



Nicotine and cannabis vaping among early high school adolescents: Disparities of use across sociodemographic characteristics and associations with psychosocial factors

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ABSTRACT

Objective. This study examines whether adolescent nicotine and cannabis vaping types (i.e., nicotine-only, cannabis-only, and dual use) differ across sociodemographic and school characteristics (e.g., age, gender, sexual identity, race/ethnicity, socioeconomic status [SES], school setting/type), and associations of vaping types with psychosocial factors. **Methods.** From 2021 to 2022, 9th and 10th grade adolescents (N = 2,476) in Colorado and Ohio participated in a survey measuring vaping behaviors and psychosocial factors including substance use attitudes, alcohol use, mental health, aggression, and family and school risk and protective factors. **Results.** Past month vaping prevalence was 89.7 % for non-use, 5.9 % for nicotine-only, 1.0 % for cannabis-only, and 3.4 % for dual use. Chi-square tests of independence showed several significant sociodemographic differences for past month vaping: higher nicotine-only vaping prevalence for females (vs. males) ($p < 0.001$), higher nicotine-only and dual vaping prevalence for LGB+ (vs. heterosexual) youth ($ps < 0.01$), higher dual vaping prevalence for Hispanic and multiethnic (vs. White) adolescents ($p < 0.001$), and higher nicotine-only, cannabis-only, and dual vaping prevalence for lower (vs. higher) mother education ($ps < 0.001$). Regression models examining associations between vaping types (vs. non-use) and psychosocial factors indicated a robust pattern of worse levels of substance use attitudes, alcohol use, mental health, aggression, and family and school factors for nicotine-only and dual users. Results followed a similar pattern but to a lesser degree for cannabis-only users. **Conclusions.** Findings identify characteristics of adolescents who may be particularly vulnerable to higher vaping risk (females, LGB+, Hispanic, multiethnic, low SES) and suggest needs for preventive interventions aimed to reduce all types of vaping for better adolescent behavioral health.

1. Introduction

Nicotine vaping (e-cigarette use) is the most common method of tobacco use among US adolescents (Cooper et al., 2022), with 11.9 % and 16.9 % of US 10th and 12th graders, respectively, reporting past 30-day use in 2023 (Miech, 2024). Cannabis (marijuana) vaping of wax, oil, or hash oil containing tetrahydrocannabinol (THC) is also increasingly prevalent among young people (Lim et al., 2022), with a past 30-day

prevalence of 8.5 % and 13.7 % among US 10th and 12th graders, respectively. Additionally, dual nicotine and cannabis vaping is common and increasing among adolescents (Keyes et al., 2022). E-cigarettes are rarely used alone (Gilbert, Kava, & Affifi, 2021), and nicotine vaping can increase the likelihood of progressing to cannabis use, including cannabis vaping (Staff, Vuolo, Kelly, Maggs, & Silva, 2022; Wong, Lohrmann, Middlestadt, & Lin, 2020).

Dual use of nicotine and cannabis vaping and poly use of vaping with

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alcohol and other drugs can have additive and multiplicative addiction and health consequences, particularly during adolescence, a key developmental period (Roberts et al., 2022). For example, dual vaping (i.e., use of both nicotine and cannabis vaping within the past 30-days, either concurrently or separately) is associated with poorer short-term physical health and increased risky health behaviors compared to vaping a single substance (Jacobs, Idoko, Montgomery, Smith, & Merianos, 2021). While inhaling vaporized nicotine or cannabis is generally considered to be less harmful than conventional smoking (Travis et al., 2022), the widespread adoption of various vaping devices and products (including high-potency THC) has substantial public health implications (Chadi, Minato, & Stanwick, 2020). Research shows that nicotine and cannabis vaping are associated with adolescent physical and mental health problems, poorer brain development, increased risk for combustible cigarette smoking and other drug use, and greater addiction potential to multiple substances (Carlsen, Skjerven, & Carlsen, 2018; Harrell et al., 2022). Given the public health concerns of vaping, more research is needed to better understand whether certain adolescents are at-risk for various nicotine and cannabis vaping patterns, including nicotine-only, cannabis-only, and dual use.

