping	6.49	2.63	16.01
Ten+	Frequent Use, Any Vaping	20.87	8.55	50.95

* Adjusted for grade, sex, race, parental education, urbanicity, nicotine use, and year

Past 30-Day Nicotine Predictor	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Smoking Only	Occasional Use, No Vaping	6.47	4.95	8.44
Smoking Only	Frequent Use, No Vaping	12.12	7.65	19.19
Smoking Only	Occasional Use, Any Vaping	6.51	4.45	9.54
Smoking Only	Frequent Use, Any Vaping	15.63	9.17	26.63
Vaping Only	Occasional Use, No Vaping	4.32	3.76	4.96
Vaping Only	Frequent Use, No Vaping	2.66	1.74	4.06
Vaping Only	Occasional Use, Any Vaping	18.87	16.28	21.86
Vaping Only	Frequent Use, Any Vaping	24.71	18.06	33.82
Both	Occasional Use, No Vaping	8.61	6.72	11.03
Both	Frequent Use, No Vaping	13.02	7.45	22.73
Both	Occasional Use, Any Vaping	33.64	26.05	43.43
Both	Frequent Use, Any Vaping	86.45	57.49	130.01

Online Table 10. Adjusted* association between nicotine use (combustible and vaping) with cannabis use (combustible and vaping), None vs Occasional (1-39 Instances) vs Frequent (40+ Instances), 2017-2019

* Adjusted for grade, sex, race, parental education, urbanicity, binge drinking, and year

Online Table 11. Adjusted* association between occasions of binge drinking in the past two weeks with cannabis use (combustible and vaping), None vs Occasional (1-39 Instances) vs Frequent (40+ Instances), 2017-2019

Number of Times Binge Drinking in Past Two Weeks	Past 30-Day Cannabis Outcome	Odds ratio	Lower bound 95% confidence interval	Upper bound 95% confidence interval
Once	Occasional Use, No Vaping	3.91	3.23	4.72
Once	Frequent Use, No Vaping	3.70	2.30	5.97
Once	Occasional Use, Any Vaping	4.51	3.65	5.57
Once	Frequent Use, Any Vaping	4.39	3.04	6.34
Twice	Occasional Use, No Vaping	4.05	3.21	5.13
Twice	Frequent Use, No Vaping	4.52	2.64	7.75
Twice	Occasional Use, Any Vaping	6.21	4.84	7.97
Twice	Frequent Use, Any Vaping	4.14	2.82	6.09
Three to Five	Occasional Use, No Vaping	4.12	3.02	5.62
Three to Five	Frequent Use, No Vaping	5.79	3.03	11.04
Three to Five	Occasional Use, Any Vaping	7.65	5.38	10.89
Three to Five	Frequent Use, Any Vaping	8.96	5.80	13.85
Six to Nine	Occasional Use, No Vaping	6.25	3.46	11.30
Six to Nine	Frequent Use, No Vaping	6.20	2.19	17.54
Six to Nine	Occasional Use, Any Vaping	5.70	2.98	10.89
Six to Nine	Frequent Use, Any Vaping	7.44	3.24	17.11
Ten+	Occasional Use, No Vaping	4.53	1.98	10.38
Ten+	Frequent Use, No Vaping	21.29	7.26	62.41
Ten+	Occasional Use, Any Vaping	5.34	2.16	13.18
Ten+	Frequent Use, Any Vaping	24.63	9.75	62.22

* Adjusted for grade, sex, race, parental education, urbanicity, nicotine use, and year