1.1. Sociodemographic differences by vaping type and associations with psychosocial factors

Adolescent vaping risk may differ across sociodemographic characteristics (e.g., race/ethnicity, gender, sexual identity, socioeconomic status [SES], and urban/rural settings) and may be higher among certain minoritized groups (Harrell et al., 2022; McCauley, Baiocchi, Gaiha, & Halpern-Felsher, 2024). Although some research findings are mixed, nationally-representative studies have found that White high school students are more likely to use e-cigarettes compared to most other racial/ethnic groups, and sexual minority youth are more likely to use e-cigarettes than heterosexual youth (Dai, Ramos, Faseru, Hill, & Sussman, 2021; Lee & Tan, 2022). Other studies have shown that transgender youth of color (Felner et al., 2022) and youth with lower SES who have never smoked cigarettes (Green, Gray, Sweeting, & Benzeval, 2020) are more likely to vape nicotine. Though relatively less is known about sociodemographic differences in cannabis vaping, recent reviews indicate that it may be more common among lower SES, Hispanic, and Black youth (Harrell et al., 2022; Trivers, Phillips, Gentzke, Tynan, & Neff, 2018). Importantly, few studies examine sociodemographic differences in dual use of nicotine and cannabis vaping, and more research is needed on whether certain subpopulations of adolescents are more likely to report single or dual use vaping patterns.

Additionally, limited research has examined associations between single and dual nicotine and cannabis vaping and adolescent psychosocial factors across individual, family, peer, and school domains. Liu et al. (2024) found that among adolescents in New England states, dual vaping was related to total social media sites used and household tobacco use, while cannabis-only vaping was related to older age and depression. Another study showed that dual use of e-cigarettes and cannabis was associated with lower academic grades and depression among adolescents in Massachusetts (Liu, Tan, Winickoff, & Rees, 2023). Research using a sample of adolescents in Florida found that nicotine vaping and dual nicotine and cannabis vaping were associated with more illicit substance use (Boccio & Jackson, 2021) and bullying victimization (Boccio, Leal, & Jackson, 2022). In longitudinal work conducted with adolescents in Pennsylvania, Moustafa, Rodriguez, Pianin, Testa, and Audrain-McGovern (2022) reported a pattern of dual vaping latent classes that were associated with greater cigarette and cigar smoking, alcohol use, peer vaping, positive e-cigarette expectations, depression, and sensation seeking, compared to non-users. Due to potential regional or state differences in vaping patterns, additional research is needed to test associations in other US states and with a broad set of psychosocial variables, including substance use attitudes, alcohol use, mental health, and family and school factors. Examination

of psychosocial factors in several domains is motivated by the Social Development Model (Catalano & Hawkins, 1996) and Problem Behavior Theory (Jessor & Jessor, 1977), which suggest that risk and protective factors in multiple developmental contexts contribute to the co-occurrence of problem behaviors.

1.2. The current study

This study adds to the adolescent vaping literature by examining the prevalence of current nicotine-only, cannabis-only, and dual use vaping across sociodemographic groups (i.e., gender, sexual identity, race/ethnicity, SES), and school and contextual variables (i.e., rural/urban locale, public/nonpublic school, and US state) that are less frequently examined. Results will help determine which adolescents are at highest-risk for using single and multiple vaping products, and factors associated with vaping use types across several developmental contexts. Findings can inform preventive approaches addressing single vs. dual vaping and tailored messaging for certain sociodemographic groups.

We examined the following research questions: 1) For each vaping use type (nicotine-only, cannabis-only, dual use), are there differences in past month use across sociodemographic groups? 2) Is past month vaping use type associated with psychosocial factors (i.e., substance use attitudes, alcohol use, mental health, aggression, and family and school variables)?

2. Methods

2.1. Study sample and procedures

The current analyses used data from the baseline assessment of a large-scale cluster randomized trial examining effects of a high school substance use prevention program (Steeger et al., 2023). In fall 2021 and fall 2022, two cohorts of 9th grade students across 50 high schools in Colorado and Ohio completed web-based or paper surveys in school. These states were targeted because their adolescent tobacco and cannabis use rates were comparable to the national averages when the study began (CDC, 2020). High schools were recruited using a variety of methods including listserv advertisements, emails, and an informational webinar. After recruiting schools, all 9th graders were invited to participate. Some smaller schools combined 9th and 10th grades, and in these schools, 10th graders were eligible to participate.

The research team worked with schools to provide an opt-out notification to parents/guardians (or an opt-in parental informed consent when preferred by the school); informed assent was given by each participant. All communications and survey language were provided in English and Spanish. School teachers or other staff monitored survey administration. Of 3,185 eligible students, 2,476 (77.7 %) participated in the survey. This study was approved by the University of Colorado Boulder Institutional Review Board.

2.2. Measures

Survey measures were drawn from the following sources: Centers for Disease Control and Prevention's Youth Risk Behavior Survey (Brener, Eaton, Grunbaum, Hawkins, Kann, Kinchen, Ross, & Whalen, 2004; Kann et al., 2014); the Communities That Care (CTC) youth survey (Arthur, Hawkins, Pollard, Catalano, & Baglioni, 2002; Glaser, Horn, Arthur, Hawkins, & Catalano, 2005), the Monitoring the Future High School Survey (Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2017), and the Healthy Kids Colorado Survey. School-level data (school type and setting) were accessed through the National Center for Education Statistics (NCES).

2.2.1. *Vaping use type* was assessed with two items: (1) nicotine vaping: During the past 30-days, on how many days did you use an electronic vapor product? (2) cannabis vaping: How many times (if any) have you vaped marijuana during the past 30-days? Participants

reporting ≥ 1 days/times on one or both questions were considered to have vaped nicotine and/or cannabis in the past 30-days. Vaping use types were coded into four mutually-exclusive categories: Past 30-day non-use of nicotine and cannabis vaping, nicotine-only, cannabis-only, and dual vaping.

2.2.2. *Sociodemographic characteristics* were age, gender (male, female, non-binary), sexual identity (heterosexual, LGB+), race/ethnicity (White, Black, Hispanic/Latinx, multiracial/multiethnic, other [including Asian, Native Hawaiian or other Pacific Islander, and American Indian or Alaska Native]), and mother’s level of education (less than high school completion, high school completion or more).

2.2.3. *Psychosocial factors* were measured across individual, peer, family, and school domains (Hawkins, Catalano, & Miller, 1992). Psychosocial measures were vaping-specific and general substance use attitudes, reasons for use, intentions to use substances, and harm risk perceptions (scale 1–4); past month alcohol use (count variable 0–6; categories of 0 days to 30-days) and binge drinking (count variable 0–6; categories of 0 days to 20 or more days); mental health including anxiety (scale 1–3), depression (scale 1–4), past year considering attempting suicide (no/yes), and past year actual suicide attempts (no/yes); past year physical fighting (count variable 0–7; categories of 0 times to 12 or more times); and family and school factors including parent use of tobacco, marijuana, or alcohol (no/yes items coded as a sum, 0–3), family management and school bonding (scales 1–4), and academic grades (scale 1–5; Mostly Fs to Mostly As). See Supplementary Table 2 for additional survey measure details.

2.3. Analysis plan

For research question 1 (differences across sociodemographic groups), Rao-Scott chi-square tests of independence adjusting for school clustering were conducted to examine whether prevalence of vaping use types differed across sociodemographic groups and school/contextual characteristics. Analyses were performed per separate vaping type using dummy variables (i.e., nicotine-only vs. non-use, cannabis-only vs. non-use, and dual use vs. non-use). For research question 2 (psychosocial factor differences between vaping types), we ran a series of regressions models in Mplus software using the TYPE = COMPLEX analysis command, which controls for non-independence of observations from students clustered within schools, and the MLR estimator, which handles non-normality of dependent variables (Muthén & Muthen, 2017). Analyses used linear regression models for continuous measures reported with standardized betas, logistic regressions for binary measures with odds ratios (ORs), and zero-inflated Poisson (ZIP) regression models for count measures reported as rate ratios (RRs)—exponentiated coefficients from the model count component (Pittman et al., 2020). Covariates were age, gender, sexual identity, and mother education. Chi-square tests were conducted using SAS v.9.4, and regression analyses were conducted in Mplus using FIML to account for missing data. Chi-square analyses handled missing data via listwise deletion such that cases were dropped, per analysis, if they were missing sociodemographic or vaping type variables. Finally, False Discovery Rate (FDR) corrections (Benjamini & Hochberg, 1995) were applied to significance tests in research question 2 and in sensitivity analyses to account for multiple testing.

Table 1
Past 30-day vaping use type by participant sociodemographic characteristics and school characteristics.

| Baseline variable | TOTAL | Non-use | Nicotine-only vaping (N = 139) | | Cannabis-only vaping (N = 23) | | Dual vaping (N = 81) | |
|-------------------------|------------------|------------------------------------|--------------------------------|---------------------------------|-------------------------------|---------------------------------|----------------------|---------------------------------|
| | (N = 2,476) N | (N = 2,127) N (row %) or M (SD) | N (row %) or M (SD) | chi-square p-value ^a | N (row %) or M (SD) | chi-square p-value ^a | N (row %) or M (SD) | chi-square p-value ^a |
| Age | 2450 | 14.29 (0.58) | 14.33 (0.67) | | 14.35 (0.71) | | 14.5 (0.78) | |
| Grade | | | | 0.108 | | + | | 0.130 |
| 9th | 2277 | 1967 (90.1) | 123 (5.9) | | 22 (1.1) | | 70 (3.4) | |
| 10th or mixed grades | 177 | 144 (85.2) | 15 (9.4) | | 1 (0.7) | | 9 (5.9) | |
| Gender | | | | <0.001 | | 0.367 | | 0.156 |
| Male | 1181 | 1033 (91.9) | 46 (4.3) | | 10 (1.0) | | 35 (3.3) | |
| Female | 1060 | 902 (87.3) | 79 (8.1) | | 10 (1.1) | | 42 (4.4) | |
| Nonbinary | 183 | 152 (89.4) | 12 (7.3) | | 3 (1.9) | | 3 (1.9) | |
| Sexual identity | | | | <0.001 | | 0.157 | | 0.002 |
| Heterosexual | 1593 | 1411 (92.2) | 68 (4.6) | | 14 (1.0) | | 37 (2.6) | |
| LGB+ | 528 | 415 (83.0) | 52 (11.1) | | 8 (1.9) | | 25 (5.7) | |
| Race/ethnicity | | | | 0.634 | | + | | <0.001 |
| White | 1274 | 1132 (92.1) | 66 (5.5) | | 5 (0.4) | | 26 (2.2) | |
| Black | 153 | 134 (91.8) | 8 (5.6) | | 1 (0.7) | | 3 (2.2) | |
| Hispanic/Latinx | 424 | 355 (87.4) | 25 (6.6) | | 8 (2.2) | | 18 (4.8) | |
| Multiethnic | 433 | 359 (86.9) | 25 (6.5) | | 4 (1.1) | | 25 (6.5) | |
| Other race/ethnicity | 152 | 121 (84.6) | 11 (8.3) | | 5 (4.0) | | 6 (4.7) | |
| Mother education | | | | <0.001 | | <0.001 | | <0.001 |
| Less than HS | 287 | 222 (81.0) | 25 (10.1) | | 6 (2.6) | | 21 (8.6) | |
| Completed HS or more | 1578 | 1395 (91.1) | 79 (5.4) | | 12 (0.9) | | 45 (3.1) | |
| School setting | | | | 0.341 | | 0.738 | | 0.148 |
| Rural | 1205 | 1022 (88.4) | 75 (6.8) | | 12 (1.2) | | 47 (4.4) | |
| Urban/suburban | 1271 | 1105 (91.0) | 64 (5.5) | | 11 (1.0) | | 34 (3.0) | |
| School type | | | | 0.502 | | + | | 0.673 |
| Public | 2080 | 1772 (89.4) | 120 (6.3) | | 21 (1.2) | | 70 (3.8) | |
| Non-public | 396 | 355 (91.7) | 19 (5.1) | | 2 (0.6) | | 11 (3.0) | |
| State | | | | 0.415 | | 0.798 | | 0.969 |
| Colorado | 1479 | 1254 (89.2) | 88 (6.6) | | 16 (1.3) | | 48 (3.7) | |
| Ohio | 997 | 873 (90.6) | 51 (5.5) | | 7 (0.8) | | 33 (3.6) | |

Note. Total N = 2,476. HS = high school. Means and SDs presented for age. Row percentages not summing to 100 are the result of missing data, which varied per analysis. Participants were included per analysis if they had data for both vaping use type and sociodemographic/school characteristic for each chi-square test.

^a p-value for Rao-Scott chi-square test of independence, adjusted for school clustering (reference: non-use). + Not able to be calculated due to small cell sizes.

3. Results

Past month vaping prevalence was 89.7 % (n = 2,127) for non-use, 5.9 % (n = 139) for nicotine-only vaping, 1.0 % (n = 23) for cannabis-only vaping, and 3.4 % (n = 81) for dual use vaping. Table 1 shows sample descriptives by vaping use type. Psychosocial factor descriptives and zero-order correlations for sociodemographic and psychosocial variables are in Supplementary Tables 1 and 3.

3.1. Sociodemographic characteristics by vaping use type

Age was significantly correlated with greater risk of dual vaping ($r = 0.07, p < 0.01$) but was not related to nicotine-only or cannabis-only vaping ($ps > 0.05$). Chi-square tests showed several significant associations between adolescent sociodemographic characteristics and past month vaping within each vaping type (Table 1). For nicotine-only vaping vs. non-use, there were significant differences by gender, sexual identity, and mother education ($ps < 0.001$). Females reported greater prevalence of nicotine-only vaping compared to males (8.1 % vs. 4.3 %). Adolescents who identified as LGB + were more likely than heterosexual youth to report nicotine vaping (11.1 % vs. 4.6 %), and adolescents with lower-educated (compared to higher-educated) mothers reported more nicotine-only vaping (10.1 % vs. 5.4 %).

For cannabis-only vaping vs. non-use, there was one significant association between mother education and adolescent cannabis-only vaping, $p < 0.001$; a greater percentage of adolescents with lower-educated compared to higher-educated mothers reported cannabis-only vaping (2.6 % vs. 0.9 %). For three sociodemographic characteristics (grade, race/ethnicity, and school type), some observed counts within cells were less than five, and chi-square tests were not conducted.

For dual vaping vs. non-use, there were significant differences across sexual identity, $p = 0.002$; race/ethnicity, $p < 0.001$; and mother education, $p < 0.001$. LGB + identity (compared to heterosexual) was associated with greater prevalence of dual vaping (5.7 % vs. 2.6 %), Hispanic and multiethnic (vs. White) youth were more likely to report dual vaping (4.8 % vs. 2.2 % and 6.5 % vs. 2.2 %, respectively), and lower (vs. higher) mother education was associated with greater prevalence of dual vaping (8.6 % vs. 3.1 %).

Differences among school grade, school setting (urban/suburban vs. rural), school type (non-public vs. public), or state (Ohio vs. Colorado) were all nonsignificant within vaping types ($ps > 0.05$; Table 1).

3.2. Vaping use type predicting psychosocial factors

Regressions examining associations between vaping use type and psychosocial factors indicated a robust pattern of higher risk for nicotine-only and dual user (vs. non-use; Table 2). For example, nicotine-only and dual use vaping types were associated with significantly greater pro-vaping and general substance use attitudes ($\beta = 0.05-0.47, ps < 0.01$); greater alcohol use and binge drinking (RR = 1.59-3.65, $ps < 0.01$); higher anxiety and depression ($\beta = 0.05-0.16, ps < 0.01$), higher suicidal ideation and more suicide attempts (ORs = 4.48-7.59, $ps < 0.001$); more fighting (RR = 1.43-1.74, $ps < 0.001$); higher parent substance use ($\beta = 0.13-0.17, ps < 0.001$) and lower family management ($\beta = -0.09- -0.12, ps < 0.01$), and lower grades and school bonding ($\beta = -0.08 - -0.15, ps < 0.01$). The magnitude of most associations was similar for nicotine-only and dual use vaping, though some associations were larger for dual use than nicotine-only vaping (e. g., alcohol use, binge drinking, suicide, fighting, parent substance use, family management, and grades).

Results followed a similar pattern but to a lesser degree for cannabis-only vaping, such that the magnitude of associations was somewhat smaller than for nicotine-only and dual use vaping, and there were fewer significant associations (Table 2). However, there were no significant associations ($ps > 0.05$) between cannabis-only vaping vs. non-use and parent substance use, school bonding, and most mental health measures

Table 2

Results from adjusted regression models examining associations between vaping use types and psychosocial factors.

| Psychosocial Measures | Nicotine-Only vs. Non-Use | | Cannabis-Only vs. Non-Use | | Dual Use vs. Non-Use | |
|---|-------------------------------|-------|-------------------------------|-------|-------------------------------|-------|
| | β , RR, or OR [95 % CI] | p | β , RR, or OR [95 % CI] | p | β , RR, or OR [95 % CI] | p |
| Vaping & Substance Use Attitudes | | | | | | |
| Think it is cool to vape | 0.38 [0.31, 0.44] | <.001 | 0.08 [0.02, 0.13] | 0.011 | 0.31 [0.21, 0.40] | <.001 |
| Think it is cool to use substances | 0.30 [0.24, 0.36] | <.001 | 0.09 [0.04, 0.14] | <.001 | 0.35 [0.25, 0.44] | <.001 |
| Vaping to make friends | 0.31 [0.24, 0.38] | <.001 | 0.10 [0.05, 0.15] | <.001 | 0.32 [0.23, 0.42] | <.001 |
| Substance use to make friends | 0.27 [0.21, 0.33] | <.001 | 0.10 [0.06, 0.15] | <.001 | 0.33 [0.24, 0.41] | <.001 |
| Intentions to vape | 0.47 [0.42, 0.52] | <.001 | 0.10 [0.04, 0.16] | 0.001 | 0.41 [0.32, 0.49] | <.001 |
| Intentions to use substances | 0.36 [0.31, 0.40] | <.001 | 0.13 [0.07, 0.18] | <.001 | 0.42 [0.33, 0.50] | <.001 |
| Vaping harm risk | -0.07 [-0.11, -0.04] | <.001 | -0.06 [-0.11, -0.04] | 0.035 | -0.07 [-0.12, -0.03] | 0.003 |
| Substance use harm risk | -0.05 [-0.09, -0.02] | 0.001 | -0.07 [-0.12, -0.02] | 0.005 | -0.07 [-0.11, -0.03] | <.001 |
| Alcohol Use | | | | | | |
| PM alcohol use | RR = 2.94 [1.52, 4.35] | <.001 | RR = 3.24 [0.91, 5.58] | 0.004 | RR = 3.65 [1.66, 5.64] | <.001 |
| PM binge drinking | RR = 1.59 [0.68, 2.50] | 0.001 | RR = 1.28 [0.36, 2.20] | 0.006 | RR = 2.07 [0.90, 3.23] | 0.001 |
| Mental Health | | | | | | |
| Anxiety | 0.10 [0.06, 0.14] | <.001 | 0.01 [-0.04, 0.05] | 0.744 | 0.05 [0.02, 0.09] | 0.005 |
| Depression | 0.16 [0.11, 0.19] | <.001 | 0.04 [-0.01, 0.10] | 0.122 | 0.15 [0.11, 0.18] | <.001 |
| PY considered attempting suicide | OR = 5.22 [3.83, 7.13] | <.001 | OR = 1.69 [0.49, 5.83] | 0.405 | OR = 6.53 [4.04, 10.58] | <.001 |
| PY suicide attempts | OR = 4.48 [2.88, 6.97] | <.001 | OR = 3.62 [1.27, 10.33] | 0.016 | OR = 7.59 [4.03, 14.31] | <.001 |
| Externalizing/Aggression | | | | | | |
| PY physical fighting | RR = 1.43 [1.11, 1.74] | <.001 | RR = 1.37 [0.69, 2.05] | <.001 | RR = 1.74 [1.38, 2.09] | <.001 |
| Family Factors | | | | | | |
| Parent substance use | 0.13 [0.09, 0.17] | <.001 | 0.04 [-0.02, 0.08] | 0.213 | 0.17 [0.12, 0.22] | <.001 |
| Family management | -0.09 [-0.13, -0.04] | <.001 | -0.05 [-0.16, -0.01] | 0.029 | -0.12 [-0.18, -0.06] | 0.001 |
| School Factors | | | | | | |
| Grades | -0.13 [-0.18, -0.08] | <.001 | -0.08 [-0.13, -0.04] | <.001 | -0.15 [-0.19, -0.10] | <.001 |
| School bonding | -0.10 [-0.14, -0.06] | <.001 | -0.03 [-0.09, 0.04] | 0.400 | -0.08 [-0.13, -0.03] | 0.002 |

Note. Nicotine-only use: $n = 139$; cannabis-only use: $n = 23$; dual use: $n = 81$; non-use: $n = 2,127$. PM = past month, PY = past year. Values are standardized betas (β) for continuous variables, rate ratios (RR) for count variables, or odds ratios (OR) for binary variables. All models controlled for age, gender, sexual identity, and mother education. All significant p -values (at $p < 0.05$) remained significant after FDR corrections for multiple testing (FDR thresholds: $p < 0.05$ for nicotine-only, $p < 0.037$ for cannabis-only, and $p < 0.05$ for dual use).

(except suicide attempts, OR = 3.62, $p < 0.05$).

Additionally, sensitivity analyses of dual use vs. nicotine-only vaping were conducted to determine whether dual use vapers showed more problematic psychosocial factors across developmental domains than nicotine-only vapers. Results indicated more problem behaviors among dual use vapers (i.e., greater peer-related reasons for use, intentions to use substances, alcohol use, binge drinking, fighting, parent substance use, and lower grades; see Supplementary Table 4).

4. Discussion

This study contributes to the vaping literature by distinguishing nicotine and cannabis vaping and examining several sociodemographic characteristics across vaping types, including dual and exclusive use patterns. We examined associations between vaping types and a theoretically-relevant set of comprehensive psychosocial factors. We also extend existing literature by examining school and state-level factors across vaping types, which few studies do. Results show several significant associations between minoritized and/or marginalized groups and past month vaping status. LGB+ (vs. heterosexual) identity was associated with higher prevalence of nicotine-only and dual nicotine and cannabis vaping, and adolescents who identified as Hispanic or multiethnic reported more dual vaping than White youth. Lower mother education (a proxy for SES) was associated with greater prevalence of all nicotine and cannabis vaping patterns. Results are consistent with recent studies reporting higher vaping prevalence among sexual and gender minority (SGM) youth (Azagba, Ebling, & Shan, 2023; McCauley et al., 2024), racial/ethnic minoritized youth (e.g., Hispanic/Latino or Black; Cambron, 2023; Keyes et al., 2022), and intersectional identities (e.g., Black SGM youth; Felner et al., 2022).

Substance use disparities are often attributed to minority stress models, which hypothesize that substance use (e.g., vaping) may be a maladaptive coping mechanism aimed to reduce negative affect stemming from minority-related stressors of discrimination and stigma (Livingston, Flentje, Heck, Szalda-Petree, & Cochran, 2017; Mereish, Miranda, Liu, & Hawthorne, 2021). Other possible explanations for greater vaping prevalence observed among minoritized adolescents include a long history of targeted marketing by the tobacco industry of low-income, racial minority, and SGM communities (Hiscock, Bauld, Amos, Fidler, & Munafò, 2012); other substance use that often co-occurs with vaping (Lanza et al., 2020); and peer influences or family/household tobacco use (Wang et al., 2022). Given that vaping exposes youth to harmful constituents and is associated with nicotine addiction, cigarette smoking initiation, respiratory harm, and mental health problems (McGrath-Morrow et al., 2020), sociodemographic differences in vaping prevalence may ultimately contribute to widening disparities of physical and behavioral health outcomes.

The finding that more female than male youth reported nicotine-only vaping is contrary to some research reporting higher e-cigarette use among males or no significant gender differences (Alam & Silveyra, 2023). There is some evidence that females may have more positive attitudes toward e-cigarettes (Piñeiro et al., 2016), and that e-cigarettes have been more highly advertised and targeted to females via social media in recent years (Alam & Silveyra, 2023). Additional prospective research on gender differences in adolescent vaping use types is needed to understand whether our results represent a more recent trend in increased female nicotine vaping, or if results are sample-specific.

Next, associations between vaping use type and psychosocial factors

indicated a robust pattern of higher risk across all developmental domains for nicotine-only and dual use (compared to non-use), and all domains other than mental health and school bonding measures for cannabis-only use. These results parallel findings from existing research focused on adolescent e-cigarettes and psychosocial correlates (e.g., higher e-cigarette susceptibility and internalizing and externalizing problems, positive attitudes toward vaping, illicit drug use, family e-cigarette use, and lower school connectedness; Barrington-Trimis et al., 2015; Erhabor et al., 2023). The current study replicates several of these findings for nicotine vaping and extends existing work by examining whether there were similar patterns of associations for cannabis-only and dual vaping, and whether there were associations with additional psychosocial factors rarely examined in other vaping studies (e.g., general substance use attitudes, binge drinking, anxiety, suicide, aggression, family management). Our findings are supported by developmental theories describing how adolescent problem behaviors (e.g., substance use, externalizing and internalizing problems) tend to cluster together and co-occur across multiple domains (individual, family, peer, school, and community) (Hawkins et al., 1992). Results of sensitivity analyses show that dual vapers, compared to nicotine-only vapers, had more problem behaviors across developmental domains (other than mental health), which is consistent with broader substance use research that finds more psychosocial problems and poorer cessation outcomes for polysubstance vs. single substance users (Peters et al., 2012).

Prevention implications of this study are informed by robust associations of nicotine and cannabis vaping patterns with higher risk across developmental domains, and higher vaping prevalence among minoritized groups. The significant associations across several socioecological domains also suggest that adolescents may benefit from multilevel preventive interventions to prevent or reduce nicotine and cannabis vaping and poor health outcomes. Within universal prevention programs, minoritized groups and dual vapers may need additional selective interventions to further reduce vaping, associated health disparities, and elevated problem behaviors. Further, there were no differences in vaping prevalence among school characteristics, suggesting that adolescent vaping rates were similar across urban/rural school settings, public/nonpublic schools, and the two states in this study. Thus, this research suggests that adolescent prevention messaging content may be similarly applied across school settings in Colorado and Ohio.

Perhaps surprisingly, no state-level differences in vaping prevalence were found despite different recreational marijuana legalization (RML) statuses at the time of data collection in 2020–2021 (i.e., RML was passed in Colorado in 2012 and in Ohio in 2023). Recent studies indicate generally modest or no evidence of RML laws increasing odds of adolescent cannabis use (Pawar, Firmin, Wilens, & Hammond, 2024). Despite a large gap between the dates of legal adult cannabis policy changes in Colorado and Ohio, these two states are similar regarding tobacco policies (CDC, 2024). For example, municipalities in both states have pursued prohibition of flavored products to prevent or reduce adolescent vaping, as certain flavors are associated with greater willingness to try nicotine and cannabis vape products (Chaffee et al., 2023). However, neither state has a state-wide ban on flavored products (Bach, 2024). Beyond regulating flavors, there are several other policy approaches that have been shown to prevent youth tobacco use. For example, a study in California examined the association of the tobacco and cannabis retail environment and adolescent use of tobacco/vape and cannabis. The authors found that stronger policies related to licensing, location, and other retail regulations were associated with lower past-month use and co-use among adolescents (Bostean et al., 2023). In the current study, robust predictors of adolescent cannabis use and other substance use behavior (e.g., family and peer use and norms, low perceived harm; Hawkins et al., 1992; Stone, 2020) might play a larger role than policy differences, such as RML, across both states. Nonetheless, policy approaches are an important part of comprehensive youth substance use prevention.

Colorado and Ohio, like most US states, have ongoing adolescent

surveillance systems, whether part of the Youth Tobacco Survey, Youth Risk Behavior Survey, or comparable systems (Healthy Kids Colorado Survey, 2024; Ohio Youth Surveys, 2024). States with surveillance systems should ensure inclusion of items specifically tracking nicotine and cannabis vaping, given their prominence in the marketplace and relatively high prevalence of use among youth. These surveillance systems are critical for informing state and local decisions about prevention programming needs, and how to best direct limited prevention resources. For example, in Colorado, data from the Healthy Kids Colorado Survey are provided to communities throughout the state in custom reports (Wright-Kelly, MacFarland, Fine, Morgan, & Brooks-Russell, 2024). In turn, Colorado has a state-wide prevention funding effort, called 'Community Organizing for Prevention' based on the Communities that Care model (Arthur et al., 2010; CDPHE, 2024), for which the state-wide surveillance data serve as a primary evaluation metric. Tracking youth substance use, including nicotine and cannabis vaping, is essential for reporting progress toward statewide prevention goals.

4.1. Limitations

This cross-sectional study cannot determine causality of associations, and it is possible that vaping may both affect and be affected by psychosocial factors. Like other studies that use adolescent survey measures, there may be self-report bias including both under- and over-reporting of substance use and other behavioral health measures. Additionally, the cannabis-only vaping use group was small ($n = 23$), and some observed cell sizes were too small to adequately test for differences between sociodemographic/school characteristics and cannabis vaping. This study was also unable to examine additional categories of intersectional sociodemographic characteristics (e.g., across gender, sexual identity, race/ethnicity) (Sheffer et al., 2022). Vaping frequency, quantity, and use of cannabis in other forms were not assessed in this study but should be examined in future work to understand adolescent vaping use patterns more fully. It is also important to note that although this study uses a large sample that is generalizable across many school- and student-level characteristics in two US states, results should be replicated in nationally-representative data sets.

4.2. Conclusions

This research demonstrates sociodemographic differences in past-month nicotine-only, cannabis-only, and dual vaping among adolescents from Colorado and Ohio. Results identify characteristics of early high school adolescents who may be particularly vulnerable to higher vaping risk, including adolescents who reported female gender, LGB + sexual identity, Hispanic and multiethnic race/ethnicity, and lower SES. All patterns of nicotine and cannabis vaping, including dual use and single use of either substance, were associated with poor psychosocial factors, including other substance use behaviors and attitudes, mental health problems, and family and school risk factors. These findings highlight vaping as a key indicator of potential behavioral health problems in adolescence and the need for interventions to prevent or reduce all types of vaping to improve adolescent behavioral health.

CRedit authorship contribution statement

Christine M. Steeger: Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization, Software, Writing – review & editing. **Charleen J. Gust:** Writing – original draft, Software, Formal analysis, Data curation, Methodology, Writing – review & editing. **Alyssa F. Harlow:** Writing – original draft, Conceptualization, Methodology, Writing – review & editing. **Christopher Cambron:** Writing – original draft, Formal analysis, Conceptualization, Data curation, Software. **Jessica Barrington-Trimis:** Writing – original draft, Conceptualization, Methodology. **Katie Massey Combs:** Writing – original draft, Methodology, Data curation,

Conceptualization, Writing – review & editing. **Ashley Brooks-Russell:** Methodology, Writing – review & editing, Conceptualization. **Karl G. Hill:** Writing – review & editing, Conceptualization, Funding acquisition.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.abrep.2024.100577>.

Data availability

Data will be made available on request.

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